The Analysis & Operations Optimization to Mitigate under Utilization of Equipment's at Coal Handling Plants of Super Critical Thermal Units

By

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(DEPARTMENT OF POWER MANAGEMENT)

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DEDICATION

I was encouraged by all the teachers and management gurus and encouraged by all the gurus who have given continuous guidance and kindness, blessings, for my power management research. I always have pursued my Ph.D. from your support only, I will be ever grateful. Sir, I dedicate you my doctoral research, I am always grateful, to my beloved guide, co-guiding and external guides, UPES- CCE team & UPES-SRC, Associate Dean, Dean , Vice Chancellor, Chancellor for all kinds of supports.

My elder brother Shri Baij Nath Dubey B.Sc. (Science), M. A.(Economics) retired former lecturer Inter College Todarpur, Azamgarh U.P (teacher) whose unimaginable passion and blessings have always inspired me & "I am blessed to do better in studies and have inspired me to get supreme education. I have always been grateful for his Ph.D. support.

I dedicate my Ph.D. (Power Management) to my faithful, gentle, honest, heavenly parents Father Lalta Dubey & Mother Kalpa Dubey whose blessings made me always inspired, they blessed me always to do better in studies and have inspired me to get supreme education.

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My Son Prateek Dwivedi (Graduate Engineer) in Computer Science and Engineering from the JIT Nagpur University 2017. My Daughter Shachi Dwivedi is an overview of B-Tech (Graduate Engineering) in Computer Science and Engineering from O.P. Jindal University 2017. Both encouraged me to study.

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I must also thank to all Adani power plant CHP heads & Plant HODs for giving me the data of different plants related to my topics of research. I convey my special thanks to sh. Vneet Jain Sir CEO Power Business ,Upinder Singh CEO L&T Power Rajpura Chandigarh , sh. B.K.Mishra Sir, - Director Lanco Power, Sh. Jayadeb Nanda Sir, COO-Adani Power, sh. Nirmal Sharma Sir Head –O&M Kawai sh. Anand Kumar Singh station Head , Mundra for his their valuable &moral support time to time. I am too much thankful to Ms. Naina Chopra Visiting faculty - UPES who spared her half day time from her busy schedule to give me for the econometric basic concept & data analysis.

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DECLARATIONS

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it consist no material previously published or written by another person or material which has been accepted for award of any other degree or diploma of the diversity or other institute of higher learning, except where due acknowledgement has been made in the text.

Shesh Nath Dubey

Sign:

Date: 25.06.2018

THESIS COMPLETION CERTIFICATE

This is to certify that the thesis on ' The Analysis & Operations Optimization to Mitigate under Utilization of Equipment's at Coal Handling Plants of Super-Critical Thermal Units" is partial completion of the requirements for the award of the degree of Doctor of Philosophy (Management) is an original work carried out by SHESH NATH DUBEY under our joint supervision and guidance.

It is certified that the work has not been submitted anywhere else for award of any other diploma or degree of this or any other university institute.

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Signature of Supervisor
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Table of Contents	Page No

CHAPTER 1

Chapter 1

Introduction

Absolutely, in current scenario the availability of coal & its price hike are the big challenge for the super critical thermal Power units. Many power plants are closed only due to lack of Fuel. Energy & Fuel management of Coal Handling Plant (CHP) in India has been undertaken in a technologically efficient manner. In the broad perspective, saving amount of coal per KWH of electricity generation need to be assessed in a CHP which will have some value addition to the national economy. The Coal Handling Plant is the backbone of the any Thermal Power Plant. Fire is a wonderful gift of nature to the humanity. It is the most inherent part of all elements of the universe. On one side it is essential for existence whereas it proves devastating if not properly controlled. Fire continues to be an inherent danger in Indian coal mining industry & CHP-coal yards and needs integrated approach. Besides the fires, due to spontaneous heating, the problem of fire in open yard coal piles has become more complex in the light of large-scale mechanization with high capacity heavy earth moving machines, coal handling plants,. In addition to environmental degradation due to a large volume of coal smoke and other noxious gases, fires create difficult yard conditions and thus adversely affect safety and productivity at coal handling plant. Fire-causes loss of production, loss of equipment, down time of equipment, injuries and even loss of human lives. "Prevention is better than cure" also holds good for fire. Energy is the prime mover for growth of a developing nation. Coal, with its large resources and easy affordability is, and will remain the primary source of energy in India.

Energy demand in the country is increasing exponentially and is throwing greater challenges to the coal producing companies. Huge amount of revenue, about 70% of O&M cost is involved with the Fuel management in the thermal power plants. The In Plant Fuel Management (IPFM) is taking care of the Fuel & Energy losses Management. In a broad perspective, these are the qualitative & quantitative assessment for assessing the impacts of energy losses in handling at Transfer Points (TP) in CHP Unit. The Losses prevention methods are used that blend both qualitative and quantitative losses prevention techniques. The goal of any of these methods is to help to the decision-maker to choose a course of action, given a better understanding of the possible outcomes that could occur.

Losses management at CHP is the application of proactive strategy to plan, lead, organize, and control the wide variety of fuel & energy losses that are woven into the fabric of a power sector’s daily and long-term functioning. The objective of this study is to control the losses of fuel & energy at CHP of power sector. The implication of this study is that a lot of fuel and energy in terms of revenue for the organization and to the nation can be saved. Today the coal & Energy scenario in India as well as in internationally global village level become more critical and the fuel cost is too much high. The consequences is, the fuel cost have got increased drastically, which impact on the generation cost and getting break-even point from business to power producers. The power purchase agreements (PPAs) are signed on the fixed price and at this time the scenario is entirely different in just with effect from 2011 onward. The GDP growth in global recession became drastically moved downward on global level and the hike in the coal prices playing the crucial role are not in control of the electricity/power producers. So the fuel cost as well as surface coal, fuel &energy losses cost need to be reduced and generation cost to be minimized in order to make the super critical power units sustainable in power generation.

The first conveyor belts were developed in the late 18th century, with most sources pointing at the year 1795 as the first instance of a conveyor. Consisting of leather belts running over wooden beds, they were short and were powered with hand cranks and a series of pulleys. Changes in technology are certain to keep the industry in motion as users look for faster throughput, diverted sorting and use of wireless technologies. Primitive conveyor belts were used since the 19th century. In 1892, Thomas Robins began a series of inventions which led to the development of a conveyor belt used for carrying coal, ores and other products. In 1901, Sandvik invented and started the production of steel conveyor belts. In 1905 Richard Sutcliffe invented the first conveyor belts for use in coal mines which revolutionized the mining industry. In 1913 Henry Ford introduced conveyor-belt assembly lines at Ford Motor Companies’ Highland Park, Michigan factory. In 1972, the French society REI created in New Caledonia the then longest straight-belt conveyor in the world, at a length of 13.8 km. With the dawn of the 20th century came the industrial revolution as well as much great advancement in conveyor technology. In 1901, the first steel belt was invented in Sweden. They can be installed almost anywhere, and are much safer than using a forklift or other machine to move materials. They can move loads of all shapes, sizes and weights. Also, have many advanced safety features that help prevent accidents A.L.N. Arun Kumar.

1.1 Brief Description about Operational plants and future coming power projects:--

About the Super Critical Coal Based Power Plants which CHP - data have been taken for the panel id data.

- Adani Power Ltd. Mundra, Gujarat (660 x 2)
- Adani Power Ltd. Mundra, Gujarat (660 x 3)
- Plant 3: KWPCL. Raigarh, Chhattisgarh (600X1)
- Plant 4: Adani Power Ltd. Tiroda, Maharashtra (660X5)
- Plant 5: Adani Power Ltd. Kawai, Rajasthan (660 X 2)

ADANI POWER LIMITED

The Adani group entered into the power business in year 2006 in the history of India on its first location at Mundra to cater to the Mundra port and SEZ business. The Adani port is the largest coal handling port which always deals with the imported coal .It is the only port which delivered the imported coal to needy coal based power plants and about 50% fulfilment of country need is with this port and all are operated with the Mundra location. Adani port is the world largest managed coal terminal in the world.

In spite of zero experience in the power generation sector, the Adani group have scaled up our operations and capitalized on this foundation. Today, in the world, Mundra is the largest private single location thermal power plant. In Gujrat, at Mundra location330x4 +660x5 = 4620MW. Adani power have plants in Maharashtra in Tiroda location 660x5 =3300 MW, in Rajasthan 660x2 =1320 MW in Kawai location, and 600x2=1200 mw in Udupi and 600 MW in KWPCL Raigarh.

Now with the current installed capacity >11000MW the Adani power has become the largest private power producer in India. Adani group is moving forwards to his ambitious target of 20000 MW by year 2020. Adani has the excellent operation team of (O&M) Operation & Maintenance Function and team of construction and Techno/commercial and engineering teams.

To evacuate the power from the generating units of adani power plants for the benefit of end users adani power has set up the transmission team at the central and state level utilities. Within three years of span of time adani power created >circuit of 5000KM of transmission system in the country which gave the new height to adani group power business for the publically listed business in the India and overseas shortly afterward .

Since its inception the Adani power sector grow tremendously with sheer dynamism of group as well as new businesses incubate successfully. Now, we can say the adani power –power business is the largest business of Adani group which is operating successfully the operations. Helping in building the nation.

ADANI Group Core Values

C.T.C. –COURAGE, TRUST AND COMMITTMENT

Courage

Dare--We shall embrace new ideas and businesses

Trust

Faith --We shall believe in our employees and other stakeholders

Commitment

Deliver on the promise .We shall stand by our promises and adhere to high standards of business.

4620 MW (5 X 660 MW + 4 X 330 MW)

1.2 Mundra, Gujarat –MUNDRA 660X2 & 660X3

Mundra is the first super-critical generating unit in India. By synchronising the first super-critical technology based 660MW generating unit at Mundra Adani Power has created the history in India. The Mundra power project is also the fastest project implementation ever by any power developer in the country with a record completion of inception to synchronisation within 36 months. Till date, nobody has synchronized the unit in less than 36 month in India.

Benchmarks:

In Mundra #6 & unit #9 super critical unit's synchronizations achieved in less than 3.5 months only from boiler light up activity.

At the world level, fastest and best implementation from the inception carried out only in 36 months the supercritical unit #5 of 660 MW synchronization at Mundra.

#8&#9 of Mundra TPP steam blowing completed within two days from light up of boiler of two units.

Within 4 days full load operations have done of unit 3, 5&9 from synchronization time at Mundra.

In Mundra location a P&M lab is established which is accredited through NABL.

Achievements:

I.M.S. Certification completed which consist the QMS, 90001:2008 under IMS umbrella.

EMS - ISO 140001 achieved under IMS.

OSHAS IS 18001 certification achieved under IMS.

Energy management system ISO 50001 achieved.

Honourable President of India awarded the NECA awards continuously two years to Mundra plant through Ministry of power and BEE.

Prestigious Awards Green tech safety received by Mundra plant.

Mundra plant also got safety award for Innovation

Mundra plant received the Golden Peacock award.

Excellent category awards achieved after receiving the 5S certification from Q.C.F.I.

Unique Features:

- For all 9 units sufficient water is available due to sea sore is available, so 100% water source is present here.
- First super critical 660 MW units synchronized in India.

- 1st in the world, HVDC power transmission System at Mundra which is registered under clean developing mechanism.
- In India longest and first HVDC System of 500KV Bipolar HVDC TO Mohindergarh from Mundra station.
- In single location largest thermal power station of India.
- A single conveyor of length 7.5 kilometres is installed from port to power plant and it is having handling capacity of 5000 MT/hr.

Resources:--

Fuel:

Fuel supply agreement of 6.045 MTPA with coal India limited subsidiary for operation of the plant .plant is operated for imported coal and plant is designed for majority of the imported coal.

Water:

Mundra TPP to function off sea water based cooling water system through closed cycle induced draft circulating water system. The sea water drawn is recycled 4 times, conserving water and through the smaller diameter of pipe line discharge into the sea.

For cooling system sea water is used, for other auxiliary system sea water is purified through reverse osmosis process which capacity is 47 x10 lakhs litters fresh water per day. In boiler demineralized water is used which is made in the plant. Each 660 MW unit converts 2000 litters water in one hour convert into the steam which is 250 times of atmospheric pressure and temperature is about 566 degree centigrade. Steam is sent to turbine through the high pressure thick steam pipes and after that it is collected into the condenser for cooling through sea water and to the boiler recycling back continuously and this complete process is going on and cycle is moving on.

Ash Management:

In Mundra, there is no wet ash system transferring ash from plant to ash pond. There is ash bagging system and 100% ash utilization is done. For 100% ash utilization Mundra have developed ash bagging plant and disposal. Each machine capacity is 18 ton per hour and total 54 MT ton per hour may done simultaneously by all three machines installed at Mundra .

1.3 Tiroda, Maharashtra   3300 MW (5 X 660 MW)

Tiroda plant capacity is 3300MW. It has 5 units of same capacity 660 MW x5. All five units have super critical technology units. Super critical technology is better. In environmental management tiroda is using new technology and is registered by UNFCCC under CDM. APML is the largest thermal power plant in Maharashtra state which total capacity is 3300 mw .it comprises 660x5. All are super critical coal based thermal units.

In MIDC this plant is located which is the growth centre, Tiroda location is in Gondia district on SH 249 Bhandara-Gondia state highway.it is 125 kilometres away from Nagpur city. Where major airport is there and commercial complex is situated. The major railway station is Gondia on Mumbai hawara route which is 30 km away from the plant .Mumbai port is the nearest sea port at distance 985 kms. From sea level plant is located about 328,25 meters. Maximum temperature at plant is about 47degree centigrade and relative humidity is 58% at mean level annually.

In environmental management Tiroda is using new technology and is registered by UNFCCC under CDM

APML is the largest thermal power plant in Maharashtra state which total capacity is 3300 mw .it comprises 660x5. All are super critical coal based thermal units. The first unit of Tiroda plant is commissioned on 28 august 2012 and subsequently other units commissioned one by one at six months interval. The plants run at full capacity in 11th Oct. 2014 when all units have fully commissioned.

Plant Details:

The Tiroda Maharashtra Adani power plant have the significant supercritical technology which is environmental friendly and fuel efficient technology. It is the super critical technology so it is operated on 254 ksc/ Pressure and 571 degree temperatures. The turbine generator is a 3 cylinder tandem compound, 4 exhausts, static excitation, condensing reheat turbine and hydrogen cooled generator with 22kv stator voltage .For high operating efficiencies smooth operation and maximum reliability DEH system is designed.

The total land of plant is about 456 hectares, where all major equipments such as Turbine, Generator Boiler, Switch yards Cooling tower , Transformers cooling towers ,Ash handling plant , Coal handling plant Track hopper, CW pump house, Wagon tippler ESP, ETP, Reservoir Ash dyke etc. For continuous coal supply, we have rail route on Mumbai Howrah route RUR- rail under rail system is there.

Achievements:

The tiroda plant has set highest bench mark in operational efficiency parameters by achieving the highest level of operational excellence through business transformation. The highest standard of housekeeping &safety and 5s are being maintained inside the plant premises.

Adani power Maharashtra limited has nagged the following recognitions and rewards.

In 3rd national conclave NCQCC-15 5S Par excellent award.

Two silver and and one gold award at VCQCC15 in dec 14 found.

During Safety rating survey by NSC 4 Green triangle accreditation in May 2015 found.

For best practices and innovative safety system the Prestigious Awards Green tech safety award 2014 received by Tiroda plant.

By National Safety council best safety practice award in Oct -2015 given to Tiroda plant.

From Institution of engineers (India) commendation certificate for adopting best safety practices given to Tiroda plant.

Fuel:

4.91 Million ton per annum coal under fuel supply agreement is presently met the coal supply as per the plant requirement. FSA is with coal India limited. Remaining coal is met through the coal availability under the MoU, e-auction from various coal India subsidiary / plants and by imported coals.

Water:

Total plant requirement has of 5.5 million cubic meters per month which is taken from river Wainganga. Here make pump is installed by Tiroda plant and draw the water from the source.

Tiroda power has laid pipe lines 18kms. Long for uninterrupted water supply to two reservoirs 14 &33 hectares at the plant location. The water from the said river caters the requirement of plant mainly for condenser cooling .Induced draft cooling towers are installed to cool the circulating water for reuse. Here zero discharge philosophy is working in throughout the plant .Steam is sent to turbine through the high pressure thick steam pipes and after that it is collected into the condenser for cooling through sea water and to the boiler recycling back continuously and this complete process is going on and cycle is moving on.

Ash Management:

Tiroda plant has taken many steps for ash utilization. it is done during power generation processes . in spite of major hindrances such as non-availability of lime stone nearby which prevented cement manufacturing for fly ash utilization . APML is giving 48% fly ash to cement plants in the region and other initiatives such as establishment of fly ash brick plant. other initiatives taken by Tiroda plant for farmers and brick making plant from fly ash which compressive strength is good than the normal bricks. APML has installed HCSD (high concentration slurry disposal) system for 100% utilization.

Tiroda plant has equipped with new pollution equipment's of high efficiency ESP. largest in Asia, dust extraction and dust suppression system. 275 meters chimney height and low NOx burner, OFD for, limiting the SPM SOx & NOx emissions within the prescribed limits

Power Evacuation:

In APML total 3085 MW PPA is made with Maharashtra govt. which is long term PPA. 3085MW is evacuated through one 400KV dual circuit 219 kilometres Tiroda-Warora line of transmission and two 765 Tiroda Aurangabad 630 km long transmission lines.

1.4 Kawai, Rajasthan   1320 MW (2 X 660 MW)

APRL - Adani Power Rajasthan Limited is the largest power producer at a single location with 1320 mw generation capacity 660x2 units. It is super critical technology coal based thermal units. for immediate connectivity , kawai has a 1500 meters long air strip and using state of the art technology for environment challenges and management.

1.5 KWPCL Power Plant Details (1X 600 MW)

In Raigarh, Chhattisgarh KWPCL - Korba West Power Company Limited commissioned synchronized 600 MW on 1st April 2014. The company stands 626.19 MW generation capacities with commissioning.

KWPCL began in August 2010 and completed the project within 38 months. In this project BHEL have supplied the boiler turbine and generator equipment's.

KWPCL signed the FSA fuel supply agreement in Aug2013 with uninterrupted coal supply for feeding to Korba west Power Company limited.

Adani Management led Adani power limited has deal with Avantha power &infrastructure limited to buy the KWPCL Project 600mw for value of 4200 Crore as per discloser of stock market.

The KWPCL acquisition will expand our foot print in India particularly in the country particularly in coal mining sector of India and we are keen of expanding business in the country. We are ready to generate 20000MW by 2020 said by Adani power chairman.

Adani power is a subsidiary of Adani enterprises and current capacity is >12000mw in Gujrat Maharashtra Rajasthan Karnataka Chhattisgarh and Tamilnadu.

KWPCL Power plant is located in Raigarh and deals value Rs, 7 Cr/ MW. KWPCL units has synchronized on 1st April 2014 and from that date generation of 600mw is going on.

1.6 Udupi, Karnataka 1200 MW

Adani power UPCL Karnataka has 1200MW power plant is a 2x600MW is project on imported coal based in Udupi, district of Karnataka situated in village vellure of yellure between Mangalore and Udupi. UPCL is first IPP.

EXECUTIVE SUMMARY

Power generation from super critical units is increasing rapidly in India & world. For development of GDP & economic growth of country, power sectors are playing the major role. Without energy development in each area nothing is possible to survive in the world.

Each small power plant < 200MW which has auxiliary power consumption 8% to 9% of total generation capacity and gradually when capacity of generator and turbine got increased from 200MW ,500mw, 600 mw, 660 mw ,800mw and 1000mw & progressively capacity enhancement is going on. The auxiliary power consumption decreases according to capacity enhancement and reduces the APC 7%, 6%, 5% & 4% respectively according to generation capacity which ,means when power capacity of Major T.G. it reduces just half of old plants.

Several majors modifications have been carried out to optimize the APC in super critical units. Some areas like Coal handling plant in the power sectors which to be focused to optimize the CHP –APC, HSD, SCC, dependent variables in super critical units to be optimized for smooth running of CHP. In this paper we have developed the econometric model in which study of different super critical units studied and data collected and analysis carried out by statistical methodology adopting and hypothesis testing run through Stata made for targeting the objective target of the research problem and business problems.

Many literatures related to research objective searched and relevant points noted and questionnaire and research gaps noted related to business and research problems. Various researches indicate that if the power sector losses may be prevented and optimized the equipments operations and maintenance management may be better for Sustainable development of Coal handling plant. The belt utilization factor increase of 1% will increase power saving of one supercritical power saving in CHP. In this regard an attempt has been made in these reports to analyze some of the major initiatives undertaken for the CHP –APC, HSD, SCC, dependent variables & independent variables.

1.7 Upcoming Power Plants

>7000mw projects are in pipe line which is in making and under progress order placed.

Planned projects are in the state Jharkhand, M.P. U.P. Gujrat, Rajasthan & Karnataka

Chhindwara, M.P 1320 MW

Adani Power Pench is planning to install 660x2 1320mw through its SPV Adani Pench Power limited. As per adani group commitment toward the environment all units will be of super critical technology only. An environmental clearance has been taken on 16.10.2012.

Kawai, Rajasthan 1320 MW (2 X 660 MW)

APRL - Adani Power Rajasthan Limited is the largest power producer at a single location with 1320 mw generation capacity 660x2 units. It is super critical technology coal based thermal units. for immediate connectivity , kawai has a 1500 meters long air strip and using state of the art technology for environment challenges and management

Kawai Expansion 1600 MW (2 X 800 MW)

Expansion of two units of APRL Adani, Power Rajasthan limited a subsidiary of adani power limited for kawai expansion by adding 1600MW 800x2 units . It will be based on super critical technology.

Udupi, Karnataka 1200 MW

Adani power UPCL Karnataka has 1200MW power plant is a 2x600MW is project on imported coal based in Udupi, district of Karnataka situated in village vellure of yellure between Mangalore and Udupi. UPCL is first IPP. UPCL is the 1st (IPP) independent power plant using the fuel as imported coal in the country. And awarded gold shield award for early completion of Thermal power project unit 1 by Power ministry Govt. of India IN 2010-11. And also bagged the prestigious award golden peacock award , and env .mgmt. award in year 2014-15.Udupi power project supplies 90%power to Karnataka state and 10% to Panjab state.

Udupi Expansion 1600 MW (2 X 800 MW)

The study has used the econometrics modeling in order to analyze the problem and solutions were drawn accordingly.

List of Abbreviations:--

Short Form	**Full form**
CHP	: Coal Handling Plant
HSD	: High Speed Diesel
CBM	: Condition Base Maintenance
APC	: Auxiliary Power Consumption
TG	: Turbo Generator
GDP	: Gross Domestic Product
BARC	: Bhabha Atomic Research Centre
CSE	: Computer Science and Engineering
KWH	: Kilo Watt Hour
IPFM	: In Plant Fuel Management
TP	:Transfer Point
PPA	: Power Purchase Agreement
REI	: French Society
SEZ	: Special Economic Zone
O&M	: Operation and Maintenance
C.T.C	: Courage Trust Commitment
NABL	: National Accreditation Board for Testing & Calibration Laboratories

Udupi plant expansion is planned by adani group by addition 800x2 =1600 MW in existing capacity of 1200mw.through SPV UPCL. In line group is committed to environment so both units will be on super critical technology based.

Dahej 2640 MW

Another project is planned by adani group is to set up DAHEJ project of 2640 MW through its SPV Adani Power Dahej Limited. all units will be based on super critical technology and the unit environmental clearance is granted on dated 26.10.2018 for clearance for project environment.

Project GODDA in Jharkhand 1600 MW

Another project is planned by adani group is to set up Godda Jharkhand project of 2x800MW =1600 MW through its SPV Adani Power (Jharkhand) Limited. All units will be based on super critical technology.

Surguja 600 MW

Surguja Thermal Power Project of 600 MW (4 X 150 MW) set up by Adani Group .through its SPV Surguja Power Private Limited. The Coal Washery reject will be used as Primary Fuel. All the units will be based on CFBC technology.

Ash Management:

Tiroda plant has taken many steps for ash utilization. it is done during power generation processes . In spite of major hindrances such as non-availability of lime stone nearby which prevented cement manufacturing for fly ash utilization . APML is giving 48% fly ash to cement plants in the region and other initiatives such as establishment of fly ash brick plant. other initiatives taken by tiroda plant for farmers and brick making plant from fly ash which compressive strength is good than the normal bricks. APML has installed HCSD (high concentration slurry disposal) system for 100% utilization.

Tiroda plant has equipped with new pollution equipment's of high efficiency ESP. largest in Asia, dust extraction and dust suppression system. 275 meters chimney height and low NOx burner, OFD for, limiting the SPM SOx & NOx emissions within the prescribed limits

Power Evacuation:

IMS	: Integrated Management System
QMS	: Quality Management System
EMS	: Environment Management System
OHSAS	: Occupational Health Safety Assessment Series
NECA	: National Electrical Contractors Association
BEE	: Bureau of Energy Efficiency
5S	: Seiri, Seiton , Seiso , Sitkeshu , Sitsuke
QCFI	: Quality Circle Forum of India
HVDC	: High Voltage Direct Current
KV	: Kilo Volt
MT/Hr.	: Metric Ton/ Hour
MTPA	: Metric Ton Per Annum
IPP	: Independent Power Project
UNFCCC	: United Nations Framework Convention on Climate Change
CDM	:_Clean Development Mechanism
APML	: Adani Power Maharashtra Limited
MIDC	: Maharashtra Industrial Development Corporation
SH	: Super heater
Ksc /Pr.	: Kilogram /Centimetre Square Pressure
DEH	: Direct Heating Cable
RuR	: Rail under Rail
NCQCC	: National Convention on Quality Control Circle

In APML total 3085 MW PPA is made with Maharashtra govt. which is long term PPA. 3085MW is evacuated through one 400KV dual circuit 219 kilometres Tirora-Warora line of transmission and two 765 tiroda Aurangabad 630 km long transmission lines.

Kawai, Rajasthan 1320 MW (2 X 660 MW)

APRL - Adani Power Rajasthan Limited is the largest power producer at a single location with 1320 mw generation capacity 660x2 units. It is super critical technology coal based thermal units. for immediate connectivity , kawai has a 1500 meters long air strip and using state of the art technology for environment challenges and management.

KWPCL Power Plant Details (1X 600 MW)

In Raigarh, Chhattisgarh KWPCL - Korba West Power Company Limited commissioned synchronized 600 MW on 1st April 2014. The company stands 626.19 MW generation capacities with commissioning.

KWPCL began in August 2010 and completed the project within 38 months. In this project BHEL have supplied the boiler turbine and generator equipment's.

KWPCL signed the FSA fuel supply agreement in Aug2013 with uninterrupted coal supply for feeding to korba west Power Company limited.

Adani Management led adani power limited has deal with avantha power &infrastructure limited to buy the KWPCL Project 600mw for value of 4200 Crore as per discloser of stock market.

The KWPCL acquisition will expand our foot print in India particularly in the country particularly in coal mining sector of India and we are keen of expanding business in the country. We are ready to generate 20000MW by 2020 said by adani power chairman.

Adani power is a subsidiary of adani enterprises and current capacity is >12000mw in Gujrat Maharashtra Rajasthan Karnataka Chhattisgarh and Tamilnadu.

KWPCL Power plant is located in raigarh and deals value Rs, 7 Cr/MW .KWPCL units has synchronized on 1st April 2014 and from that date generation of 600mw is going on. Now it is the unit of Adani power share transferred to Adani power by Avantha power.

Udupi, Karnataka 1200 MW

VCQCC	: Vadodara convention on Quality Control Circle
NSC	: National safety council
MoU	: Memorandum of Understanding
Kms.	: Kilo meters
HCSD	: High Concentration slurry discharge
ESP	: Direct Electrical Heating
IPP	: Independent power plant
MP	: Madhya Pradesh
UP	: Uttar Pradesh
SPV	: Subsistence Prime Vendor
UPCL	: Udupi Power Corporation limited
CFBC	: Central Fuel Bed Combustion
DFD	:_Data Flow Diagram
SPM	: Suspended Particulate Matter
SOx	: Oxides of Sulphur
NOx	: Oxides of Nitrogen
MW	: Mega Watt
LDO	: Light Diesel Oil
HSD	: High Speed Diesel
*C	: Degree Centigrade
CFPP	: Cold Filter Plugging Point
LGP	: Low Ground Pressure

Adani power UPCL Karnataka has 1200MW power plant is a 2x600MW is project on imported coal based in Udupi, district of Karnataka situated in village vellure of yellure between Mangalore and Udupi. UPCL is first IPP.

Upcoming Power Plants

>7000mw projects are in pipe line which is in making and under progress order placed.

Planned projects are in the state Jharkhand, M.P. U.P. Gujrat, Rajasthan & Karnataka

Chhindwara, M.P 1320 MW

Adani Power Pench is planning to install 660x2 1320mw through its SPV Adani Pench Power limited. As per Adani group commitment toward the environment all units will be of super critical technology only. An environmental clearance has been taken on 16.10.2012.

Kawai, Rajasthan 1320 MW (2 X 660 MW)

APRL - Adani Power Rajasthan Limited is the largest power producer at a single location with 1320 mw generation capacity 660x2 units. It is super critical technology coal based thermal units for immediate connectivity; Kawai has a 1500 meters long air strip and using state of the art technology for environment challenges and management

Kawai Expansion 1600 MW (2 X 800 MW)

Expansion of two units of APRL Adani, Power Rajasthan limited a subsidiary of Adani power limited for Kawai expansion by adding 1600MW 800x2 units . It will be based on super critical technology.

Udupi, Karnataka 1200 MW

Adani power UPCL Karnataka has 1200MW power plant is a 2x600MW is project on imported coal based in Udupi, district of Karnataka situated in village Vellure of Yellure between Mangalore and Udupi. UPCL is first IPP. UPCL is the 1st (IPP) independent power plant using the fuel as imported coal in the country. And awarded gold shield award for early completion of Thermal power project unit 1 by Power ministry Govt. of

NTPC	: National Thermal Power Corporation
JSW	: Jindal South West
Cr.	: Crore
RTD	:_Resistance Temperature Detectors
VSD	: Variable Speed Drive
ToU	: Time of use
e.g.	: Exempla Garcia
AC	: Alternating Current
SPP	: Small Power Plant
NEDC	: New European driving cycle
HC	: Hydro Carbon
CMOP	: Combined Multi Optimization Programme
CO	: Carbon Monoxide
FTP	: Federal Test Procedure
HWEET	: High Way Fuel Economy Test
MOPSO	: Multi-Objective Particle Swarm Optimization
APU	: Auxiliary Power Unit
FC	: Fixed Carbon
TM	: Total Moisture
VM	: Volatile Material
AC	: Alternating Current
ANN	:_Artificial Neural Network

India IN 2010-11. And also bagged the prestigious award golden peacock award, and environment mgmt. award in year 2014-15.Udupi power project supplies 90%power to Karnataka state and 10% to Panjab state.

Udupi Expansion 1600 MW (2 X 800 MW)

Udupi plant expansion is planned by Adani group by addition 800x2 =1600 MW in existing capacity of 1200mw.through SPV UPCL. In line group is committed to environment so both units will be on super critical technology based.

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1.7 Fuel Oil: Light diesel oil (LDO) & High Speed Diesel (HSD) both are important for any type of power plants. during unit cold light up / start up hot light up /start up and unit synchronization LDO sufficient quantity is consumed and the HSD oil consumption is used in heavy earth moving machineries in huge quantity in dozer, pock lain & JCV which are frequently used in coal handling plant .Following are the properties of diesel HSD&LDO Fuel.

PL	: Pock lain
JCB	: Back Hoe Loader
HYV	: Hyva
HYDR	: Hydra
TT	: Tractor Trolley
BC	: Bob Cat
SM	: Sweeping Machine
LD	: Loader
HEMM	: Heavy Earth Mover Machine
GEN	: Generation
PLF	: Plant Load Factor
STD.DEV.	: Standard Deviation
D2,D3,D4,D5	: Plants Slop Coefficient
BUF*D2-to BUF*D5	: Plants Intercept Coefficient
OLS	:_Ordinary Least-Squares
AVG	: Average
R-SQ.	: Root Square
CONS.	: Constant
ADJ R SQ	: Ad joint Root Square
PROB	: Probability
FGD	: Desulphurization

Table 1.1: Characteristics of HDO and LDO oil

Characteristics	Requirements
Acidity, inorganic	
Acidity, total mg of KOH/G,	Max 0.30
Ash, percent by mass,	Max 0.01 0.02
Carbon residue	Max 0.351 1.5 (on whole sample)
(Rams bottom) on 10	percent residue, percent by mass
Cetane number2,	Min 45
(3),HSD FUEL	Max 6 degree C for winter and 18 degree C for summer
(4), LDO FUEL	Max. 12 degree C for winter and 21 degree C for summer 4
Copper strip corrosion for 3 h No. 2 Distillation 90 percent	at 100 degree C Not worse than No. 1 Not worse than Volume recovery at zero degree C, Max 366
Flash point5 Abel, o C, Min 32	Pensky-Martens, degree C, Min 66
Kinematic viscosity, Sediments, percent by mass, Density at 15oC, kg/m2	cSt, at 40 degree C 1.8 to 5.0 ,2.5 to 15.7 Max 0.05 0.10 820-880
To be reported Total sulphur6, Water content,	percent by mass, Max 1.0 1.8 percent by volume, Max 0.05 0.25
Cold Filter Plugging Point and 21oC for summer4)	(CFPP) 2, Max 9 degree C for winter

Source: Primary data collected and compiled by authors from the Log Book of respective plants

The Dozer are the crawler (regular tracked machine) equipped with a substantial metallic plate (blade) is being used to throw by pushing the large quantities of coal, sand, soil ,rubble, bulk materials during construction or conversion work and typically equipped at the rear with a claw-like device (ripper) to loosen the densely compacted items .

TAT	: Turn Around Time
LED	:_Light-Emitting Diode
SQ.RT.	: Square Root
PTO	: Power Track Off
CQI	: Coal Quality Index
HP	: High Pressure
ROM	Raw coal of Mines
LDO	Light Diesel Oil
MGR	Merry Go Round
BOBR	: Bottom Opening Bottom Release
RCC	: Reinforce Cement Concrete
ILMS	: In line magnetic separators
ROM	: Raw coal of mines - ROM
RIO	: Remote Input/ Output
PLC	: Programmable Logic Controller
DCS	: Distributed control system

Bulldozers may be available on a wide range of sites, mines, quarries, military bases, heavy industry and factories, power plants .Bulldozer refers only to a heavy machine fitted with a metallic blade.

Bulldozers are tracked, large and powerful heavy equipment. The tracks give it the excellent ground holding capacity, capability and mobility through high rough terrain. Wide tracks help distribute the bulldozer's weight over a large span (decreasing the ground force pressure), thus prevent it from sinking in slurry ground.

Large width track is as swamp track or low level ground pressure. Extra wide tracks are known as swamp tracks or LGP (low ground pressure) tracks. Dozers are having the transmission systems which are designed to take advantage of the track system it gives the outstanding tractive force. From above properties the Dozers are frequently used in road building, construction, mining, power plants construction, land clearing, infrastructure development, and any other projects requiring highly mobile, solid, and stable heavy earth-moving equipment. Other dozer is the wheeled dozer, which mostly is four wheels driven by a four wheel-drive system and having the hydraulic, articulated steering system. The blade is fixed in forward of the articulation joint, & it is hydraulically actuated. The Dozer's primary tools are the blade and the ripper. "Dozer" is sometimes used inaccurately for construction vehicles such as a large front loader vehicle.

CBMS or Predictive Maintenance methods are an extension of preventive maintenance and have been proved to minimize the cost of maintenance, improve operational safety and reduce the frequency and severity of in-service machine failures. The basic theory of condition monitoring is to know the deteriorating condition of a machine component, well in advance of a breakdown M. Joshi.

There are varieties of critical equipments in Coal Handling Plants. These components require routine inspection to ensure their integrity. The purpose of the inspection is to identify any degradation in the integrity of the systems during their service life and to provide an early warning in order that remedial action can be taken before failure occurs. Assessing the condition is necessary to optimize inspection and maintenance schedules, of Coal Handling Plant to make decisions and to avoid unplanned outages.

List of symbols:

Symbols used in the Doctoral Thesis	Letter Name
α	Alpha
β	Beta
γ	Gamma
δ	Delta
η	Eta
θ	Theta
λ	Lamda
μ	Mu
ν	Nu
π	Pi
ρ	Rho
σ	Sigma
τ	Tau
υ	Upsilon
φ	Phi
χ	Chi
ψ	Psi
ω	Omega

1.8 Business Problems:

There is a huge amount of energy and fuel losses due to improper handling of coal in CHP in all Super Critical Units Power Plants. Before defining business problem the overarching questions that arise here are: Can coal sealing may be optimized? Can CBM of CHP equipments can be optimized the efficiency to mitigate capacity utilization? Can scrapers may play roll to save energy consumption? In a broad perspective for national and international level the Belt Utilization factors of CHP is around 66%. Even in case of many Super critical power units like National Thermal Power Corporation (NTPC); Jindal South West Energy (JSW Energy) ; Adani Power Limited (APL), Mundra; Adani Power Maharashtra Limited,(APML), Tiroda; Adani Power Rajasthan Limited (APRL) ,Kawai, Tata Power, Mundra. Reliance Power, Sasan , Larsion and Toubro (L&T) Nabha Power Hindustan power Lalitpur review of CHP data shows the average BUF is ranging between 60-66%. The CHP, which utilization factor is 65% is known as good CHP in energy generation sector. However, there is scope to increase BUF at least up to 70-75%. So far as Indian and Global scenario is concerned the maximum BUF so far achieved is 60-65%. Energy losses during rainy season are also increasing due to idle running of conveyors.

There was lack of Proven / Practical Methodologies of using more than 66% of BUF in order to minimize the auxiliary power consumption, under-utilization of equipment capacity, optimizing the running-hours of equipments for minimization of fuel losses – all these leading to revenue-loss. Losses in Super-Critical units where 1460 MW loss per unit/Annum worth 11.24 Cr. /Annum as pilot study made.

BUSINESS PROBLEM STATEMENT: (Correctly defined)
Due to inadequate and improper utilization of belt, high speed diesel (HSD) fuel oil & specific coal consumption (SCC) , there is huge financial loss .

Table 1.2: Average Belt Loading and Power Consumption in CHP

Source: Adani Power Super Critical Units

Note: 1200 KW is daily average energy consumption

Although the existing CHPs in regional, national and global level have achieved up to 66% of BUF, but it is not known how to achieve more than 66% of BUF. Further there is lack of proved/ standard methodologies of using more than 66% of BUF in order to minimize energy and fuel losses and optimize the running hours of conveyor belt leading

List of Figures:

S.N.	Average belt loading in Metric Ton (MT)	BUF achieved	Average Power consumption per MT. in Supercritical units of CHP	BUF in Indian power sector	Power consumption deviation difference of BUF	FOR Super Critical units Belt Running / Hours.
1	1800	100%	1200 KW per Hour with 1800Metric Ton capacity =0.66 KW/Hour/MT	not achieved	100%BUF power consumption is 0.66 KW/Hour	6.0 hrs.
2	1700	94.40%	1200/1700 Metric Ton =.705KW/Hour	not achieved		6.5
3	1600	88.80%	1200/1600/Metric Ton =0.75KW/ Hour	not achieved		7.0
4	1500	83.30%	1200/1500/ Metric Ton =0.80KW/ Hour	not achieved		7.5
5	1400	77.70%	1200/1400/ Metric Ton =0.857KW/ Hour	not achieved		8.0
6	1300	72.20%	1200/1300/ Metric Ton =0.923KW/ Hour	Achieved		8.5
7	1200	66.60%	1200/1200/ Metric Ton =1.000KW/ Metric Ton	Achieved		9.0
8	1100	61.10%	1200/1100/ Metric Ton =1.09KW/ Hour	Achieved		9.5

Chapter 6

9	1000	55.50%	1200/1000/ Metric Ton =1.2KW/ Hour	Achieved		10.5
10	900	50.00%	1200/900MT =1.33KW/ Hour	Achieved by Super critical units	50% BUF then power consumption goes 1.5KW /Hr.	12.0
11	800	45%	1200/800/HR =1.5KW/HR	Achieved by Super critical units		13.0

to maximization of revenue. As estimation that due to BUF less the APC cost yearly , Rs.10.51Cr.losses per annum occurring .

Business gaps Observed on basis of optimization theory literatures

- Conventional Scrapers uses are not mentioned in energy saving equipments

* Sealing of skirting not mentioned may improve capacity utilization

* CBM of CHP Equipments Optimization required

The average belt loading and achievement of BUF of Supercritical unit is shown in Table 1 in order to understand the business problem of the study. Table 1 also show that BUF achievement is directly proportional to average Belt loading which is inversely proportional to Belt running hours. Thus more the BUF achieved more will be average belt loading and hence less will be the running hours of Belt leading to less amount of energy consumption (also see Table 1 in Annexure).

The supercritical as of now have achieved 50% of BUF with 900 MT of Belt loading capacity for the bunker feeding of super critical unit for the 12 belt running hour's duration. This can be increased up to >80% by suitable methodology/ technological intervention.

Table 1.3: Annual Average Energy/ Revenue Loss

List of Tables: Page No

Relationship of BUF, Power Consumption, Running hrs. of belt & Power Losses Occurred	Annual Average Energy Loss
• When belt loading is decreasing, running hrs. is increasing. • So power consumption is increasing resulting losses of energy. Thus for 50% BUF the power loss is 0.9KW per hr. • Our main business problem is how to minimize the energy losses by maximizing the BUF from 60% to more than 80%. • In place of 8hrs running of belt we are running 13hrs daily to feed the bunker for power generation i.e. excess of power consumption is due to extra belt running and less achievement of BUF. • The Average revenue in the Indian power sector can be raised up to a maximum of Rs. 10.51 crore if overall BUF can be increased from 60% to 80%	4MW/day *365days =1460 MW per Annum Thus total saving per Annum may be 1460MW *1000 *Rs.3.00 *24 Hrs. = Rs. 10.51Cr. saving may be realized

Source: Super Critical Units of India

Since wet dust suppression system uses optimum amount of water for suppressing dust, therefore use of dust collector which discharges dust in the form of slurry is very elegant approach to control dust at large scale. Every thermal power plant is equipped of a large CHP where coal is handled.

Such plants consume large quantity of water in order to suppress dust properly which is undesirable. Therefore use of dust collector units at particular places of CHP plant where dust particles are airborne is highly recommended, since it discharges dust in the form of slurry (Kumar et al., 2011).

Annexures:

CHAPTER-2

Chapter 2

Survey of Literature

2.1 Introduction:

Saving the energy and fuel is directly proportional to revenue. Small power plant are consuming less fuel quantity & few losses of energy but when we talk about the Supercritical boilers where coal quantity is consumed in bulk and the auxiliary power consumption is very high, it is our responsibility to save the auxiliary power as well as several fuel handling losses. This can be undertaken in such a controllable way that losses of fuel and energy can be minimized and standardized in the super critical units of CHP. Based upon these premises we have surveyed existing literature as follows:

2.2 Power Plant level Belt Utilization Factor of Coal handling plant of Different Power Plants in India

We have studied average belt loading factor of several Indian Supercritical power plants and found that, not a single plant has achieved more than 67% of BUF as shown below

Sl. No.	The Power Plants of Supercritical units > 660MW capacity	Belt utilization factor	Gap in Literature
1)	Adani power ltd Mundra, Gujrat 660mwx5Units	60-67%	BUF is not optimized
2)	Hindusthan power ltd. Lalitpur UP 660MWx 3Units	55-65%	BUF is not optimized
3)	International power plants USA &China 660mw x. n nos	56-66%	BUF is not optimized
4)	Adani power Maharashtra Ltd. Tiroda Maharashtra 660mwx5 Units	50-55%	BUF is not optimized
5)	Adani power ltd. Kawai Rajasthan 660x2Units	55-60%	BUF is not optimized
6)	Tata power 800mw x5 Mundra Gujrat	60-65%	BUF is not optimized
7)	Reliance Sasan M.P 660MW x 6 units	60-65%	BUF is not optimized
8)	L&T Power Raj Pura Chandigarh 700MW x3units	60-65%	BUF is not optimized

Source: Coal Handling Plant Operation Log books of Various Supercritical Thermal Power Plants Data Collection. **Remarks**: No Power plant has been reached to more than 67% average belt utilization factor/belt loading factors

2.3 Automation and Conveyor Control Systems

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
To study the automation trends in coal handling system.	The trends were learned on the basis of experiences gained during the project execution of the automatic operation for the stockyard system of the Schleenhain lignite mine in Germany.	Fully automated stockyard system can contribute to safe and efficient coal supply of modern power plants. (Mulhbach)	• Optimal BUF is not studied. • Did not talk about minimizing running hours of Belt. • Pollution abatement is not studied.
To study the conveyor control systems required for smooth and safe operations	The system will work only by using tachometer, load cell and electronic cards in place of relays.	System developed is having greater reliability and protection and does not require sensors. (Joshi, An intelligent conveyor system for coal handling plant)	• Conveyor control system studied but BUF optimization is not studied. • System development discussed but minimizing the running hours of Belt did not talked. • Management of coal and

			fuel is not studied. • Abatement of pollution is not studied.

2.4 Maintenance of equipment

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
To study the maintenance methods for critical equipment in coal handling system	For vibrations: Vibration analyzers, detection meters, shock pulse For temperature: Thermocouples, Resistance temperature detectors (RTD), Infrared cameras, pyrometers, laser thermometer	Methods suggested will lead to plant shutdown before damage, cause of failure can be analyzed, optimize use of resources. (M.N.Joshi)	• Vibration issue discussed but Optimal BUF is not studied. • RTD discussed but did not talk about minimizing running hours of Belt. • Failure studied but Management of fuel is not studied. • Pyrometers discussed but Pollution abatement is not studied.

Presents review of belt conveyor design modification and latest technologies used in different application to reduce failure, maintenance cost and equipment related fatal accidents.	Focus is on design of drive mechanisms of belt conveyors, drum (pulley) and belt failures, energy & efficiency, increasing friction, fire & safety, maintenance and inspection.	Proper designing of conveyor system which is desired for the application keeping all parameters in mind and by inventing new approaches towards better design. It has been also focused on inspection and online monitoring of all components while transferring coal through belt conveyor to reduce maintenance cost & fatal accidents in mines. (Devendra Kumar1, Feb 2013)	• Conv design modified but Optimal BUF is not studied. • Drive mechanism studied but did not talk about minimizing running hours of Belt. • Fuel Management is not studied. • Environment Pollution abatement is not studied.

2.5 Problems in Conveyor/ Equipment

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
Failure of wet dust suppression system and remedy for it	This result is proved by doing an experiment.	Existing system is failing due to low working pressure and remedy is to	• DSP studied but Optimal BUF is not studied.

		increase the efficiency of spray nozzle. (Joshi, Failiure of wet dust suppression system)	• Spray nozzles efficiency discussed but did not talk about minimizing running hours of Belt. • Surrounding area Pollution abatement is not studied.
To investigate the different problems in a conveyor system and solution for it.	Dual scrapper system, brush system and rubber scrapper.	Problems in different conveyor systems are improper alignment of idlers, belt running off at tail pulley, excessive wear on bottom of belt and corrosion in the frame. Remedies are preventive maintenance, adjusting loading material, greasing and painting. (G.Velmurugan, June 2014)	• Scrapper system studied but Optimal BUF is not studied. • Belt sway discussed but did not talk about minimizing running hours of Belt. • Loading of belt discussed but management of coal and fuel is not studied.
Focuses on actual	Fish bone diagram is	Causes of belt failure is due to 4M	• Cause effect diagram

situation of coal handling plant for failure of belt structure and analyze the technical characteristics with probable reasons for prevention and elimination	prepared after visiting the sites, depth of searching and go through thinking, all possible causes, sub causes and sub sub causes.	(man, machine, method and material) viz. inadequate training of man, poor quality of material, misalignment of old idlers, improper cleaning. Solution is proper housekeeping, providing shading provision over the structure and improve life period. (Biswal)	discussed but Optimal BUF is not studied. • Belt failure discussed but did not talk about minimizing the running hours of Belt. • Fuel Management is not studied. • Structure life period studied but Pollution abatement is not studied.

2.6 Energy efficiency

Objective of Study	Methods Used	Major Findings	Research Gap
To study an optimal switching control and a variable speed drive (VSD) based optimal control to improve the energy efficiency of belt	A specific energy calculation model was used which included many specific formulas. Case study named coal conveying system was used in which at an anonymous	The optimal switching control strategy achieves large reductions of energy cost, however, it can hardly save energy. On the other hand, the VSD based optimal control strategy reduces the energy cost greatly, meanwhile, it saves the energy	• VSD studies but BUF optimization is not studied. • Energy cost discussed but did not talk about minimizing the running hours of Belt.

conveyor systems at the operational level, where time-of-use (TOU) tariff, ramp rate of belt speed and other system constraints are considered.	location these methods were used and found successful.	consumption considerably as well. An energy consumption reduction, while making financial sense, makes the VSD based optimal control strategy a sustainable scheme for energy management. Furthermore, a conclusion can be drawn that the belt conveyors with higher belt speeds or further decreased feed rates have the larger potential for improvement of operation efficiency. (Xia, Feb 2010)	• Fuel Management Energy APC is not studied. • Operational efficiency studied but Pollution abatement is not studied.
To make a model based optimization approach to improve the efficiency of belt conveyors at the operational level.	An analytical energy model is firstly proposed which lumps all the parameters into four coefficients. Subsequently, both an off-line and an on-line parameter estimation schemes are	Variable speed control of belt conveyors indeed save energy. Also the belt conveyor deviates from its design operation condition the more energy can be saved by speed control. A belt conveyor can be driven in its optimal operation efficiency through the	• Analytical energy model studied but optimal BUF is not studied. • Operational efficiency discussed but did not talk about minimizing the running hours of Belt.

	applied to identify the new energy model, respectively. Simulation results are presented for the estimates of the four coefficients. Finally, optimization is done to achieve the best operation efficiency of belt conveyors under various constraints. Six optimization problems of a typical belt conveyor system are formulated, respectively, with solutions in simulation for a case study.	optimization of its performance indicators, e.g., energy consumption Or energy cost. With the consideration of Time of use (TOU) tariff, load shifting is achieved by operation efficiency optimization. Further, by integrating a technical issue into the objective function, a balance Between the economic indicator and the technical indicator can be obtained. (Shirong Zhang, 2010)	• Economical and technical indicators discussed but management of fuel is not studied. • Land Pollution abatement is not studied.

2.7 Nature of Belt/ Technology

To establish the dynamic properties	An experiment was done creating	Stress wave propagation speed increases non	• Belt dynamic

of belting material. The dynamic elastic modulus, viscous damping and study of flow of material (rheological) constants of the belt were measured. Two types of belt a fabric belt and steel cord belt commonly used in coal mines are examined.	an artificial apparatus.	linearly with an increase in tension in the belts. For the same tension force, the stress wave propagation speed of the steel cord belt is greater than that of the fabric belt. The dynamic performance parameters of the belts, including the dynamic elastic modulus, the rheological constant and the viscous damping, vary with tension force. The natural frequency of the transverse vibration in the belts slightly increases with the tensile load in a nonlinear way. The natural frequency of the transverse vibration in the steel cord belt is greater than that in the fabric belt. Tension force on the belt is the main factor that influences longitudinal vibration: The effect of excitation frequency is smaller. This indicates that more attention should be paid to controlling tensile	process discussed but optimal BUF is not studied. • Belt types discussed but did not talk about minimizing running hours of Belt. • Fuel Management is not studied. • Surrounding Pollution abatement is not studied.

		loading in belt conveyor design. Steel cord belts have the same response characteristic to shock excitation as an elastic body. This indicates that the vibration characteristics of a belt are mainly determined by the elastic properties of its framework material. (HOU You-fu, 2008)	
Two new conveyor technologies that offer the opportunities for significant improvement for the handling of coal in power plants, in bulk transportation facilities and other coal handling operations. 1.Flow engineered chutes 2.Air supported conveyors	Based on material testing and flow studies.	The first technology provides better control, continuous coal flow in higher capacities and dramatic reductions in material spillage and in the release of airborne dust. The second technology offers high efficiencies and low maintenance, reduction in release of coal dust. (Bierie.G, 2007)	• Coal flow better control studied but optimal BUF is not studied. • Did not talk about minimizing running hours of Belt.

			• Air born dust discussed but Pollution abatement is not studied.

According to CERC, a properly structured losses identification, analysis, and mitigation process can moderate the risks associated with power sectors. CERC is of the view that documentation is critical, and properly recording the identification, analysis, and loss mitigation plans and results for each loss element allows for lessons to be learnt and actions to be taken if necessary.

2.8 Ware housing optimization theory

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
framework and a classification of warehouse design and control problems	Descriptive and review based	The author discussed ware houses design &structure organization Quick retrieval of item from ware houses	• In ware houses the materials housekeeping is focused, however optimal BUF is not studied. • Shed covering of fuel is discussed managemen

			t of fuel is not studied. • There is Pollution but to abate it is not studied.

Objective of Study	Methods Used	Major Findings	Research Gap
Optimization of Auxiliary Power Consumption of Combined Cycle Power Plant	Here an attempt is made to improve the efficiency of above mention auxiliaries. To improve the performance of the pumps various methods have been suggested in the present study. This includes impeller trimming, de-staging and installation of variable frequency drives(VFD). Similarly methods for	Before modifications actual data are collected for pumps and compressors. Power and efficiency are calculated and same are compared with ideal values reported in supplier manuals. On the basis of discrepancies in above data, methods for performance improvements are	• APC not discussed but optimal BUF is not studied. • Pump compressors energy efficiency discussed but

	improving compressor efficiency have also been suggested in the present study.	suggested. Dr R N Patel Tejas N Ravala	did not talk about minimizing running hours of Belt. • Management of fuel is not studied. • Under capacity utilization of equipment is not studied.

2.9- Installation of Variable Frequency Drives (VFD):

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
Installation of Variable Frequency Drives (VFD):	The base speed of the motor is directly proportional to frequency of the current drawn to it. So, by changing the	A variable frequency drive (VFD) is an instrument which controls the rotational speed of an alternating current (AC) electric motor. It controls the frequency of the	• Study shows the VFD is better in place of normal drive to be replaced to

	supply frequency, the motor speed can be changed.	electrical power supplied to the motor and hence varies the speed of the motor as per the user requirement	implement for the energy saving but not exact quantity of saving is mentioned • Did not talk for minimizing running hours of Belt. • Management of fuel is not studied. • Under capacity utilization of equipment is not studied.

2.10 - Energy Conservation in Compressors

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
Energy Conservation in Compressors Unfortunately, running air	The total energy use of a compressor system depends on several factors.	Change the filters. Filters are located throughout the system to ensure clean air for	• Cleaning of filters studied but optimal

compressors (AC) often uses more energy than any other equipment. Studies show that the average compress air typically comprises from about 5 % to 20 % of a plant's annual electric cost.	The air compressor type, model and size are important factors in the compressor's energy consumption, but the motor power rating, control mechanisms, system design, uses and maintenance are also fundamental in determining the energy consumption of a compressed air system. Factors affecting the Compressor Performance are: (1) Compressor inlet temperature and pressure (2) Compressor discharge temperature and pressure (3) Humidity of the surrounding atmosphere	end uses. Often these filters are not known of or are simply not checked. Dust, dirt, moisture and grease can clog the filters leading to a pressure drop in the system. This pressure drop is not often seen for what it is and more compression energy is used to compensate for the clogged filters resulting in increased energy use . 4. CONCLUSION The major conclusions derived from the present study are as follows: The study of operating parameters of the present show that the efficiency of the said systems are poor and power consumption is very high at off design conditions.	BUF is not studied. • Pressure filter discussed but did not talk about minimizing running hours of Belt. • Clogging of filters discussed but management of fuel is not studied. • Belt Under capacity utilization of equipments is not studied . • Belt Scraper

		. The suggestions for improvements in efficiency and power for pump like de-staging, impeller trimming and installation of VFD were given and also been implemented. After implementation of the above recommendations, power, efficiency etc, were again calculated. For economic viability economic indices like SPP, B/C ratio and cost of saved energy were calculated. Results indicate that in all four recommendations SPP is less with sizable annual savings. Cost of saved energy is also very less in comparison with existing energy cost Rs.3 per kWh.Dr R N Patel	uses not mentioned in energy saving equipments

2.11 The Efficiency of Restorable Networks Using Preconfigured Cycles (p-cycles)

Objective of Study	Methods Used	Major Findings	Research Gap
Recent work on restorable networks has shown experimentally that one can support 100% restoration with an optimized set of closed cycles of spare capacity while requiring little or no increase in spare capacity relative to a span-restorable mesh network.	This is important and unexpected because it implies that future restoration schemes could be as capacity efficient as a mesh network, while being as fast as ring-based networks because there is no real-time work at any nodes other than the two failure nodes.	This paper complements the prior work by giving a greater theoretical basis and insight to support the prior results. We are able to show in a bounding-type of argument that the proposed protection cycles ("p-cycles") have as high a restoration efficiency as it is possible to expect for any type of preconfigured pattern, and are categorically superior to preconfigured linear segments or trees. We are also able to show that the capacity efficiency of a fully preconfigured p-cycle network has the same well-known lower bound as that of a span restorable mesh	• Mesh network discussed but Optimal BUF is not studied. • Restoration discussed but did not talk about minimizing running hours of Belt. • Theoretical underpinning on mesh network discussed but preconfigured p cycle network discussed but management of fuel is not studied. • Belt Under capacity utilization

		network which is cross-connected on-demand. These results provide a theoretical underpinning for the efficiency of p-cycles and confirmation of the experimental observations D. Stamatelakis August 2000	of equipments is not studied . • Belt Scraper uses not mentioned in energy saving equipments

2.12 Monitoring improper of CBM of CHP Equipments

Objective of Study	Methods Used	Major Findings	Research Gap
Development Of Condition Based Maintenance For Coal Handling Plant Of Super critical units in Thermal Power plants	Detection meters, Shock pulse etc. Thermocouples, RTD Infra red cameras, Pyrometers, Laser Thermometer Analytical lab or Portable lab kit Spectrographic analysis, On-line systems	As close to source of vibrations. Surface or internally mounted Surface Any lubrication sample Wear Debris in lubricant used between wear surface via magnetic plugs Mounted on shafts Below the conveyors and in panels M.,M. Joshi	*wear debris analysis discussed but Optimal BUF is not studied. *CBM discussed but did not talk about minimizing running hours of Belt. *spectrographs discussed but management

			of fuel is not studied. *coffin box skirt sealing sealing system not studied

2.13 Optimization of Fuel Consumption and Emissions for Auxiliary Power Unit Based on Multi-Objective Optimization Model

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
Optimization of Fuel Consumption and Emissions for Auxiliary Power Unit	The four competing objectives of this CMOP are fuel-electricity conversion cost, hydrocarbon (HC) emissions, carbon monoxide (CO) emissions and nitric oxide (NOx) emissions. Then, the multi-objective particle swarm optimization (MOPSO) algorithm and weighted metric decision making method are employed to solve the APU operating point multi-objective optimization model.	bench experiments under New European driving cycle (NEDC), Federal test procedure (FTP) and high way fuel economy test (HWFET) driving cycles show that, compared with the results of the traditional fuel consumption single-objective optimization approach, the proposed multi-objective optimization approach shows significant improvements in emissions performance, at the expense of a	*HC &NOx discussed but optimal BUF is not studied. *NEDC &FTP &HWFET studied but did not talk about minimizing running hours of Belt. *emission of performance studied but management of fuel is not studied. *Coffin box skirt sealing

		slight drop in fuel efficiency **Yongpeng Shen**	sealing system not studied

2.14 Applications of maintenance optimization models: a review and analysis

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
Applications of maintenance optimization models a review and analysis	Maintenance optimization has flourished as a mathematical discipline within operations research and it is likely to do so in the future, considering the problems listed in recent reviews. Its impact on decision making within maintenance organizations is limited so far. Yet there are a number of case studies published which show that mathematical models are a good means to achieve both effective and efficient maintenance.	As application tool technology (both soft- and hardware) is only recently becoming available at low costs and is rapidly developing, we expect that the near future will see many decision support systems incorporating maintenance optimization models. Economic pressure is likely to enforce the changes in culture that are necessary to make these packages standard tools for the modern maintenance manager Rommert Dekker.	Maint. Optimization model discussed but Optimal BUF is not studied. *change in culture discussed but did not talk about minimizing running hours of Belt. *maintenance optimization mdel discussed but management of fuel is not studied. *conveyors coffin box skirt sealing system not studied

			*Maintenance. management to be strengthened

2.15 Optimization of power consumption of belt conveyer system by replacing adjustable non-contact type internal scraper

Objective of Study	Methods Used	Major Findings	Research Gap
Optimization of power consumption of belt conveyer system by replacing adjustable non-contact type internal scraper	Conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Belt Conveyor systems are used widespread across a range of industries due to the numerous benefits they provide. Though these conveyors have numerous advantages they also require huge amount of power to drive belts. As the result of increased fuel prices in global markets and scarce of fuels electricity tariff is increasing tremendously.	By reducing drive power requirement we can save huge amounts of money as well as reduce green house gas emissions. The project involves analysis of changes in power consumption by replacing the contact type internal scraper with Adjustable Type Non-contact internal scraper Arun \ Kumar.	Green house gas emission discussed but optimal BUF is not studied. *power consumption discussed but did not talk about minimizing running hours of Belt. *non-contact type scrapper discussed but management of fuel is not studied. *belt conv. coffin box skirt sealing system not studied

2.16 On efficiency of optimization in power Systems

Objective of Study	**Methods Used**	**Major Findings**	**Research Gap**
On efficiency of optimization in power Systems	Two classic optimization problems were studied: 1) economic dispatch problems of thermal power units, 2) unit commitment problems. In both tasks the total fuel costs and the environmental impacts were minimized.	The study showed that the maximal efficiency of optimization in thermal power plants and in power systems may reach 30% and even more. M. Keel.	Optimization in thermal power discussed but optimal BUF is not studied. *power saving discussed but did not talk about minimizing running hours of Belt. *Conveyors coffin boxes skirt sealing system not studied

Most of the scholars on above themes did their research considering the theory of optimization.

2.16.1: CERC Guidelines

CERC Guidelines (2010)	Descriptive	Disseminates knowledge w.r.t regulations and design coal handling of the power plant. (Please see Annexure 3)	

2.17 Variables Identified from Literature

Need to Support the dependent and independent variables proper justifications given to take the dependent & independent variables. Details mentioned below.

Sl. No.	**Variables**	**Authors**	**Factors (dependent/ Independent)**	**Inferences**
1	APC: Auxiliary power consumption	VIKRAM VI (2017)	Dependent	A-Use of Wash Coal or Blending with A- grade coal. B- F-grade coal has high ash content. Overall performance can be improved by using wash coal or blending of F-grade coal with A- grade coal instead of only using F-grade coal. C- Avoiding idle running of conveyors & crusher in CHP Avoiding idle running of conveyors & crusher in CHP.

2	BUF : Belt utilization factor	Damiyan , Adeodu, Dada (2014)	Independent	Belt conveyor system can be employed for easy handling of materials beyond human capacity in terms of weight and height.
3	LIGHTING OF CHP: CHP Area Illumination	Vincent china (2017)	Independent	LP INTL focus on high technology, green, save energy, wisdom auto fields.. LP INTL takes care of the environment and takes action on it

4	SCC: Specific coal consumption	Nowling (2015)	Dependent	SCC: Quantity required producing 1 unit of energy. It may be calculated for thermal power plant by dividing Plant Heat Rate by GCV of Coal. Latent heat losses are not easily detectable by a thermometer & energy losses are associated with a phase change of water. Improve Plant Efficiency and Reduce CO_2 Emissions When Firing High-Moisture Coals Unburned combustible losses are efficiency losses from incomplete combustion of fuel in the boiler. These losses are generally influenced by both fuel properties (fuel volatility) and operations practices (excess air level, fuel fineness).
5	TM: Total moisture	Naveen Chandralal1, D. Mahapatra1*,	Independent	The size distribution shows a mean size of 10mm and low

		D. Shome2 and P. Dasgupta3 (2014)		proportions of ultra-fine material, which makes the crushed coal suitable for stockpile drainage as there should be ample clearance between particles. Dry conditions allowed the piles to drain free moisture at a loss rate of between 0.7 and 1.7% per day. Additional rain periods ensured that the overall effect was a gain in moisture for the trial period. It would be apparent that the greatest drying benefit would be gained by sheltering the coal from rain. Any drying benefits gained by stockpiling could be reversed by rainfall exposure. This evaluation would suggest that, without consideration for the weather condition effecting the stockpile temperature and

				moisture, a natural drainage period of between 18 and 25 days would assist in the reduction of moisture associated with the high moisture low rank coal. The critical stockpile temperature has been stipulated as 60 ◦C and this temperature are likely to be reached in approximately 18 days. There is some evidence to suggest that the stockpile temperatures may reach higher than the suggested critical temperature before uncontrolled heating continues. Few occasions temperatures exceeded sixty degrees and then dropped. Of course, the impact on temperature of both wind and rain can dramatically change the heat generated from oxidation processes. This evaluation would suggest that, without

				consideration for the weather condition effecting the pile temperature and moisture, a natural drainage period of between 18 and 25 days would assist in the reduction of moisture associated with the coal. The reduced moisture content of the drained material could be expected to reach approximately 27% Total Moisture over this period. Further, to evaluate the same coal with small stockpiles under ambient conditions but with and without shelter from rain and using different initial
6	VM: Volatile material	J.H.Slaghuis C .Ferreira M. R. Judd (1991) ONLINE -2003	Independent	Volatile decomposition products originating from the mineral phase of coal were found to contribute up to 45% of the total amount of volatile material in coal (as determined by ISO method 562). The

				magnitude of this contribution was found to be directly related to the maceral composition of coal. It was established that these minerals are associated mainly with the inertinite macerals of coal. Inertinite macerals often form the main constituent of the ROM coals produced in South Africa. Coal types consisting mainly of the so-called reactive macerals, namely vitrinite and exinite, appear to contain few if any of these minerals, despite high overall ash values.
7	AC : Ash content	Mahamudul Hashan, M. Farhad Howladar, Labiba Nusrat Jahan and Pulok Kanti Deb (2013)	Independent	Ash content of coal is the non-combustible residue left after coal is burnt. It represents the bulk mineral matter after carbon, oxygen, Sulphur and water (including from clays) has been driven off during combustion

				Several kinds of impacts (e. g. health, environmental and boiler) of coal Ashes are also discussed in the study. From the values of ash concentration, it can be seen that the coal of Barapukuria, Phulbari and Dighipara might cause less environmental and health destruction while Jamalgonj and Khalashpir coalmine's coal will cause much Hazard.
8	FC: Fixed Carbon	ST JOSEPH (2010)	Independent	Fixed carbon is the solid combustible residue that remains after a coal particle is heated and the volatile matter is expelled. The fixed-carbon content of a coal is determined by subtracting the percentages of moisture, volatile matter, and ash from a sample.

				FixedCarbon=100([Moisture]+[Volatile]+[Ash])
9	GCV : Gross Calorific Value	VISHAL AGRAWAL , MESHROGHLI (2015)	Independent	Relationships of ultimate and proximate analysis of 4540 US coal samples from 25 states with gross calorific value (GCV) have been investigated by regression and artificial neural networks (ANNs) methods. Three set of inputs: (a) volatile matter, ash and moisture (b) C, H, N, O, S and ash (c) C, H exclusive of moisture, N, O exclusive of moisture, S, moisture and ash were used for the prediction of GCV by regression and ANNs. The multivariable regression studies have shown that the model (c) is the most suitable estimator of GCV. Running of the best arranged ANNs structures for the models (a) to (c) and

				assessment of errors have shown that the ANNs are not better or much different from regression, as a common and understood technique, in the prediction of uncomplicated relationships between proximate and ultimate analysis and coal GCV. Estimation of gross calorific value based on coal analysis using regression and artificial neural networks
10	HSD :HIGH SPEED DIESEL	R&D Toyota Labs (2014)	Dependent	The **diesel** engine is **high** compression, self-ignition engine. Fuel is ignited by the heat of **high** compression. HSD is normally used as a fuel in medium and **high speed** compression ignition engines (operating above 750 rpm) in commercial vehicles, stationary **diesel** engines, Locomotives and pumps etc.

				Development of cost effective combustion system further improvement with fuel economy with energy management .decrease frictional loss & engine weight
11	DZ: Dozer	Sophiya jones (2016)	Independent	09th June 2016 – Navi Mumbai, India: Market reports on India presents the latest report on “Bulldozer and Angle dozer Market in India to 2020”. This report gain an outlook of the historic development, current market situation, and future outlook of the bulldozer and angle dozer market in India to 2020 The report Bulldozer and Angle dozer Market in India to 2020 - Market Size, Development, and Forecasts offers the most up-to-date industry data on the actual market situation,

				and future outlook for bulldozers and angle dozers in India. The research includes historic data from 2009 to 2015 and forecasts until 2020 which makes the report an invaluable resource for industry executives, marketing, sales and product managers, consultants, analysts, and other people looking for key industry data in a readily accessible document with clearly presented tables and graphs.
12	PL: Pock lain	Amarjit Singh, Dr. Vinod Gupta (2012)	Independent	India has the potential to develop into a significant market for Automobile manufacturers. Indian automotive industry holds significant scope for expansion, both in the domestic market, where the vehicle penetration level is on the lower side as compared to

				world average, and in the international market, where India could position itself as a manufacturing hub.
13	JCB: Pay Loader	Ghazi Abu Taher1, Yousuf Howlader2, Md. Asheke Rabbi3, Fahim Ahmed Touqir4 **(2014)**	Independent	The total process is controlled by a control system automatically. We mainly focus on the packaging system. The control system helps to package the right amount of material in several packet. It stops the machine for a certain time between two packaging process. So once it is set the requirement of skilled operator is also reduced as compared to a manual system.
14	HYV :Hyva /Dumper	Prof. Mrs. R. S. Tupkar1 Aditya R. Malewar2 Rohit A. Ramteke3 Harshal S. Lakhade4 Shubham R. Navghare5 (2015)	Independent	Conventional tipper mechanism an unload materials only at the backside of the tipper using hydraulically operated cylinder which may cause the problems of road blockage in the limited space area. The unidirectional dumper overcomes the problem

				of unloading the vehicle on side way by using hydraulic cylinder. By using cylinder the material can be unloaded in 1800 as per requirement. The Unidirectional dumper is developed and tested for its movement in all 1800 possible angle to unload the materials in the tipper trolley and monitor the inclinations for its gradualism (linearity).
15	HYDR: Hydra mobile crane	Brian Nielsen Henrik Clemmensen Pedersen Torben Ole Andersen Michael Rygaard Hansen (2005)	Independent	For loader crane applications resolved motion control is assumed to be one of the areas for development in the future. To develop and evaluate different control strategies for a resolved motion control system, information about the dynamic behavior of these cranes is necessary. In the current paper a model of a loader crane with a flexible telescopic arm

				is presented, which may be used for evaluating control strategies. The telescopic arm is operated by four actuators connected hydraulically by a parallel circuit. The operating sequences of the individual actuators are therefore not controllable, but depend on the flow from the common control valve, flow resistances between the actuators and friction. The presented model incorporates structural flexibility of the telescopic arm and is capable of describing the dynamic behaviour of both the hydraulic and the mechanical system, including the relative movement of the individual mechanical bodies in the telescopic arm. The model is verified through comparisons between simulated and

				measured results for various operating conditions.
16	TT :Tractor trolley	Manish S Lande1* and Sunil J Rajpal1	Independent	Tractor trolley or trailers are very popular and cheaper mode of goods transport in rural as well as urban area. But these trailers are manufactured in small scale to moderate scale industry. Especially in the small- and middle-scale agricultural machinery industry, insufficient use of new technology and new design features can cause problems such as Breakdowns and failures during field operations. In present work finite element analysis approach is used to make a safer working condition of trolley axle as well as for stress concentration, weight and cost reduction of existing trolley axle.

17	BC: Bob Cat veh	John A. Litvaitis Email author , Gregory C. Reed, Rory P. Carroll, Marian K. Litvaitis, Jeffrey Tash, Tyler Mahard, Derek J. A. Broman, Catherine Callahan, Mark Ellingwood (2015)	Independent	Distribution of vehicle-killed bobcats was correlated with road density, especially state and interstate highways. Collision models suggested that some regions may function as demographic sinks. Simulated movements in the context of the cost-surface map indicated that some major roads may be barriers. These patterns were supported by the genetic structure of bobcats. The sharpest divisions among genetically distinct demes occurred along natural barriers (mountains and large lakes) and in road-dense regions. In conclusion, our study has demonstrated the utility of using bobcats as a model organism to understand the variety of threats that roads pose to a wide-ranging species. Bobcats may

				also be useful as one of a group of focal species while developing approaches to maintain existing connectivity or mitigate the negative effects of roads.
18	SM: Road Sweeping machine	India mart (2017)	Independent	Hydraulic Capacity: 151 kg Hydraulic Road Sweeper without bucket system: Cleans the road and collects dust at one side of the road. Road Sweeper is a new effective and efficient machine to sweep the roads Truck Mounted Floor Sweeping Machine is a compact, appealing and with a high-standard design profile equipment. This is designed to be used in all environments both public and industrial,
19	LD: Loader	Cater Pillar Co .Auto Works (2017)	Independent	Caterpillar loader is used to load materials in CHP.

CHAPTER 3

Chapter 3

Research Methodology and Scope of Study

3.1 Research Problem defined clearly as given below

The literature suggest that there have rarely existed any studies on improvement of increasing BUF and its impact on energy consumption and belt running hours in CHP. There is scope of increasing BUF more than 60-67% nationally as well as globally.

In CHP of supercritical units a minimum of 13-32 MW auxiliary power is consumed on a daily basis during stacking and reclaiming processes and if we can increase BUF by more of 15 to 20% the consumption of energy consumption can be reduced by 15-20% in CHP.

Survey of literature suggests that there is need to study management of losses of energy and secondary fuel oil in CHP.
As estimated 4MW/day *365days =1460 MW per Annum1460MW *1000 * Rs.*3.00 *24 Hrs. = 10.51 Cr. Losses in Super-Critical units where 70 lakhs HSD loss per unit/Annum. Total loss 11.23 Cr. Per annum.

3.2. Research problem

The above literature suggest that there have rarely existed any studies on improvement of increasing BUF and its impact on energy consumption and belt running hours in CHP. There is scope of increasing BUF more than 60-67% nationally as well as globally. In CHP Supercritical units. A minimum of 13-32 MW auxiliary power is consumed on a daily basis during stacking and reclaiming processes and if we can increase BUF by more of 15 to 20% the consumption of energy consumption can be reduced by 15-20%. Thus survey of literature suggests that there need to study management of losses of energy and diesel fuel oil in supercritical units.

3.3 Research Gap

•Under capacity utilization of equipments (Belt) i.e. Belt utilization factor is not studied in super critical units.

•Literature does not mention about minimizing running hours of belt and to optimize the Belt utilization factor (BUF).

• Management of High Speed Diesel (a kind of fuel) has not been studied in super critical units.

•Specific coal consumption has rarely been studied in super critical units.

3.4 Research Questions

1. What are the factors affecting auxiliary power consumption in Super Critical Units of thermal power plants?
2. Can BUF be optimized in Super Critical Units of thermal power plants?
3. Can energy and fuel (HSD) losses be minimized in Super Critical Units thermal power plants?
4. Can revenue losses be minimized through capital investment for BUF and SCC optimizations in other equipments in Super Critical Units thermal power plants?

3.5 Objectives of the Study

1. To study the impact of BUF on auxiliary power consumption in (APC) in Super Critical Units coal based power plants.
2. To study the impact of Heavy earth mover machines (HEMM) on HSD in Super Critical Units of thermal power plants.
3. To study the nature of specific coal consumption (SCC) through total moisture (T.M.) , Ash Content , Volatile material (VM) , fixed carbon (FC), Gross calorific value (GCV), E-auction and linkage coal in Super Critical Units of thermal power plants.

3.6 Theoretical Frame Work

This study will be based upon theory of optimization. Optimization is the act of obtaining the best result under given circumstances. In design, construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, *optimization* can be defined as the process of finding the conditions that give the maximum or minimum value of a function (Rao, 2009).

In our study we are trying to solving the Belt utilization Factor (BUF) problems CHP. Because resources are scarce, all optimization problems in economics are problems of constrained optimization: maximizing or minimizing some objective function subject to one or more constraints. E.g. maximizing the BUF subject to the state of technical knowledge and High speed diesel (HSD) or the exogenous demand function for the auxiliary power. Minimizing the energy consumption and consumption of HSD Oil lead to maximization of output in terms of maximizing BUF.

The production manager's problem in CHP is to

$$\min_{wrt\ \ l\ \ and\ \ k} \; e = al + bk \qquad \ldots (1)$$

$$\text{Subject to } x = f(k,l)$$

That is the production manager in CHP wants to minimize expenditures e, subject to a number of constraints. The solution to this problem is the conditional input demand functions for labor and capital.

The conveyor runs in auto mode so remote operation from control room is done so here labour not considered in study of analysis. In CHP total manpower is out sourced by an agency not in company role.

Application of Optimization Theory

According to (ABB, Energy efficiency hand book) optimization, in its broadest sense, can be applied to solve economics of any engineering problem. He has given some typical applications of theory of optimization as given below:

- Design of aircraft and aerospace structures for minimum weight
- Finding the optimal trajectories of space vehicles
- Design of civil engineering structures such as frames, foundations, bridges, towers, chimneys, and dams for minimum cost.
- Minimum-weight design of structures for earthquake, wind, and other types of random loading
- Design of water resources systems for maximum benefit.
- Optimal plastic design of structures
- Optimum design of linkages, cams, gears, machine tools, and other mechanical components
- Selection of machining conditions in metal-cutting processes for minimum production cost
- Design of material handling equipment, such as conveyors, trucks, and cranes, for minimum cost
- Design of pumps, turbines, and heat transfer equipment for maximum efficiency
- Optimum design of electrical machinery such as motors, generators, and transformers
- Optimum design of electrical networks
- Shortest route taken by a salesperson visiting various cities during one tour
- Optimal production planning, controlling, and scheduling
- Analysis of statistical data and building empirical models from experimental results to obtain the most accurate representation of the physical phenomenon
- Optimum design of chemical processing equipment and plants
- Design of optimum pipeline networks for process industries
- Selection of a site for an industry
- Planning of maintenance and replacement of equipment to reduce operating costs
- Inventory control

- Allocation of resources or services among several activities to maximize the benefit
- Controlling the waiting and idle times and queueing in production lines to reduce the costs
- Planning the best strategy to obtain maximum profit in the presence of a competitor
- Optimum design of control systems in the thermal power plants maximum requirements of fuel is a coal.

Thus, we have consider the coal based super critical super critical thermal unit as engineering system for management where the theory of optimization will play important role in optimizing these APC,HSD & SCC. Thus, in our study we are trying to optimize APC, HSD & SCC with help of their identified factors in coal based super critical units.

3.7. Methodology and Data Source

The research methodology to be adopted for this study will be based on empirical quantitative data analysis and experimental research. This study will be based upon econometric modeling with use of historical as well as experimental data. For generating the experimental data Supercritical unit data will be taken as sample of the power plant.In order to achieve our objectives, we shall consider four Supercritical units of Indian power stations to estimate the Auxiliary power consumption, HEMM-HSD, for Boiler light up - specific coal consumption SCC using their determinants which are objective wise explained below.

We shall use fixed effect model, random effect model and panel data model to estimate the Auxiliary power consumption, HEMM- HSD, & specific coal consumption (SCC). In each model we shall use plant specific dummy and their interaction with the determinants of dependent variables in order to allow intercept and slope coefficient to vary across plants. Thus estimating the panel data models effort will be made to establish the relationship between Auxiliary power consumption, HEMM- HSD, for specific coal consumption SCC and their determinants. The objective wise econometric specifications are given below.

CHAPTER 4

Chapter 4

Optimizing Auxiliary Power Consumption in Coal Handling Plant of Coal Fired Power Plants

4.1 INTRODUCTION

The Indian Power mix is dominated by thermal energy (Tim Buckley, 2017). Thermal plants are an integral part of the Indian economy. The energy demand in the country is increasing exponentially that is throwing greater challenges to the Indian power sector and to the thermal power plants (Dennis Meadows, 2005). In the current scenario, the challenges for the super critical thermal Power units can be linked with the availability of coal & its price hike. (Garg, 2012).

Saving the energy and fuel is directly proportional to revenue. (Reddy, 2012) Small power plant are consuming less fuel quantity & few losses of energy but when we talk about the Supercritical boilers where coal quantity is consumed in bulk and the auxiliary power consumption is very high, (Narain) it is our responsibility to save the auxiliary power as well as several fuel handling losses. This can be undertaken in such a controllable way that losses of fuel and energy can be minimized and standardized in the super critical units of CHP. (joshi)

Many power plants are closed only due to lack of fuel (Coal shortage back to haunt power plants, 2017). Energy & Fuel management of Coal Handling Plant (CHP) in India has been undertaken in a technologically efficient manner. In the broad perspective, saving amount of coal per KWH of electricity generation need to be assessed in a CHP which will have some value addition to the national economy. Huge amount of revenue, about 70% of O&M cost is involved with the Fuel management in the thermal power plants. Thus, the Coal Handling Plant is the backbone of the any Thermal Power Plant.

The conveyer belts are not utilized to their full capacity and are run for longer periods than their capacity. This causes under-utilization of the conveyer belt capacity that further increases Auxiliary power consumption. If we increase the BUF the APC will be reduced. APC reduction is direct revenue saving for the Organization. There have rarely existed any studies on improvement of increasing BUF and its impact on energy consumption and belt running hours in CHP. There is scope of increasing BUF more than 60-67% nationally as well as globally. In CHP supercritical units, the minimum of 13- 32 MW auxiliary power is consumed on a daily basis during stacking and reclaiming processes and if we can increase BUF by more of 15 to 20% the consumption of energy consumption can be reduced by 15-20%. It is very important to adopt proactive strategy to plan, lead, organize, and control the wide variety of fuel.

The literature failed to address this issue of fuel management, minimizing the belt running hours and proper optimization of BUF. Thus, the objective of this study is to control the losses of APC at CHP of Super critical thermal units of India.

The implication of this study is that a lot of APC losses in terms of revenue for the Nation & Organization can be saved & operations system will be optimized.

4.2 METHODOLOGY AND DATA SOURCE

In this study we aim to minimize the APC in order to mitigate our business problem. This is the kind of cost minimization problem in order to achieve maximum output. Thus in order to estimate APC function, we have identified the independent factor that is BUF. The APC function can be written as given below:

$$APC_{it} = \beta_1 + \beta_2 BUF_{it} + u_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

Where the variables used in the eq. 4.1 are defined in Table-1:

Table 4.1: Variables for estimation of APC

Variables	Name of the variables	Definition
Dependent	APC	Auxiliary Power Consumption
Independent	BUF	Belt Utilization Factor

Source: Variable estimation of APC by Authors from the Log Book data of respective CHPs

We aim to study the above function using panel data. The data of 5 Power plant units serve as our cross- sectional units. The five plants that are undertaken in our study are as follows:

Plant 1: Adani Power Ltd. Mundra, Gujarat (660 x 2)
Plant 2: Adani Power Ltd. Mundra, Gujarat (660 x 3)
Plant 3: KWPCL. Raigarh, Chhattisgarh (600X1)
Plant 4: Adani Power Ltd. Tiroda, Maharashtra (660X5)
Plant 5: Adani Power Ltd. Kawai, Rajasthan (660 X 2)

The Data for individual plants on the preceding variable are collected from primary survey and log books of respective plants. The data is available on a monthly basis for a period of 36 months from January 2014- December 2016. Thus, there are five cross-sectional units and 36 time periods. Thus, we have 180 observations in total.

The panel data gives us freedom to study the data of these five plants over a period of time. The panel data is suited to study the dynamics of change as it allows us to study the repeated cross section of observations.

In eq. 4.1 (OLS regression), the differential dummies are introduced for the five plants. The introduction of dummy variable in the model allows the intercept to vary between the plants. (Brand, 2010) This means it allow us to study the impact on APC when the BUF is zero for each plant.

The econometric specification of eq. 4.1, thus, can be modified as follows:

$$APC_{it} = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \alpha_4 D_{4i} + \alpha_5 D_{5i} + \beta_2 BUF_{it} + \mu_{it} \qquad \ldots (4.2)$$

Here,

The plant dummies are as follows:
D1= 1 if the observation belongs to plant 1, 0 otherwise
D2= 1 if the observation belongs to plant 2, 0 otherwise
D3= 1 if the observation belongs to plant 3, 0 otherwise

D4= 1 if the observation belongs to plant 4, 0 otherwise

D5= 1 if the observation belongs to plant 5, 0 otherwise

In order to avoid the problem of dummy variable trap we have not introduced dummy for plant 1. It forms as the comparison plant. Therefore, α_1 represents the intercept of plant 1 and α_2, α_3, α_4 and α_5, the differential intercept coefficients, tell by how much the intercepts of plant 2, plant3, plant 4 and plant 5 differ from the intercept of plant1 respectively.

APC_{it} = Auxiliary Power Consumption of i-th plant at t-th time period

BUF_{it} = Belt utilization factor of i-th plant at t-th time period

Since, not only intercept for all the plants vary but the slope of the independent variable also varies across different plants. It can be inferred that the OLS-2 model also allow us to study the difference in the relationship of APC and BUF across the 5 plants.

The econometric specification of eq. 4.2 can again be modified as follows:

$$APC_{it} = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \alpha_4 D_{4i} + \alpha_5 D_{5i} + \beta_2 BUF_{it} + \gamma_1 (D_{2i} BUF_{it}) + \gamma_2 (D_{3i} BUF_{it}) + \gamma_3 (D_{4i} BUF_{it}) + \gamma_4 (D_{5i} BUF_{it}) + u_{it} \quad \ldots (4.3)$$

The results achieved by OLS can be biased. Thus, to further delve deeper we use the fixed effect model and random effect model. The fixed-effect enables us to analyse the impact of BUF that varies over the different time period. Fixed effect helps us to explore the relationship between BUF and APC within an entity that means the different plants. Fixed Effect removes the effect of the time-invariant characteristics that helps us to assess the net effect of the BUF on the APC. To capture the fixed effect, the econometric specification of eq. 4.1 can be modified to:

$$APC_{it} = \beta_1 + \beta_2 BUF_{it} + \alpha + \mu_{it} \quad \ldots (4.4)$$

Where, α is the unknown intercept for each plant.

The objective behind the random effects model is that it allows us to study and know whether the differences across entities i.e. the plants have some influence on APC or not.

The econometric specification of eq. 4.1 can be modified to:

$$APC_{it} = \beta_1 + \beta_2 BUF_{it} + \alpha + \mu_{it} + \in_{it} \quad \ldots (4.5)$$

Where, $\mu_{it} =$ between error in plant

$\in_{it}$ = within error plant

The choices between the two models are made by conducting the Hausman test (A., 1978).

To check for the unit root problem the, Phillip Perron unit root test and augmented dicky fuller unit root test was conducted.

It was observed that the model lacks the controlling variable and thus results achieved can be biased. We introduced the two controlling variables in the model i.e. generation at plant level and plant load factor. Due to the data collection constraints the model could be build for 3 plants. The equation 4.1 was modified to:

$$APC_{it} = \beta_1 + \beta_2 BUF_{it} + \beta_3 GEN_{it} + \beta_4 PLF_{it} + u_{it} \quad \ldots (4.6)$$

Where,

GEN= generation at plant level

PLF= Plant load factor

To study the impact of variables in a better manner we modify equation 4.6 into:

$$APC_{it} = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \beta_2 BUF_{it} + \beta_3 GEN + \beta_4 PLF + \mu_{it} \quad \ldots (4.7)$$

Where,

D1=1 if the observation belongs to plant 1that is Adani Power Ltd. Mundra, or else 0

D4 = 1 if the observation belongs to plant 4 that is Adani Power Ltd. Tiroda, Maharashtra or else 0

D5= 1 if the observation belongs to plant 5 that is Adani Power Ltd. Kawai, Rajasthan or else 0

Since, not only intercept for all the plants vary but the slope of the independent variable also varies across different plants. It is observed that the eq 4.7 model allow us to study the difference in the intercept of dependent variable and independent variable but fails to address the difference in the relationship of APC, BUF, GEN and PLF across the 3 plants, which eq 4.8 allows us to. Thus, equation 4.7 was modified to:

$$APC_{it} = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \beta_2 BUF_{it} + \beta_3 GEN_{it} + \beta_4 PLF_{it} + \gamma_1 (D_{2i} BUF_{it}) + \gamma_2 (D_{3i} BUF_{it})$$
$$+ \gamma_3 (D_{2i} GEN_{it}) + \gamma_4 (D_{3i} GEN_{it}) + \gamma_5 (D_{2i} PLF_{it}) + \gamma_6 (D_{3i} PLF_{it}) + u_{it}$$

... (4.7)

4.3 DESCRIPTIVE DATA ANALYSIS

4.3.1 Auxiliary Power Consumption

Auxiliary power consumption is defined as the power consumed to run the plant and to keep safe lighting for work. The total energy consumed in coal handling plant is called auxiliary power consumption of CHP. The lighting of coal handling plant is also a part of auxiliary power consumption.

4.3.2 Belt Utilization Factor

Belt utilization factor is the ratio of conveyor belt's utilized capacity per hour in metric ton with the conveyor belt's maximum capacity. Belt utilization factor is the ratio of current belt load carrying capacity utilized & it's designed capacity. It is taken in percentage. For example, suppose a belt designed capacity is 2000MT/hr. and actually it is carrying only 12000mt /hr coal so its belt utilization factor is 1200/2000x100=60% BUF.

Table 4.2: Summery Statistics of APC and BUF

Variables	Plants	Obs.	Mean	Std. Dev.	Min	Max
APC	Mundra (660X2 CHP)	36	1.341444	2.450198	0.771	15.63
BUF	Mundra (660X2 CHP)	36	65.12972	11.71697	0	74.9
APC	Mundra (660X3 CHP)	36	1.341444	2.450198	0.771	15.63
BUF	Mundra (660X3 CHP)	36	65.12972	11.71697	0	74.9
APC	Chhattisgarh(600X1 CHP)	36	2.010556	1.96213	0	6.58
BUF	Chhattisgarh(600X1 CHP)	36	26.38889	24.23961	0	67
APC	Tiroda (660X5 CHP)	36	2.226	0.539	1.18	3.12
BUF	Tiroda (660X5 CHP)	36	46.044	4.601	37.440	54.29
APC	Kawai (660X2 CHP)	36	1.259	0.309	0.909	1.98
BUF	Kawai (660X2 CHP)	36	50.561	11.657	20.320	67.850

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

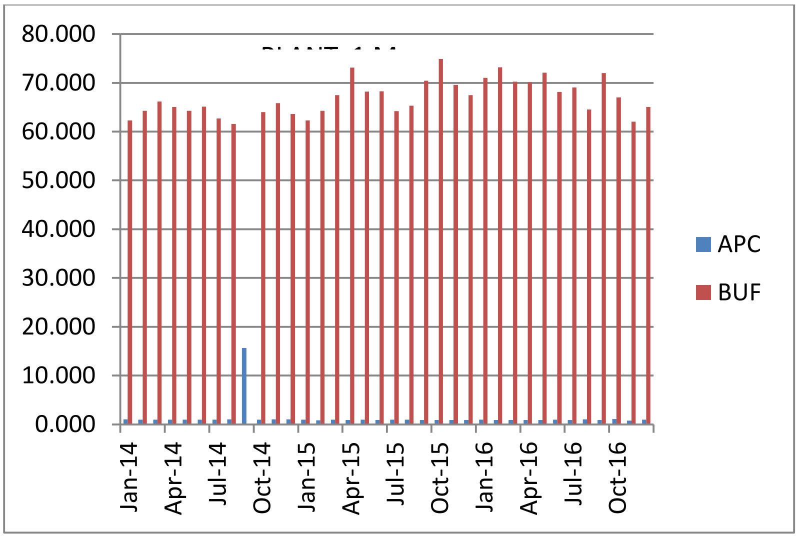

Fig.4.1: APC and BUF of Mundra (660X2 CHP)

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig4.1, shows the monthly average of BUF and APC from Jan 2014 to Dec 2016. The variation in APC & BUF is observed month wise. The highest BUF is noticed in the month of October 2015 and the lowest being in August 2014. The changes in the APC is proportional to that of BUF, i.e. if BUF is improved then APC is optimizes and if BUF is decreasing then APC is in increasing trend. It is further observed that annually BUF for plant 1 is not more than 65.2%. The summary statistics are self-explanatory. In month of Sept 2014, plant was shut-down due to unavailability of coal. The coal handled during the period was zero. The high value of APC during the system reflects the power consumption by lights during system overhauling.

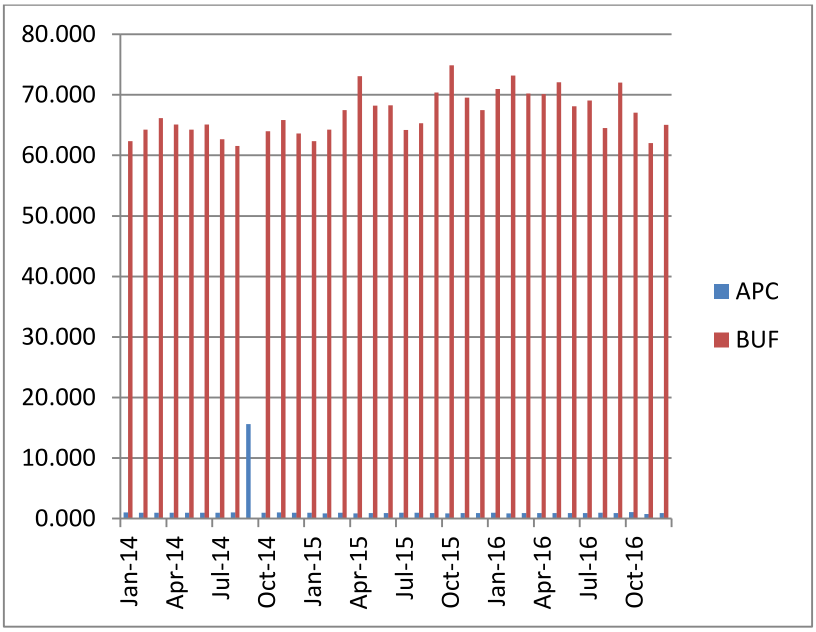

Fig4.2: APC and BUF of Mundra (660X3 CHP)

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-4.2, shows the trend of monthly average of BUF and APC from Jan 2014 to Dec 2016. The variation in APC & BUF is observed month wise. The highest BUF is noticed in the month of October 2015 and the lowest being in August 2014. The change in the APC is proportional to that of BUF, i.e. if BUF is improved then APC is optimizes and if BUF is decreasing then APC is in increasing trend. The annual average BUF is observed as not more than 65.2%. The summary statistics are self-explanatory. During September 2014, plant 2 was not operational due to coal shortage. Thus, coal handled is zero but power consumption in lighting during system overhauling shows high value of APC. During the time period of thirty six months BUF has not been more than 65% that further shows APC is not optimized.

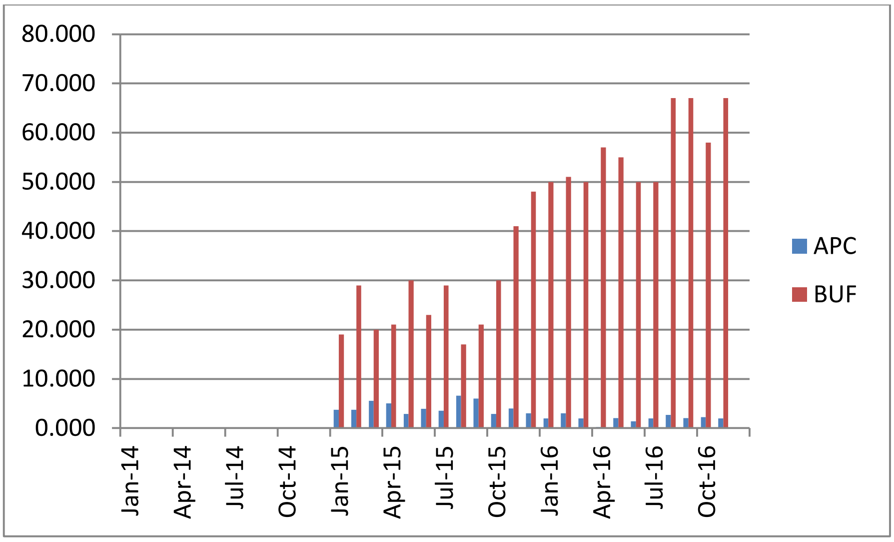

Fig4.3: APC and BUF of Chhattisgarh (600X1 CHP)

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig4.3, shows that plant was not operating from Jan 2014 to Dec 2014 due to non-availability of coal that caused plant shut down during that period. Power plant re-started its operation in January 2015 but BUF achieved for the period was less than18% that was lowest for the year. It gradually increased and reached up to 67 % in the month of Dec 2016. When BUF is less then, auxiliary power consumption is more and when BUF is more than auxiliary power consumption is less. From the above graph, it is clear that BUF and APC may be optimized and improvement may be done. It is also seen from the graph of fig 3 that annually average BUF for plant 3 is not achieved more than 26%.In May 2016 less auxiliary power consumption is shown and in three months max. average BUF are shown.

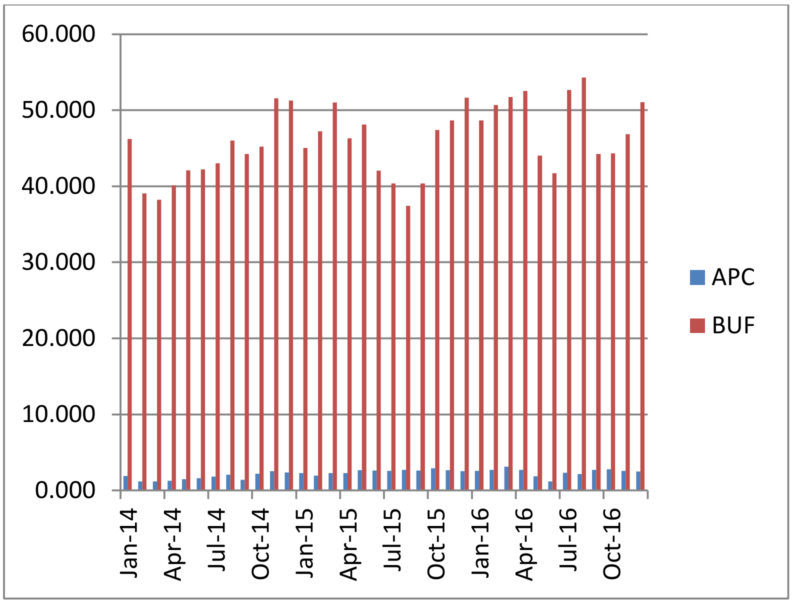

Fig.4.4: APC and BUF of Tiroda (660X5 CHP)

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig 4.4, shows the trend of monthly average of BUF and APC for plant 4 from Jan 2014 to Dec 2016. The variation in APC & BUF is observed month wise. The highest BUF is noticed in the month of September 2016 and the lowest being in March 2014 & August 2015. The changes in the APC is proportional to that of BUF, i.e. if BUF is improved then APC is optimizes and if BUF is decreasing then APC is in increasing trend. The annual average BUF for plant 4 is observed as not more than 47%.

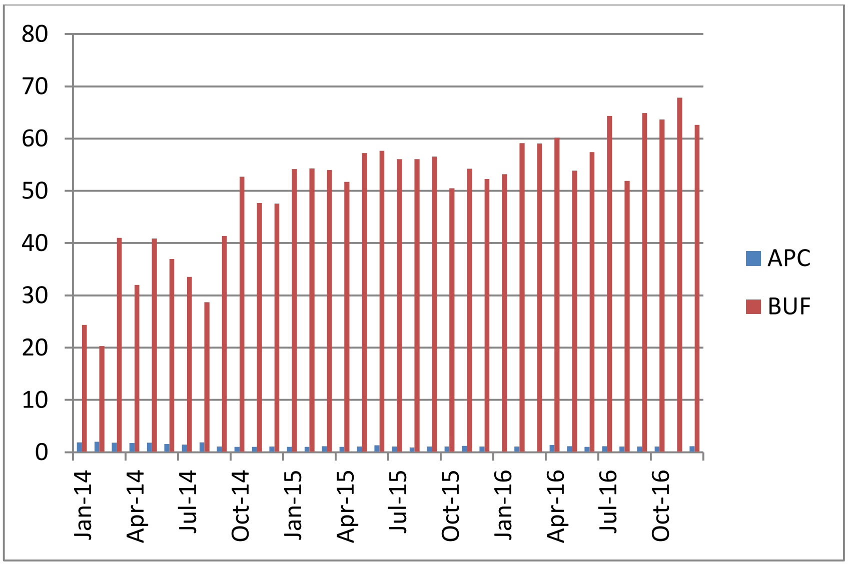

Fig.5: APC and BUF of Kawai (660X2 CHP)

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig 4.5, shows the trend of monthly average of BUF and APC for plant 5 from Jan 2014 to Dec 2016. The variation in APC & BUF is observed month wise. The highest BUF is noticed in the month of November 2016 and the lowest being in February 2014. The changes in the APC are proportional to that of BUF, i.e. if BUF is improved then APC is optimizes and if BUF is decreasing then APC is in increasing trend. The annual average BUF for plant 5 is observed as not more than 67%.

4.4 RESULT AND DISCUSSION

4.4.1 Unit Root Test

The panel data involves cross-sectional and time series data both. It is necessary to ensure that the time-series is stationary in order to generalize the relationship between the dependent and independent variables over the period of time (Nielsen, 2005). For our analysis, we conducted Augmented Dicky fuller test and Phillip-Perron unit root test. The results are given below in the table 4.3 and table 4.4:

Table 4. 3 Results of Unit Root test without Drift

	Augmented Dicky Fuller				***Phillip-Perron test***			
Variable name	***Inverse chi-squared(6)***	***Inverse normal***	***Inverse logit t(19)***	***Modified inverse chi-square***	***Inverse chi-squared (6)***	***Inverse normal***	***Inverse logit t(19)***	***Modified inverse chi-square***
	P	z	L*	Pm	P	Z	L*	Pm
APC	**178.7581*** **	**(12.5408)*** **	**(29.2751)*** **	**49.8710*** **	**178.7581 *** **	**(12.5408) *** **	**(29.2751) *** **	**49.8710*** **
BUF	**158.4942*** **	**(11.2099)*** **	**(25.9562)*** **	**44.0213*** **	**158.4942 *** **	**(11.2099) *** **	**(259562) *** **	**44.0213*** **
PLF	**133.6041*** **	**(10.6114)*** **	**(21.8802)*** **	**36.8361*** **	**133.6041 *** **	**(10.6114) *** **	**(21.8802) *** **	**36.8361*** **
GEN	**143.3836*** **	**(11.1416)*** **	**(23.4818)*** **	**39.6552*** **	**143.3836 *** **	**(11.1416) *** **	**(23.4818) *** **	**39.6552*** **

Source: Table developed by author based on the logbook data from Super Critical Units

Table 4.4 Result of Unit Root test with drift:

	Augmented Dicky Fuller			
Variable name	*Inverse chi-squared(6)*	*Inverse normal*	*Inverse logit t(19)*	*Modified inverse chi-square*
	P	*z*	*L**	*Pm*
APC	162.8145***	(11.7952)***	(26.6640)***	45.2685***
BUF	128.3928***	(10.1405)***	(21.2067)***	35.3318***
GEN	97.0413***	(8.9967)***	(15.8924)***	26.2814***
PLF	92.6757***	(8.7330)***	(15.1774)***	25.0211***

Source: Table developed by author based on the logbook data from Super Critical Units

Table 4. 3 Results of Unit Root test without Drift

1) ******indicate sig. at 1% level, ** indicate sig. at 5% level and * indicate sig. at 10% level.***
2) ***The values in parenthesis indicates negative values***

Table 4.4 Results of unit root test with drift

1) ******indicate sig. at 1% level, ** indicate sig. at 5% level and * indicate sig. at 10% level.***
2) ***The value in parenthesis indicates negative values***

It can be inferred from table 4.3 and table 4.4 all the variables used in the model are free from the unit root problem as the variables are significant as per both the tests. Therefore, our data set is stationary.

Table 4.5 Result of APC Estimation using OLS Regression

Source: Table developed by author based on the logbook data from Super Critical Units

APC	OLS-1	OLS-2
BUF	0.019075*** (0.004698)	0.0200021*** (0.005281)
D2	-1.84175*** (0.277267)	-1.84805*** (0.479521)
D3	-1.84175*** (0.277267)	-1.81954*** (0.380209)
D4	-0.15909 (0.228637)	-0.25095 (0.332324)
D5	-1.21774*** (0.238001)	-1.36743*** (0.440733)
*BUF*D2*	-	-.0009419** (0.0062899)
*BUF*D3*	-	-.001387** (0.0048343)
*BUF*D4*	-	.0015168** (0.006651)
*BUF*D5*	-	.0023843** (0.0083652)
_cons	1.507192*** (0.192991)	1.508532** (0.222804)

Number of obs	180	169
F(5, 174)	17.4	8.23
Prob > F	0	0
R-squared	0.3334	0.3177
Adj R-squared	0.3142	0.2791
Root MSE	0.88738	0.92702

4.4.1 Results and Discussions without controlling variable

Table 4.5: Result of APC Estimation Using OLS Regression

*1) ***indicate sig. at 1% level, ** indicate sig. at 5% level and * indicate sig. at 10% level.*

2) In parenthesis standard errors are given

In table 4.5, the BUF is highly significant as the p-value of the variable is extremely small. Thus, as per the results received BUF has a positive impact on APC. It can be inferred that with 1 unit change in the BUF on a scale of 1 to 100 will increase the APC by 0.019 KW per hour. The positive relation is observed between APC and BUF because with the gradual increase of coal loading on the conveyor belt to increase belt utilization factor will result in the increase in the current supply due to load variation that further increases the APC. However, it is observed that if we increase the load on the conveyor belt i.e. if we increase its capacity, the running time of the belt will gradually decrease. This further decreases the APC over the period of time as that will optimize the belt utilization; the same amount of coal can be handled in less time period. The individual dummies are significant. It can be inferred from the above data that the intercept value for the Plant 1is 1.507192. The intercept value of each plant depicts what the APC of each plant is in the absence of BUF. The intercept value for the plant 2 is 1.84175 less than that of plant 1. The difference in the intercept of plant 2 is because in Plant 1 more jamming is observed during the rainy season. In order to prevent the jamming the conveyor belt is run even with zero loading, that consumes more electricity, whereas, no such problem is observed in plant 2. Hence, APC of plant 1 is more than the plant 2 even when my BUF is zero. The intercept term for plant 3 is 1.84175 less than that of plant 1. Plant3 was not operating for a period of one year (January 2014- December 2014), because of unavailability of the coal in the area. Thus, the intercept value of plant 3 is less than the plant 1's intercept. The intercept term for plant 4 is 0.15909 less than that of plant 1 because the transfer point in this plant is less than that in plant 1. The intercept for Plant 5 is 1.21774 less than that of plant 1. The difference is observed because of the availability of track hopper that is absent in the plant 1. The difference is also observed because of the less transfer points between conveyor belts than that of plant 1.

In table 4.5, column OLS 2 regression, the differential plant dummies are interacted with the independent variable: Belt utilisation factor (BUF). The differential intercept and all the differential slope coefficients are statistically significant, we can conclude that the Auxiliary power consumption function is different for all the five plants. Here, BUF*D2, BUF*D3, BUF*D4, BUF*D5 are differential slope coefficient as D2, D3, D4, D5 are the differential intercepts.

The BUF is highly significant as the p- value of the variable is extremely small, which further signifies that BUF has a positive impact on APC. It can be further infer that with 1 unit change in the BUF in 1 to 100 scale will increase the APC by 0.020 KW per hour. The positive relation is observed between APC and BUF because with the gradual increase of coal loading on the conveyor belt to increase belt utilization factor will result in the increase in the current supply due to load variation that further increases the APC. However, if we optimize that utilization of the belt, the BUF will increase gradually over a period of time with reduction in APC.

Plant 1on average is characterized by approximately 65% BUF. The coal in this plant is fed through Silo that ensures the continuous flow of coal on the conveyor belt even in the absence of the track hopper. The intercept term for plant 1 is 1.508532 and slope coefficient of BUF is 0.0200021. Plant 2 intercept term is less than plant1's intercept term by 1.84805. Further, it can be inferred with 1 unit change in the BUF of plant2 on a scale of 1 to 100 the change observed in APC is 0.0009419 kW per hour less than that of plant 1 APC. The difference is observed because the high speed belt capacity of plant 2. Plant2 loads 2000 metric ton coal per hour while plant 1 loads 1300 metric ton per hour. Thus, more coal loading is ensured by plant2 in the given time. Hence, the APC is less than the plant 1. Plant 3's intercept term is less than plant1's intercept term by 1.81954. With 1 unit change in the BUF of plant 3 on a scale of 1 to 100 the change observed in APC is 0.001387 kW per hour less than that of plant 1's APC. The difference is observed as the plant 3 has track hopper and two truck tipplers which is absent in plant 1. The truck tipplers and track hopper reduces the unloading time of the coal on the conveyer belt. The overall time reduction in the work reduces the APC. Also, the differences are observed because the plant was not operational for a year due to the coal shortage. Plant 4's intercept term is less than plant1's intercept term by 0.25095. With 1 unit change in the BUF of plant 4 on a scale of 1 to 100 the changes observed in APC is .0015168 kW per hour more than that of plant 1's APC. This is because of the two reasons. First, the unloading is done through railway rake and the plant has only two unloading points' that causes delay in the unloading procedure. The causes APC to be high as the belt is continuously run to evacuate the coal. Second reason being, the coal inside the rake is over-sized. The over- sized coal cloaks the grizzly during the evacuation time that delay's the evacuation process. This further reduces the coal flow on the conveyor belt in the plant, resulting in under-utilization of belt capacity i.e. low BUF. Plant 5's intercept term is less than plant1's intercept term by 1.36743. With 1 unit change in the BUF of plant 5 on a scale of 1 to 100 the changes observed in APC is .0023842 kW per hour more than that of plant 1's APC. The plant 5 receives crushed coal that easily passes through the grizzly. This speeds up the evacuation process and more coal is passed on the conveyor belt, thereby, using the belt capacity more than that of plant 1.

The next analysis objective is to determine the fixed effect model or/and random effect model. In our study, we have repeated observations for individual plants. Thus, the observations in the data are not independent. By only running OLS regression, the results received could be biased. The fixed-effect model and random-effect models take into account the repetition of the observations that allow us to take control for fixed or/and random individual differences. We conduct Hausman test to choose between the random effect model and fixed effect model. For our study fixed effect model is better as per the Hausman test results'.

Table 4.6: Result of Fixed and Random Effect Model

APC	Fixed	Random
BUF	0.019075*** (0.004698)	0.0128869*** (0.0045657)
_cons	0.495125** (0.246996)	0.8085488** (0.2980682)
Number of obs	180	180
Number of groups	5	5
Obs per group: min	36	36
Avg	36	36
Max	36	36
F(1,174):	16.48	7.97
Prob > F:	0.0001	0.0048
Wald chi(2)1:	-	7.97
Prob>chi2:	-	0.0048
R-sq: within	0.0865	0.0865
between	0.6801	0.6801
overall	0.0169	0.0169
sigma_u	0.89035128	0.37770774
sigma_e	0.88737647	0.88737647
Rho	0.50167338	0.15338471

Source: Table developed by author based on the logbook data from Super Critical Units

****indicate sig. at 1% level, ** indicate sig. at 5% level and * indicate sig. at 10% level,* (*In parenthesis standard errors are given)*

In table 4.6, in fixed effect model it is observed that BUF is highly significant as the p-value of the variable is extremely small, which further signifies that BUF has a positive impact on APC. It can be further infer that with 1 unit change in the BUF in 1 to 100 scale will increase the APC by 0.019075 KW per hour. The positive relation is observed between APC and BUF because with the gradual increase of coal loading on the conveyor belt to increase belt utilization factor will result in the increase in the current supply due to load variation that further increases the APC. However, if we optimize that utilization of the belt, the BUF will increase gradually over a period of time with reduction in APC

4.3.1 Results and Discussions with controlling variable

Source: Table developed by author based on the logbook data from Super Critical Units

APC	*OLS-1*	*OLS-2*	*OLS-3*	*OLS-4*
BUF	*-.0717847*** (.0091276)*	*-.0970907*** (.0090905)*	*-.1019487*** (.010457)*	*-.1102588*** (.0109944)*
GENERATION		*.0008359*** (.0001517)*	*.0006947*** (.0002547)*	*.0008074*** (.0002672)*
PLF		*-.0078886*** (.0042711)*	*-.0059463** (.0052465)*	*-.0096592** (.0057659)*
D4			*-.3976837** (.3586902)*	*-1.841732* (2.026779)*
D5			*-.3907091*** (.4704581)*	*-1.613846** (1.015887)*
D4 BUF				*.0289867* (.044456)*
D5 BUF				*.0362837** (.0171286)*
D4GEN				*.0000133* (.00085)*
D5GEN				*-.0021465** (.0011696)*
D4 PLF				*.0001646* (.0170546)*
D5 PLF				*.0118684** (.0079139)*
_cons	*5.47744 (.5055888)*	*6.150893 (.5124148)*	*6.747444 (.7445123)*	*7.294135 (.7803996)*

Number of obs	*108*	*108*	*108*	*108*
F(1, 106)	*61.85*			
F(3, 104)		*38.52*		
F(5, 102)			*23.19*	
F(11, 96)				*11.14*
Prob > F	*0.0000*	*0.0000*	*0.0000*	*0.0000*
R-squared	*0.3685*	*0.5264*	*0.5320*	*0.5607*
Adj R-squared	*0.3625*	*0.5127*	*0.5091*	*0.5103*

****indicate sig. at 1% level, ** indicate sig. at 5% level and * indicate sig. at 10% level*
In parenthesis standard errors are given

In table 4.7, we have introduced generation at plant level and plant load factor as the controlling variable. The controlling variable helps us drive better results and solve the problem of bivariate correlation. It can be inferred from the above results in table 4.7 that generation has a positive relation with APC, with 1 unit increase in generation the APC increases by .0008359 units. The relation between these two variables is as per the business as usual model. With the increase in power generation of the plant the coal crushing and feeding at the coal handling plant increases. As a consequence, the APC increases due to load current varying of different equipment. PLF or the plant load factor has a negative impact on the APC that means with 1unit increase in PLF on a scale of 1 to 100 the APC decreases by 0.0078886. The relationship observed between the variable is different from that of the business as usual model. This is because of the policy intervention by the CERC, where tariff is now based upon the availability of the plant. Thus, power plants have taken initiatives to increase the availability of the plant that has increased there PLF. Also, the relationship between the APC and BUF is different from that of the business as usual model i.e. we are observing a negative relationship between BUF and APC (more the BUF less the APC). It is observed that the PLF of all the plants taken in the study is high. The better PLF indicates judicial use of power plant and better utilization of BUF that reduces the APC

In the above table, in column OLS 3, the individual dummies are introduced for each plant. The plant dummies are significant. It can be inferred that the intercept value for the

Plant 1 on an average is 6.747444. The intercept value of each plant depicts what the APC of each plant is in the absence of BUF, GEN and PLF. The intercept value for the plant 4 on an average is 0.3976837 less than that of plant 1 and the intercept value for the plant 5 on an average is 0.3907091 less than that of plant 1. The difference in the intercept of plant 4 and plant 5 is because FGD-Flue-gas desulfurization is functional in Plant 1 owing to fulfil the environmental norms due to which APC of plant 1 is more than that of plant 4 and plant 5 even in the absence of independent factors.

In table 4.7, column OLS 4 regression, the differential plant dummies are interacted with the independent variable: Belt utilisation factor (BUF), generation (GEN), plant load factor (PLF). The differential intercept and all the differential slope coefficients are statistically significant, we can conclude that the Auxiliary power consumption function is different for all the five plants. Here, BUF*D4, BUF*D5, GEN*D4, GEN*D5, PLF*D4, PLF*D5 are differential slope coefficient intercepts. All the interactive dummies are statistically significant. Thus, we can infer that all the plants have different APC functions. The intercept term for plant 1 is 7.294135 and slope coefficient of BUF, GEN and PLF is -0.1102588, .0008074 and -.009659. 0.0200021, respectively. Plant 4 intercept term on an averages is less than plant1's intercept term by 1.8417. Further, it can be inferred with 1 unit change in the BUF of plant 4 on a scale of 1 to 100 the change observed in APC is 0.2898 kW per hour more than that of plant 1 APC. While generation of plant 4 is more than that of plant 1 by 0.000133units and PLF of plant 4 is more by 0.001646. The differences in the APC function of plant 1 and plant 4 is due to various reasons. Despite the fact that plant 1 has more installed capacity, the relative generation of plant 4 is more. This is because of more commercial viability of the plant 4 in the region than plant 1, which operates in Mundra. The tariff rates of power generation is more for plant 4 that reaps more revenue for the plant. Also, when we analysed the PPA for plant 1 it was observed that owing to the increase in coal prices these PPA's have less commercial viability in today's scenario owing to which the surplus generation is provided by plant 4. Apart from its compliance to PPA's the plant1 is less functional due to high coal cost as it uses imported coal and plant 4 uses blended coal that is comparatively cheaper. Therefore, the PLF and GEN for plant 4 is more than that of plant 1.

Plant 5 intercept term on an averages is less than plant1's intercept term by 1.6134. Further, it can be inferred with 1 unit change in the BUF of plant 4 on a scale of 1 to 100 the change observed in APC is 0.0362 kW per hour more than that of plant 1 APC. While generation of plant 5 is less than that of plant 1 by 0.002164 units and PLF of plant 5 is less by 0.110684. The differences in the APC function of plant 1 and plant 5 is due to various reasons. The difference in generation is observed because plant1 has more installed capacity than of the plant 5. The installed capacity of plant 1 is 4620 MW and installed capacity of plant 5 is 1320 MW. Therefore, plant 1 generate more electricity than the plant 5. Also, the availability of coal is more for plant 1 as it is nearer to port and it has high speed conveyor belts. Whereas, plant 5 is at a farther distance from the ports, thus, transportation of coal takes time which further effects the PLF of the plant. PLF of plant 5 is less as plant one is more functional than plant 5. This is because plant 1 has compliance to the PPA’s signed with Gujarat government and Rajasthan government.

4.5 Concluding Remarks:

Findings:--

It can be concluded after findings reflected that the APC function of Plant 2, Plant 3, Plant 4, and Plant 5 is different from that of Plant 1. These differences are observed due to unique feature of each plant, like: coal handling, coal unloading, and coal size of each plant differs. The differences are also observed due to the different management style of each plant as discussed in section 4.3 of the chapter.

APC & BUF are two major components that effects the smooth functioning of coal handling plant. The optimization of the above two components can helps us minimize the financial losses to the business at the micro level. Whereas, at macro level it help us optimally utilize our existing resources and capacity. The study reveals that no organization at present has on an average achieved more than 67% BUF. The optimization of BUF can result in reduction in APC which can further increase our revenue and save our existing resources.

Recommendations and suggestions:--

The BUF can be optimised of we take some measures regularly. Some of them are discussed below:

The belt utilization factor can be optimised by increasing the belt loading points. The increase in the number of belt loading points will ensure more loading on the conveyor belt that further improves the BUF which will further improve the APC.

The studies have observed that coal unloading time and timely availability of equipment for coal loading has a major impact on the BUF. Thus, by decreasing the unloading time of coal on the conveyor belt, can increase the BUF. The various measures can be taken to ensure reduction of unloading time. The coal should be stored near to the conveyor belt. The minimum distance between the two ensures that the conveyor belt is not empty for a longer duration at any given point of time. This will further cut down running of empty conveyor belt. Thus, reducing the APC and utilizing the belt capacity more optimally.

BUF can further be optimised by ensuring reliable and proactive maintenance of equipment like, conveyor gearbox and motors with zero breakdown. The timely maintenance of the conveyor gearbox increase the belt availability that in turns increases belt utility capacity factor. The maintenance of pock lain, Dozers and bob-rain rake to be made on a regular basis so that coal can be pushed easily and timely on the hoppers and further on the conveyor belts. Big boulders also delays the unloading process of coal on the conveyor belt. The big boulders clogs the grizzly. They are evacuated from grizzly, crushed and then unloaded on the belt. By avoiding big boulders on grizzly, we will be able to reduce the coal handling time and speed up the unloading of coal on the belt. Thus, better BUF can be achieved by decreasing the unloading time. The coal plant with trucks should minimize the turnaround time (TAT) of rake and hydraulic trucks to be minimized to maximize BUF for better capacity utilization. Reduction in TAT increases the coal on the belt that cut downs the empty running of the conveyor belt. (Somanath Ojha, 2016)

Further, use of LED lighting should be promoted in the coal yard. High Mast lights should be substituted by LED lighting to save power consumption as LED light consumes less power than the normal bulbs that improves our APC. In order to optimise APF we also need more stringent policy interventions by government.

Thus, by adopting the above measures we can optimize our BUF that will help us to improve revenue

As per CERC recommendations –The Running hrs of CHP equipment for two units >500MW or large units like 600/ 660 MW generation is minimum 14 hrs running hours of Conveyor belt as required according to capacity of belt. If 100% PLF is achieving case then 10 hrs to be given for the wear-tear, repairing & preventive maint.

In case of single stream of conveyors are present, there is continuous run on its designed like stacker reclaimer and rated capacity of belt. While two stackers cum reclaimers are recommended .Two crushers and two vibrating screens grizzly is also recommended for 660 MW units for both streams for 14hrs running at 14hrs. , if any stream is under break down then one stream will run continuously to fill the bunker in any recommended path of CHP. Other contents are general guide lines. For APC reduction empty run of equipment are to be prevented in rainy season and chutes inclination not less than 60degree recommended in CHP.

CHAPTER 5

Chapter 5

Optimizing High Speed Diesel Oil Consumption on Heavy Earth Mover Machines in Super Critical Units of Coal Based Power Plants

5.1 INTRODUCTION

Heavy earth movers equipment (HEME) are the heavy-duty vehicle which are specially designed for executing the construction tasks, most frequently ones involving work at earth operations. They are also known as bull dozers , heavy machines, heavy duty trucks, heavy construction equipment, construction engineering equipment, mining digging equipment, heavy duty vehicles, or heavy duty hydraulics. They usually comprise five equipment systems: implement traction, structure, power train, control and information. Heavy equipment functions through the mechanical advantage of a simple machine, the ratio between input force applied and force exerted is multiplied. Some heavy equipment uses the hydraulic drives as a primary source of motion.

Till the 19th century and into the early 20th century heavy machines were drawn under human or animal power. With the advent of portable steam-powered engines the drawn machine precursors were reconfigured with the new engines, such as the combine harvester. The design of a core tractor evolved around the new steam power source into a new machine core traction engine that can be configured as the steam tractor and the steam roller.

During the 20th century, internal-combustion engines became the major power source of heavy equipment. Kerosene and ethanol engines were used, but today diesel engines are dominant. Mechanical transmission was in many cases replaced by hydraulic machinery. The early 20th century also saw new electric-powered machines such as the forklift. Caterpillar Inc. is a present-day brand from these days, starting out as the Holt Manufacturing Company. The first mass-produced heavy machine was the Fordson tractor in 1917.

The first commercial continuous track vehicle was the 1901 Lombard Steam Log Hauler. The use of tracks became popular for tanks during World War I, and later for civilian machinery like the bulldozer. The largest engineering vehicles and mobile land machines are bucket-wheel excavators, built since the 1920s.

Until almost the twentieth century, one simple tool constituted the primary earthmoving machine: the hand shovel - moved with animal and human powered, sleds, barges, and wagons. This tool was the principal method by which material was either side cast or elevated to load a conveyance, usually a wheelbarrow, or a cart or wagon drawn by a draft animal. In antiquity, an equivalent of the hand shovel or hoe and head basket—and masses of men—were used to move earth to build civil works. Builders have long used the inclined plane, levers, and pulleys to place solid building materials, but these labour-saving devices did not lend themselves to earthmoving, which required digging, raising, moving, and placing loose materials. The two elements required for mechanized earthmoving, then as now, were an independent power source and off-road mobility, neither of which could be provided by the technology of that time.

Few of the implements and Hydro mechanical Work Tools

- Excavator bucket ---used in plant CHP
- Forks –used for material lifting and shifting
- Grapple—not used in power plant
- Hydraulic hammer, hoe ram ---used to crush the boulders in mines
- Hydraulics –hydraulic system based on hydraulic oil pressure energy
- Hydraulic tilting bucket (4-in-1) used in mines
- Landscape tiller –used in mines
- Material handling arm—used in mines
- Mechanical pulveriser, crusher—used in mines and CHP
- Multi-processor –used in mines
- Pavement removal bucket –used in mines

- Pile driver –not used in CHP
- Power takes-off (PTO)—not used CHP
- Auger ----used for auto coal sampling purpose from the coal wagons in power plant
- Backhoe ----used in power plant
- Bale spear---not in use
- Broom –cleaning equipment
- Bulldozer blade—used in power plant
- Clam shell bucket –part of HEMM
- Cold plane—not used in CHP
- Demolition shears—not used in CHP
- Equipment bucket –used in backhoe
- Quick coupler—used in railway
- Rake—used to transport coal from mines to CHP
- Ripper—not used in CHP
- rotating grab—not used in CHP
- Sheep's foot compactor --to compact the mining coal
- Skeleton bucket—not used in power plant
- Snow blower –used in mining industry
- Stump grinder –not used in CHP
- Stump shear---not used in CHP
- Thumb—not used in CHP
- Tilt rotator-pock lain equipment is tilt rotator at 360defgree

- Trencher –not used in CHP

In thermal power plant, fuel management is the backbone of any super critical thermal coal based power plants. The major factor for power plants survival is health of coal handling plant as the fuel management has direct impact on the revenue. The function of HEMM is to transport and transfer the coal from yard to coal Hopper to adjacent hopper points & finally send coal to bunkers through conveyor belt for electricity generation through Mills boiler and Turbine generator. There are several systems in Coal unloading system, Coal transferring / conveying system, Coal stacking & reclaiming system, Coal crushing & bunker feeding system. Dust controlling system Ventilation system etc.

If the heavy earth mover machines, like, dozers, JCB and others, in coal handling plant is not properly managed the plant performance will be deteriorated and HSD oil consumption will be high.

For the thermal power the prime resources are HSD oil, coal, water, and railway wagon / transportation system. Oil is the prime source to synchronize the unit as the primary fuel. When unit is light up about 90 KL to 120 KL oil is consumed. Further, oil gun is used to support the running of furnace when the coal quality is poor. When unit is fully synchronized then oil support is withdrawn and oil consumption per unit is observed as 0.03 to 0.2 ml /unit generation. The high oil consumption in power generation escalates the generation cost.

In CHP, the major consumption of HSD oil is because of the process of coal handling from one place to another place. The more the distance between the coal yard and track hopper the more the oil consumption, that further adds to the cost of generation. HSD oil is also consumed during direct feeding of the coal through hoppers in each unit. Each BD 155 BEML good condition dozers consumes 35.5 -37.5 liters of HSD oil per hour. If the HSD oil consumption of the dozer is more than 42.5 to 45 liters, it is an alarming position about the machine’s condition. It alarms that we need to focus on the proactive maintenance of machine and check the engine quality conditions. To optimize the HSD consumption we have to focus on three main equipment which consume more quantity of oil. The 90% of CHP’s oil consumption are accounted by dozers, pock lain & JCV. In the super critical units where coal is handled in track hopper, oil consumption is about

1500 to 1600 liters per day and as per the current market on an average, HSD oil cost is Rs. 60 to 70 /- liters in open market. Thus, it is necessary to reduce the HSD oil consumption. (Bhatnagar, 2004)

The equipment maintenance and operator skills are also important. It has been observed that operators are using dozer in spite of coal non-availability. They do not stop engine that increases the HSD oil consumption. The idle running of these equipment results in losses in terms of revenue that need to be controlled.

Regular oil quality and condition of clutch gear and engine health also to be monitored to optimized the HSD consumption, Housekeeping is good then other accessories equipment operation may be stopped otherwise bobcat and cleaning equipment will also consume diesel which will be burden on revenue.

Unnecessary equipment used to be controlled and monitored. For showing the meter running drivers done mistake to see the reading false to be monitored and it to be controlled.

5.2 METHODOLOGY AND DATA SOURCE

In this study we aim to minimize the HSD consumption in order to mitigate our business problem. This is the kind of cost minimization problem in order to achieve maximum output. Thus in order to estimate HSD function, we have identified the independent factors. The HSD consumption function can be written as given below:

$$HSD = HSD_{PL} + HSD_{BC} + HSD_{SM} + HSD_{LD} + HSD_{DZ} + HSD_{Hyva} + HSD_{Hydra} + HSD_{TT} \quad \text{….. (5.1)}$$

Where,

HSD = high speed diesel consumption in coal handling plant

HSD_{PL} = high speed diesel consumption in Pock lain

HSD_{BC} = high speed diesel consumption in Bob cat

HSD_{SM} = high speed diesel consumption in sweeping machine

HSD_{LD} = high speed diesel consumption in loader

HSD_{DZ} = high speed diesel consumption in dozer

HSD_{hyva} = high speed diesel consumption in dumper

HSD_{hydra} = high speed diesel consumption in mobile crane

HSD_{tt}= high speed diesel consumption in tractor trolley

These are all the components of HSD consumption and using this function for our study will lead to endogeneity problem as all the explanatory variables or the independent variables are highly correlated with the dependent variable. (Moer, 2007) Therefore, in order to optimize our business problem we introduce new variable in our model. Hence, we revised the equation for our study. The new HSD consumption function is as follows:

$$HSD_{it} = \beta_1 + \beta_2 GEN_{it} + \beta_3 PLF_{it} + u_{it} \qquad \text{...... (5.2)}$$

Where the variables used in the eq. 5.2 are defined in Table-5.1:

Table 5.1: Variables for estimation of HSD

Variables	Name of the variables	Definition
Dependent	HSD	High Speed Diesel consumption
Independent	GEN	Generation at plant level
Independent	PLF	Plant Load Factor

Source: Variable source for estimation by authors from the Log Book of respective CHPs

We aim to study the above function i.e. equation 5.2 using panel data. The data of 3 plant units serve as our cross- sectional units. The three plants that are undertaken in our study is as follows:

Plant 1: Adani Power Ltd. Mundra, Gujarat

Plant 2: Adani Power Ltd. Tiroda, Maharashtra

Plant 3: Adani Power Ltd. Kawai, Rajasthan

The Data for individual plants on the preceding variable are collected from primary survey and log books of respective plants. The data is available on a monthly basis for a period of 36 months from Jan 2014- Dec 2016. Thus, there are three cross- sectional units and 36 months' time periods. Thus, we have 108 observations in total.

The panel data gives us freedom to study the data of these three plants over a period of time. The panel data is suited to study the dynamics of change as it allows us to study the repeated cross section of observations.

We have further modified the econometric specification of eq. 5.2 as follows:

$$\ln(HSD_{it}) = \beta_1 + \beta_2 \ln(GEN_{it}) + \beta_3 PLF_{it} + u_{it} \quad \text{...... (5.3)}$$

In order to delve deeper, the differential dummies are introduced for the three plants in eq. 5.2 (OLS regression). The introduction of dummy variable in the model allows the intercept to vary between the plants. (Brand, 2010) This means it allow us to study the impact on HSD consumption when all the independent variables are zero for each plant.

The econometric specification of eq. 5.3, thus, can be modified as follows:

$$\ln(HSD_{it}) = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \beta_2 \ln(GEN_{it}) + \beta_3 PLF_{it} + u_{it} \quad \text{... (5.4)}$$

Here,

The plant dummies are as follows:
D1= 1 if the observation belongs to plant 1, 0 otherwise
D2= 1 if the observation belongs to plant 2, 0 otherwise
D3= 1 if the observation belongs to plant 3, 0 otherwise

In order to avoid the problem of dummy variable trap we have not introduced dummy for plant 1. It forms as the comparison plant. Therefore, α_1 represents the intercept of plant 1 and α_2, α_3, the differential intercept coefficients, tell by how much the intercepts of plant 2, plant3, differ from the intercept of plant1 respectively.

HSD_{it} = High speed diesel consumption of i-th plant at t-th time period

GEN_{it} = Generation of i-th plant at t-th time period

PLF_{it} = Plant load factor of i-th plant at t-th time period

To check for the unit root problem the, phillip perron unit root test and augmented dicky fuller unit root test was conducted.

The results achieved by OLS can be biased. Thus, we use the fixed effect model and random effect model. The fixed-effect enables us to analyse the impact of BUF that varies over the different time period. Fixed effect help us to explore the relationship between GEN, PLF and HSD consumption within an entity that means the different plants. Fixed Effect removes the effect of the time-invariant characteristics that helps us to assess the net effect of the independent factors i.e. GEN and PLF on the HSD consumption. To capture the fixed effect, the econometric specification of eq. 5.2 can be modified to:

$$\ln(HSD_{it}) = \beta_1 + \beta_2 \ln(GEN_{it}) + \beta_3 PLF_{it} + \alpha + \mu_{it} \quad \ldots (5.5)$$

Where, α is the unknown intercept for each plant.

5.3 Descriptive data analysis:-

HSD: High Speed Diesel (HSD) is consumable oil used to run the Heavy Earth Mover Machines (HEMM). The total OIL consumed in coal handling plant is called HSD oil consumption of CHP. HSD is normally used as a fuel in medium and **high speed** compression ignition engines (operating above 750 rpm) in commercial vehicles, stationary **diesel** engines, locomotives and pumps etc. (Dragan Komljenovic, 2010)

HEMM: Heavy Earth Mover Machines (HEMM) are the machines used in the coal handling plant for material handling day to day life. There are many equipment comes under HEMM but we have taken only those HEMM which are used to use for handling the coal, i.e. : Dozers (DZ) , Pock lain (PL) Pay loader (JCB) Dumper (HYVA) Mobile Crane (HDR) Tractor -Trolley (TT) Bob Cot (BC) Road Sweeping Machine (SM) Loader (LD).

Generation: The generation may be defined in thermal power plants "A coal based thermal power plant converts the chemical energy of the coal into electrical energy. This is achieved by raising the steam in the boilers, expanding it through the turbine and coupling the turbines to the generators which converts mechanical energy into electrical energy called generation of electricity.

Plant Load Factor (PLF): is the ratio between the actual energy generated by the plant to the maximum possible energy that can be generated with the plant working at its rated power and for a duration of an entire year. The changes in the HSD are proportional to that of PLF, i.e. if PLF is improved then HSD consumption is increased and if PLF is decreasing then HSD is in decreasing trend.

SUMMARY STATISTICS

Table 5.2: Summary Statistics

Variables		*Observations*	*Mean*	*Std. Dev*	*Min*	*Max*
HSD CONSUMPTION	*OVERALL*	*N-108* *n-3* *T-36*	*20338.33*	*5841.896*	*9709*	*34206*
	BETWEEN			*0*	*20338.33*	*20338.33*
	WITHIN			*5841.896*	*9709*	*34206*
GENERATION	*OVERALL*	*N-108* *n-3* *T-36*	*1463.4*	*959.7913*	*0*	*3180*
	BETWEEN			*889.3309*	*616.929*	*2390.148*
	WITHIN			*623.6974*	*-926.7478*	*2253.252*
PLANT LOAD FACTOR	*OVERALL*	*N-108* *n-3* *T-36*	*67.40685*	*30.79229*	*0*	*98.12*
	BETWEEN			*6.252735*	*63.09333*	*74.57778*
	WITHIN			*30.3621*	*-7.170926*	*102.4335*
HSD consumption in pock lain	*OVERALL*	*N=108* *n=3* *T=36*	*545.6204*	*362.7588*	*0*	*1650*

	BETWEEN			*134.8754*	*467.75*	*701.3611*
	WITHIN			*345.4751*	*-155.7407*	*1494.259*
HSD consumption in JCB	*OVERALL*	*N=108 n=3 T=36*	*155.9167*	*241.0832*	***0***	*800*
	BETWEEN			*270.0556*	***0***	*467.75*
	WITHIN			*95.11404*	*-162.8333*	*488.1667*
HSD consumption in HYVA Dumper	*OVERALL*	*N=108 n=3 T=36*	*90.74444*	*74.81917*	***0***	*300*
	BETWEEN			*78.58699*	***0***	*136.1167*
	WITHIN			*37.97568*	*14.62778*	*254.6278*
HSD consumption in HYDRA mobile crane	*OVERALL*	*N=108 n=3 T=36*	*45.37222*	*69.83432*	***0***	*300*
	BETWEEN			*78.58699*	***0***	*136.1167*
	WITHIN			*26.85286*	*-30.74444*	*209.2556*
HSD consumption in Bob cat	*OVERALL*	*N=108 n=3 T=36*	*113.7963*	*100.8899*	***0***	*321*
	BETWEEN			*98.55048*	***0***	*170.6944*
	WITHIN			*60.36116*	*-56.89815*	*264.1019*

HSD consumption in road sweeping machine	*OVERALL*	*N=108 n=3 T=36*	*366.713*	*290.4553*	***0***	*1212*
	BETWEEN			*169.757*	*170.6944*	*464.7222*
	WITHIN			*254.8983*	*-98.00926*	*1113.991*
HSD consumption in dozer	*OVERALL*	*N=108 n=3 T=36*	*19020.18*	*5681.128*	*7808*	*32426*
	BETWEEN			*136.6235*	*18862.42*	*19099.06*
	WITHIN			*5680.022*	*7965.759*	*32543.76*

Source: Table developed by author based on the logbook data from Super Critical Units

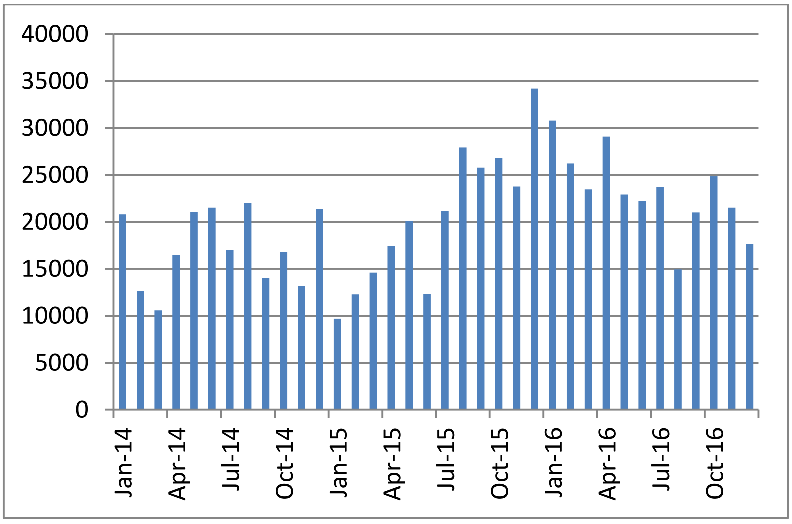

Fig 5.1: HSD Consumption of plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.1, shows the monthly average consumption of HSD oil for plant 1. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Jan 2015, the lowest HSD consumption was found in totality and in Dec 2015, HSD consumption is highest. Annual average of HSD is observed more than >33000 litres throughout the year. The summary statistics on diesel consumption are self-explanatory.

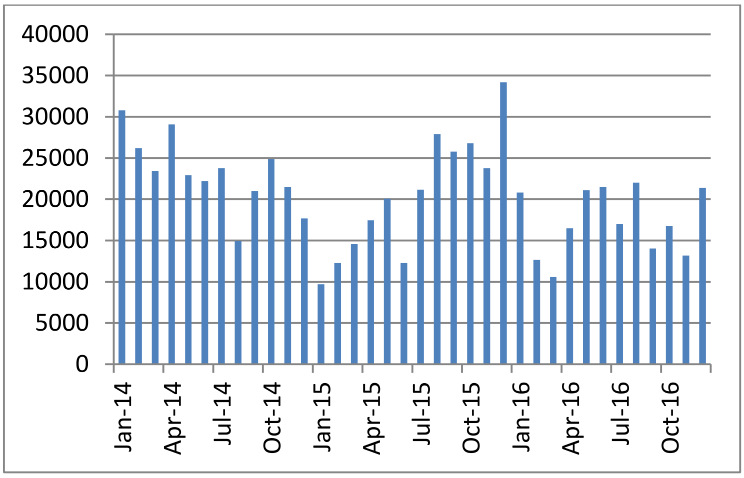

Fig 5.2: HSD Consumption of plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

In Fig 5.2, shows the monthly average consumption of HSD oil for plant2. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Jan 2015, lowest HSD consumption was observed and peak HSD consumption was observed in Dec 2015.

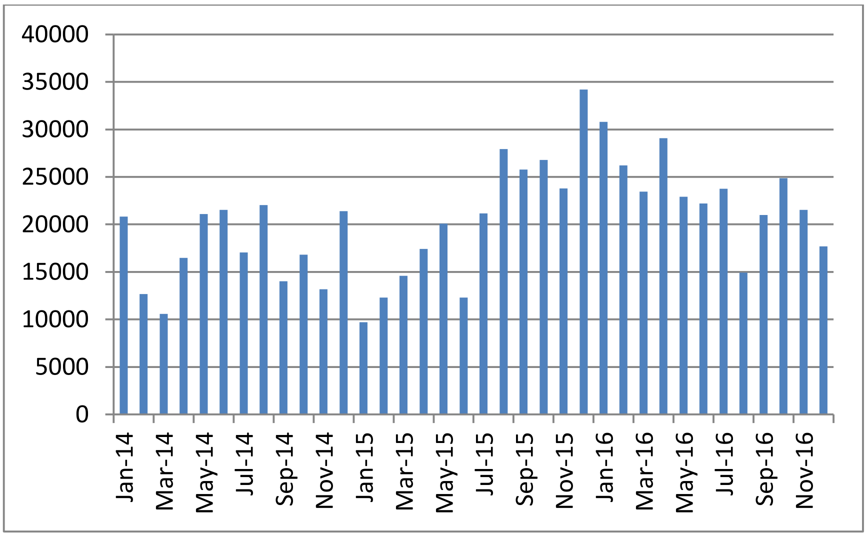

Fig 5.3: HSD Consumption of plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

In Fig 5.3, shows the monthly average consumption of HSD oil for plant2. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Jan 2015, lowest HSD consumption was observed and peak HSD consumption was observed in Dec 2015.

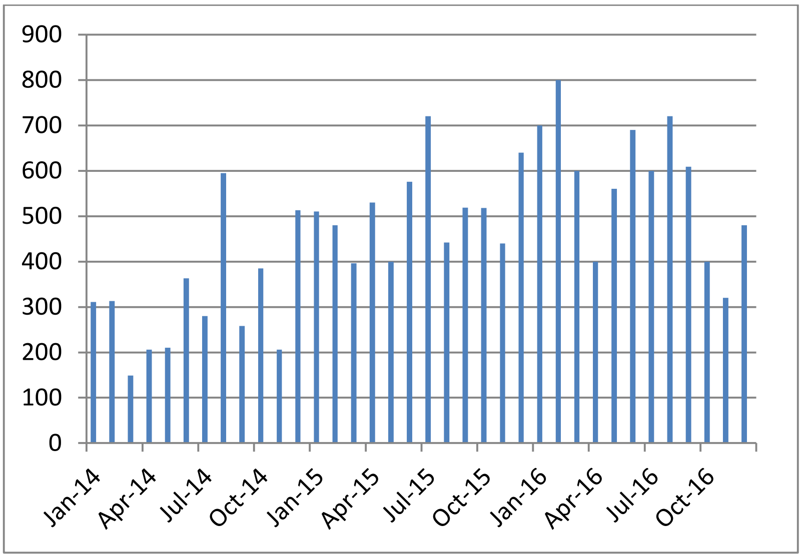

Fig 5.4: HSD Consumption in PL and JCB -plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

In Fig 5.4, shows the monthly average consumption of HSD oil in pock lain and JCB for plant 1. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Mar 2014, lowest HSD consumption in both the equipment were observed. Whereas the month of Feb 2016 observed the peak HSD consumption. It is observed that the JCB is not used in plant 1. Thus, the figure shows the trend for HSD consumption in pock lain only.

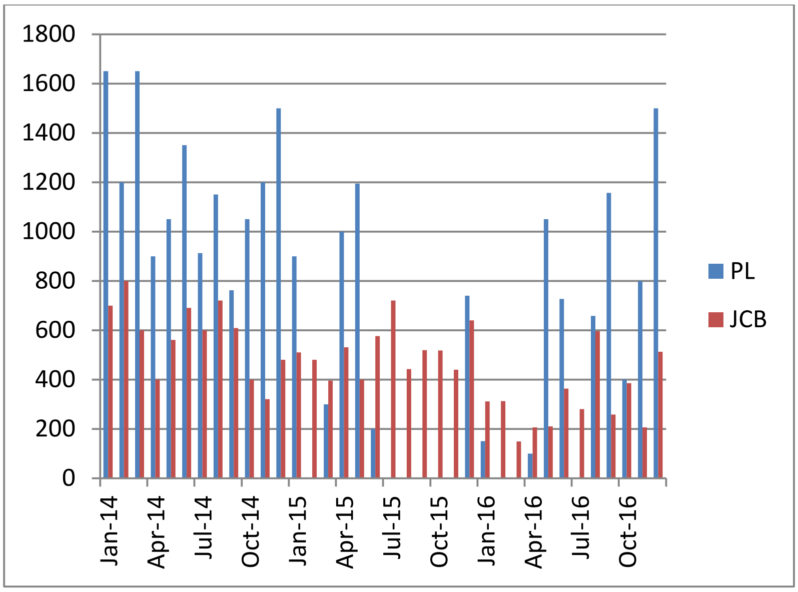

Fig 5.5: HSD Consumption in PL and JCB -plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

In Fig 5.5, shows the monthly average consumption of HSD oil in pock lain and JCB for plant 2. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. The lowest HSD consumption in pock lain was observed in the month of Jan 2015 while that in JCB was observed in March 2016. The peak HSD consumption in pock lain was observed in April 2014, while for JCB it was observed in July 2015

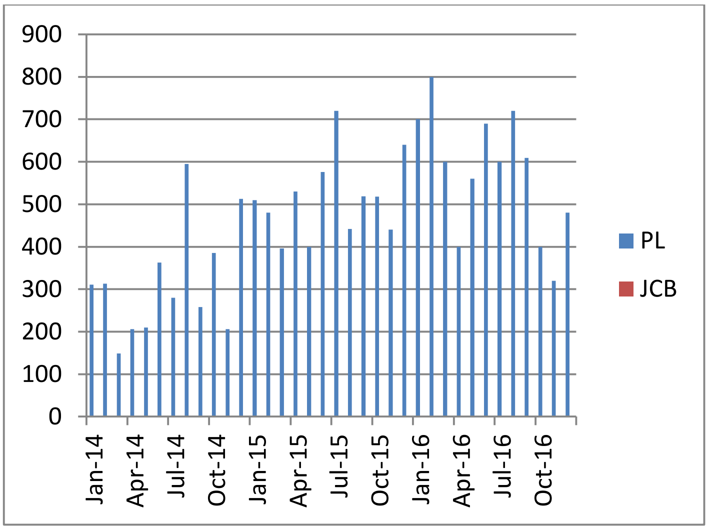

Fig 5.6: HSD Consumption in PL and JCB -plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

In Fig 5.6, shows the monthly average consumption of HSD oil in pock lain and JCB for plant 3. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Jan 2015, lowest HSD consumption was observed. Whereas the peak consumption was observed in Dec 2016. It is observed that the JCB is not used in plant 3. Thus, the figure shows the trend for HSD consumption in pock lain only.

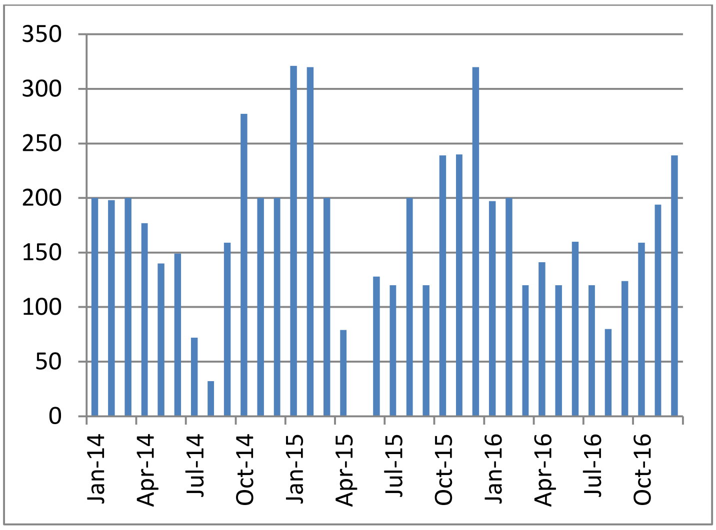

Fig 5.7: HSD Consumption in Bob Cat - plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

In Fig 5.7, shows the monthly average consumption of HSD oil in Bob cat for plant 1. The variations in HSD consumption in Bob cat is observed month wise from Jan 2014 to Dec 2016. In Aug 2014, lowest HSD consumption was observed. Whereas the peak consumption was observed in Feb & Mar 2015. Bob cat was not used in Plant 2 during the time period of the study.

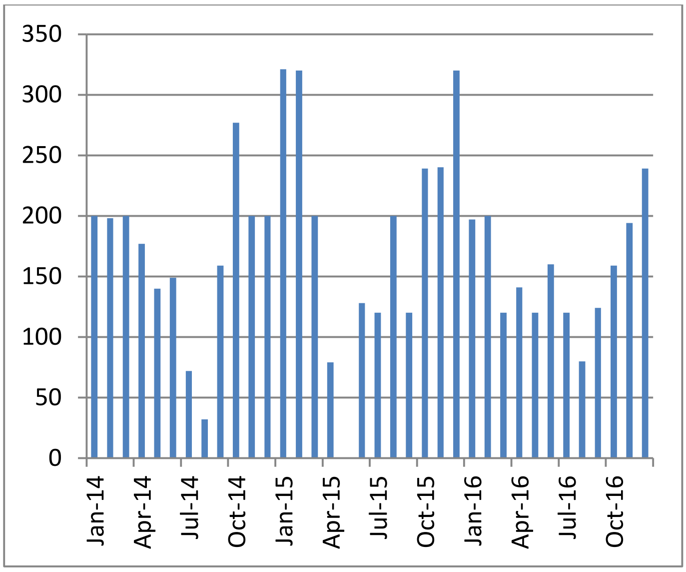

Fig 5.7: HSD Consumption in Bob Cat - plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

In Fig 5.7, shows the monthly average consumption of HSD oil in Bob cat for plant 1. The variations in HSD consumption in Bob cat is observed month wise from Jan 2014 to Dec 2016. In Aug 2014, lowest HSD consumption was observed. Whereas the peak consumption was observed in Feb & Mar 2015 and in Jan 2016.

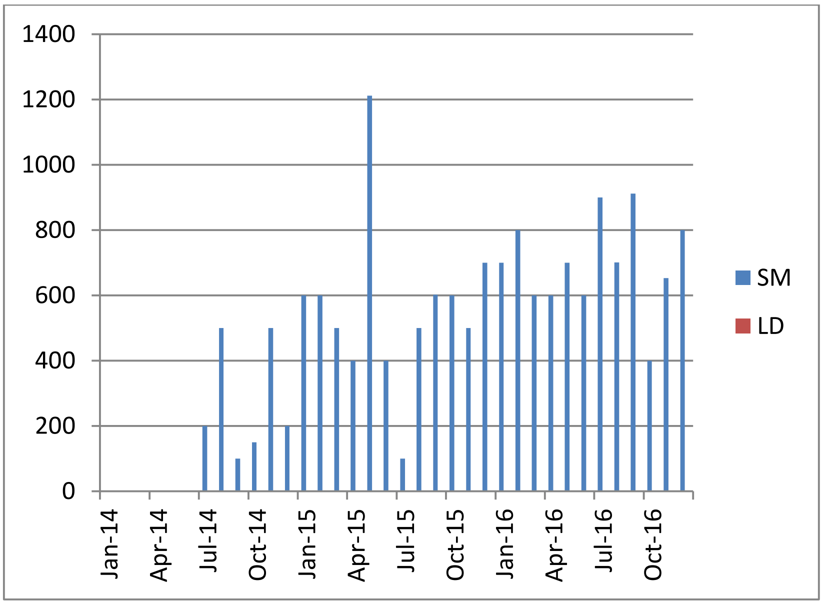

Fig 5.8: HSD Consumption in SM and LD - plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.8, shows the monthly average consumption of HSD oil in road sweeping machine and loader for plant 1. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In July 2014, lowest HSD consumption for sweeping machine was observed. In Feb 2016 the peak HSD consumption for sweeping machine was observed. Also, sweeping machine was not operational from January 2014 till July 2014. It is observed that the Loader is not used in plant 1. Thus, the figure shows the trend for HSD consumption in sweeping machine only.

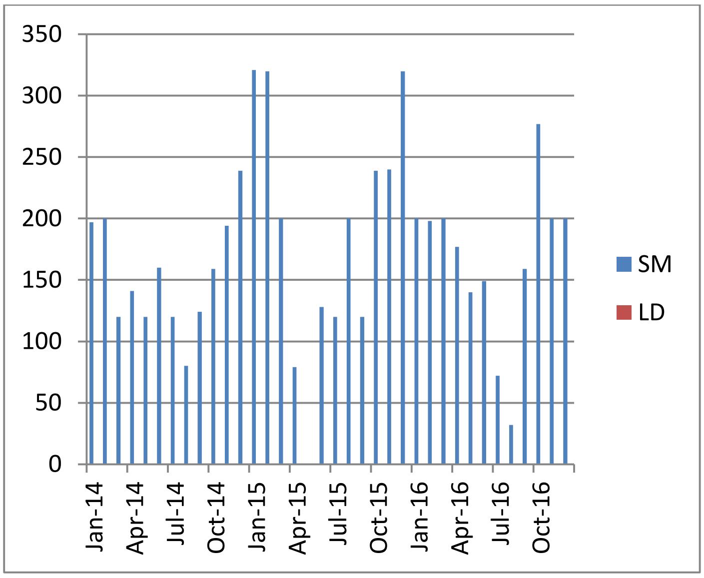

Fig 5.9: HSD Consumption in SM and LD - plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.9, shows the monthly average consumption of HSD oil in road sweeping machine and loader for plant 2. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In July 2016, lowest HSD consumption for sweeping machine was observed. In Nov 2014, Jan 2015 and Nov 2016, the peak HSD consumption for sweeping machine was observed. It is observed that the Loader is not used in plant 1. Thus, the figure shows the trend for HSD consumption in sweeping machine only. Also, sweeping machines was not used in plant 2 in May 2015.

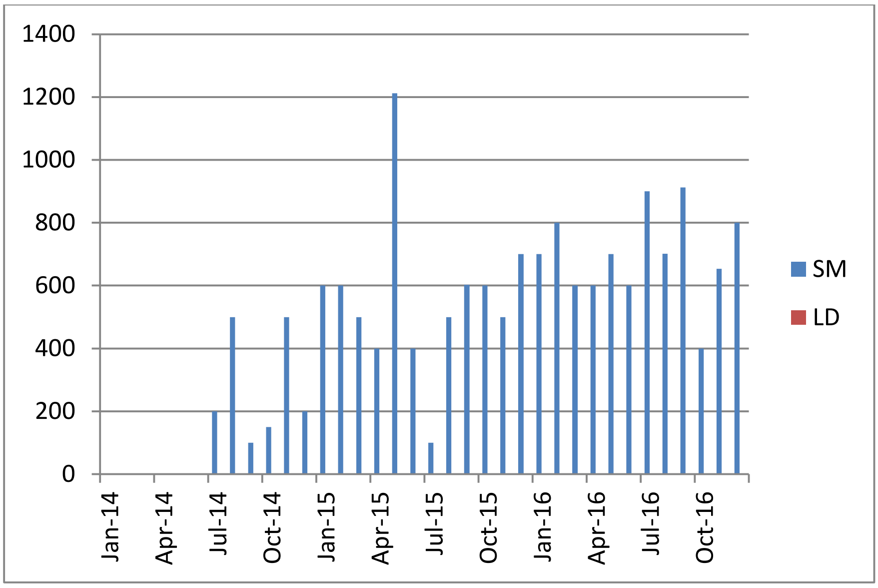

Fig 5.10: HSD Consumption in SM and LD - plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.10, shows the monthly average consumption of HSD oil in road sweeping machine and loader for plant 3. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Aug 2014 and Aug 2015, lowest HSD consumption for sweeping machine was observed. In May 2015, the peak HSD consumption for sweeping machine was observed. It is observed that the Loader is not used in plant 3. Thus, the figure shows the trend for HSD consumption in sweeping machine only. Also, sweeping machines was not used in plant 3 for a period of six months i.e. from January 2014 till June 2014.

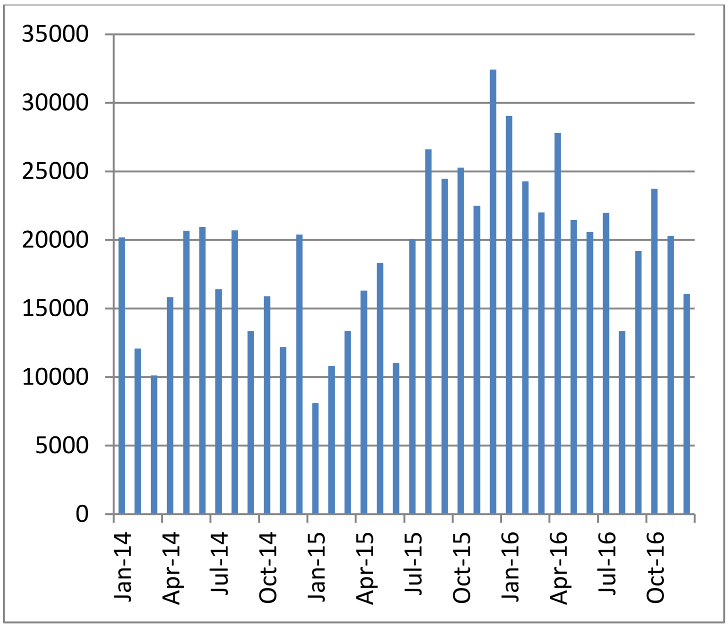

Fig 5.11: HSD Consumption in Dozers- plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.11, shows the monthly average consumption of HSD oil in dozers for plant 1. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Feb 2015, lowest HSD consumption for dozers was observed. In Dec 2015, the peak HSD consumption was observed. It is observed that the Loader is not used in plant 1. Thus, the figure shows the trend for HSD consumption in sweeping machine only.

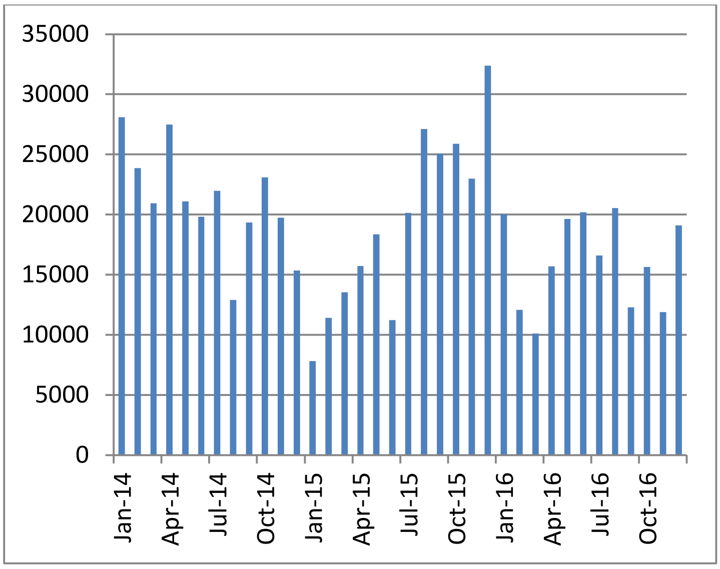

Fig 5.12: HSD Consumption in Dozers - plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.12, shows the monthly average consumption of HSD oil in dozers for plant 2. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Feb 2015, lowest HSD consumption for dozers was observed. In Dec 2015, the peak HSD consumption was observed. It is observed that the Loader is not used in plant 1. Thus, the figure shows the trend for HSD consumption in sweeping machine only.

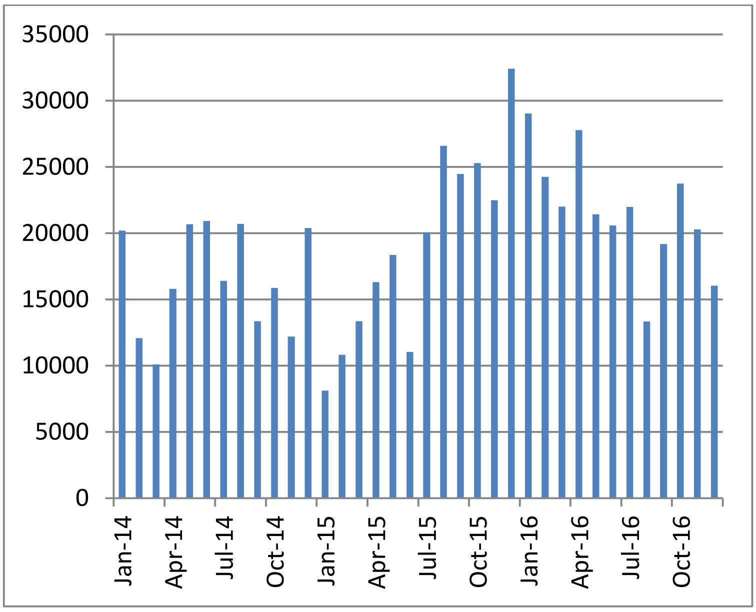

Fig 5.13: HSD Consumption in Dozers - plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.13, shows the monthly average consumption of HSD oil in dozers for plant 2. The variations in HSD consumption is observed month wise from Jan 2014 to Dec 2016. In Feb 2015, lowest HSD consumption for dozers was observed. In Dec 2015, the peak HSD consumption was observed. It is observed that the Loader is not used in plant 1. Thus, the figure shows the trend for HSD consumption in sweeping machine only.

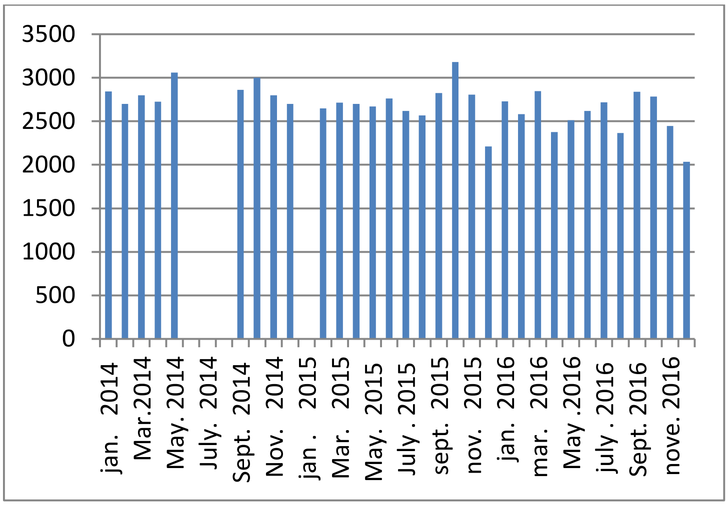

Fig 5.14: Generation in MU - plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.14 shows the plant generation in million units. The variations in generation is observed month wise from Jan 2014 to Dec 2016. The CHP is always running if generation is not there because CHP has to procure coal as per PPA. The coal is crushed and reduce to smaller chunks. It is kept in the storage coal yards in trapezoidal form of heaps. In Oct 2015 highest generation done by plant1. The lowest generation occurred in Dec 2016 due to unavoidable circumstances like, high frequency, financial commercial viability and grid etc. issue .The generation is indirectly connected to CHP coal bunkering, the coal is stored in bunkers for 6-8 hrs. depend upon the generation capacity. Each bunker has 800MT capacity. If coal is not available inside the bunkers then only generation is affected. Plant 1 has higher capacity plant.

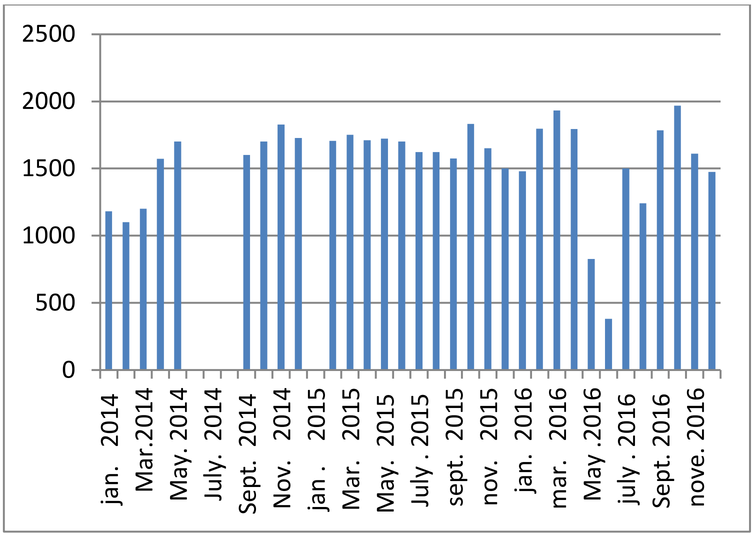

Fig 5.15: Generation in MU - plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.15 shows the plant generation in million units. The variations in generation is observed month wise from Jan 2014 to Dec 2016. In Oct 2016 highest generation done by plant2. The lowest generation occurred in June 2016 due to unavoidable circumstances like, rainy season due to which moisture in coal increased, financial commercial viability issue. Plant 2 has 5 units of super critical plant.

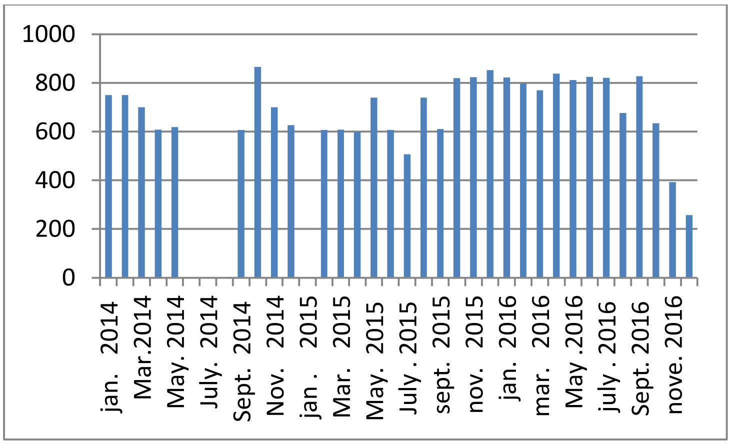

Fig 5.16: Generation in MU – plant3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.16 shows the plant generation in million units. The variations in generation is observed month wise from Jan 2014 to Dec 2016. In Oct 2014 highest generation done by plant3. The lowest generation occurred in Dec 2016 due unavoidable circumstances like, rainy season due to which moisture in coal increased, financial commercial viability issue. Plant 3 has 2 units of super critical plant 660 MW capacity.

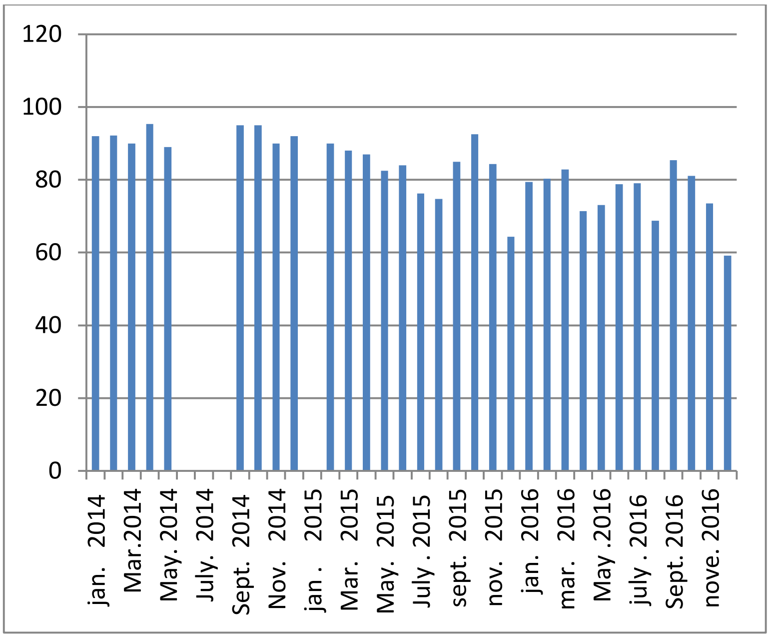

Fig 5.17: Plant Load factor – plant1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.17 shows the monthly average plant load factor for plant 1. The variations in generation is observed month wise from Jan 2014 to Dec 2016. The highest PLF is noticed 95.36% in Plant 1 and the lowest being in DEC 2016 is 59.17%. The summary statistics are self-explanatory. In Some months, plant was shut-down due to unavailability of coal. The coal handled during the period was zero.

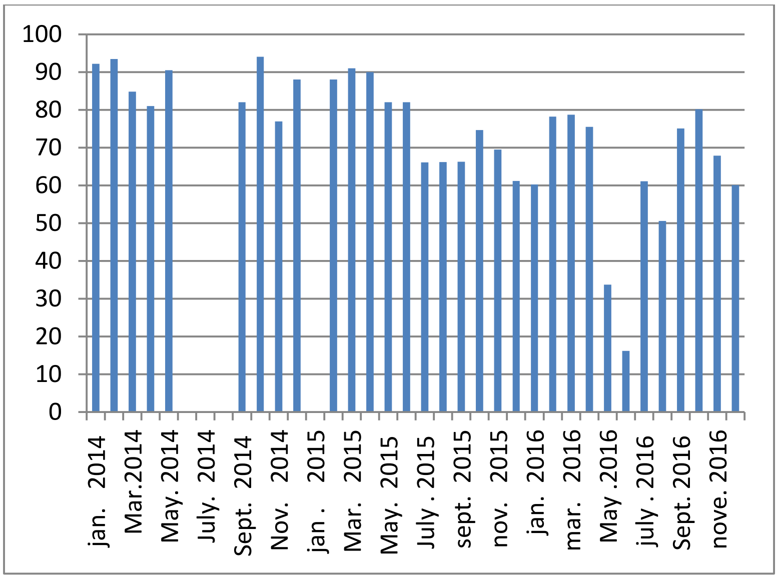

Fig 5.18: Plant Load factor – plant2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.18 shows the monthly average plant load factor for plant 2. The variations in generation is observed month wise from Jan 2014 to Dec 2016 . The highest PLF is noticed 94.01% in Oct- 2014 in Plant 2. The plant2's average PLF is found better than plant 1due to coal availability in the plant and demand is good.

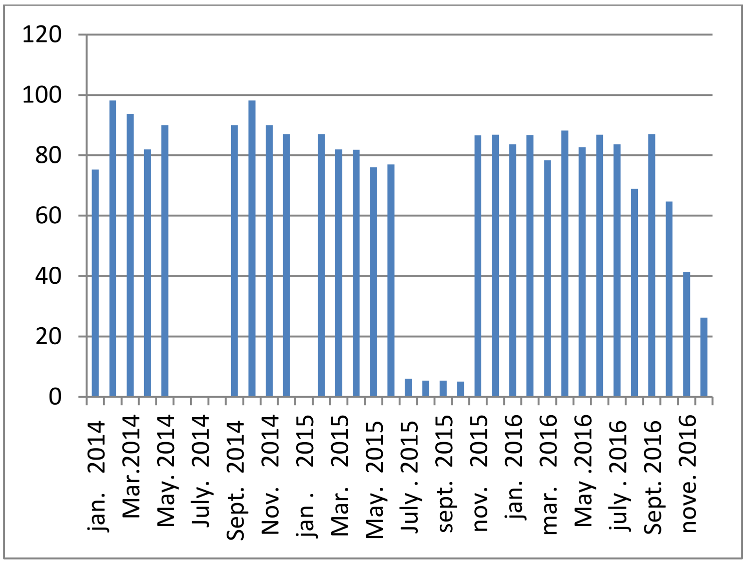

Fig 5.19: Plant Load factor – plant3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig 5.18 shows the monthly average plant load factor for plant 3. The variations in generation is observed month wise from Jan 2014 to Dec 2016. In Some months, plant was shut-down due to unavailability of coal. The coal handled during the period was zero. Comparatively, more variations are found in plant 3 than plant 1 and 2. Generation and PLF is better than plant 1 in plant 3.

5.4 RESULT AND DISCUSSION

Unit Root Test

The panel data involves cross-sectional and time series data both. It is necessary to ensure that the time-series is stationary in order to generalize the relationship between the dependent and independent variables over the period of time (Nielsen, 2005). For our analysis, we conducted Augmented Dicky fuller test and Phillip-perron unit root test. The results are given below in the table 5.2 and table 5.3

Table 5.3 Results of Unit Root test without Drift

All the variables are significant at 1% level

Source: Table developed by author based on the logbook data from Super Critical Units

	Augmented Dicky Fuller				*Phillip-Perron test*			
Variable name	*Inverse chi-squared(6)*	*Inverse normal*	*Inverse logit t(19)*	*Modified inverse chi-square*	*Inverse chi-squared(6)*	*Inverse normal*	*Inverse logit t(19)*	*Modified inverse chi-square*
	P	z	L*	Pm	P	Z	L*	Pm
HSD CONSUMPTION	79.9523	-8.0597	-13.0937	21.3482	79.9523	8.0597	-13.0937	21.3482
PLF	127.0270	-10.2536	-20.8031	34.9375	127.0270	-10.2536	-20.8031	34.9375
GEN	143.3836	-11.1416	-23.4818	39.6592	143.3836	-11.1416	-23.4818	39.6592

Table 5.4 Results of Unit test with Drift

	Augmented Dicky Fuller			
Variable name	*Inverse chi-squared(6)*	*Inverse normal*	*Inverse logit t(19)*	*Modified inverse chi-square*
	P	*z*	*L**	*Pm*
HSD CONSUMPTION	*71.1800****	*-7.5213****	*-11.6571****	*18.8158****
GENERATION	*97.0413****	*-8.9967****	*-15.8924****	*26.2814****
PLANT LOAD FACTOR	*89.7404****	*-8.5567****	*-14.6967****	*24.1738****

Source: Table developed by author based on the logbook data from Super Critical Units

**** signifies that all the variables are significant at 1% level*

It can be inferred from table 5.3 and table 5.4 all the variables used in the model are free from the unit root problem as the variables are significant as per both the tests. Therefore, our data set is stationary

Table 5.5: Result of HSD Estimation Using OLS Regression

2) In parenthesis sta

Source: Table developed by author based on the logbook data from Super Critical Units

In table 5.5, in the column OLS 1, the independent variables lnGEN, PLF are highly significant as the p-value of the variable is extremely small. It can be inferred that generation and HSD consumption are positively related i.e. with an increase in lnGEN on a scale of 1 to 100 high speed diesel consumption increases by 0.0375388%. The results received are as per as usual business model. With increase in generation we require more coal as are yet to shift towards efficiency model. As a consequence, more coal is transported to thermal plant from CHP and more HSD is consumed by HEMM equipment. The estimated relationship between PLF and HSD consumption when we keep generation as constant is negative i.e. with an absolute increase in PLF on a scale of

ln HSD	OLS-1	OLS-2
ln GEN	0.0375388*** (0.0105482)	0.0381308*** (0.0106721)
PLF	-0.0046682*** (0.0.0015431)	-0.0047959*** (0.0015698)
D2		-0.0430246* (0.0681805)
D3		-0.0139025* (0.0681852)
_cons	9.978015*** (0.0719035)	10.00225*** (0.087777)
Number of obs	108	108
F(5, 174)	2, 105	4, 103
Prob > F	0.0025	0.0151
R-squared	0.1082	0.1117
Adj R-squared	0.0912	0.0772
Root MSE	0.29168	0.29392

1 to 100 the relative decrease in HSD consumption is 0.0046682%. The estimated results show that plant 1, 2 and 3 as a whole are able to optimally utilize the existing resources. It was also observed that coal piles were kept in bunkers near to the thermal plant such that with increase in PLF the consumption was reduced as timely availability of coal reduced the use of HEMM equipment.

In table 5.5, from column OLS-2, it can be inferred that the intercept value for the Plant 1 is 10.00225. The different intercept estimates the value of HSD consumption for each plant in the absence of the independent variables. The intercept value of plant 2 is 0.0430246 less than that of plant 1 and the intercept value of plant 3 is 0.0139025 less than that of plant 1. The differences in the intercept of the plants were observed because of various managerial reason and difference plant characteristics. The use of dozers in plant3 and plant2 is minimized as crushed coal is directly passed to conveyor belt and then to bunkers using track hopper. As a consequence, the HSD consumption is less in plant2 and 3 than the plant1.

Table 5.6: Result of HSD Estimation Using OLS Regression

ln HSD	*FIXED*
ln GEN	*0.0380202**** *(0.010705)*
PLF	*-0.0047661**** *(0.0015783)*
_cons	*09.981886**** *(0.0735616)*
Number of obs	*108*
Number of groups	*3*
Obs per group: min	*36*
Avg	*36*
Max	*36*
F(3,102):	*6.34*
Prob > F:	
PROB>F	*0.0025*
F(2,102)	*0.09*
PROB>F	*0.9178*
Wald chi(2)1:	-
Prob>chi2:	-

Source: Table developed by author based on the logbook data from Super Critical Units

R-sq: within	*0.1097*
between	-
overall	*0.1082*
sigma_u	*0.01453377*
sigma_e	*0.29425749*
Rho	*0.00243357*

1) ***indicate sig. at 1% level, ** indicate sig. at 5% level and * indicate sig. at 10% level.

2) In parenthesis standard errors are given

The estimated results for OLS 1 in the table 5.5 and Fixed in the table 5.6 are similar. Thus, it can be inferred that that generation and HSD consumption are positively related i.e. with an increase in ln GEN on a scale of 1 to 100 high speed diesel consumption increases by 0.0380202%. The results received are as per as usual business model. With increase in generation we require more coal as are yet to shift towards efficiency model. As a consequence, more coal is transported to thermal plant from CHP and more HSD is consumed by HEMM equipment. The estimated relationship between PLF and HSD consumption when we keep generation as constant is negative i.e. with an absolute increase in PLF on a scale of 1 to 100 the relative decrease in HSD consumption is 0.0047661%.

5.5 Concluding Remarks:

Findings:--

The HSD oil consumption may be optimized by proactive management of HEMM. The optimization of HSD consumption will save the business revenue losses per annum. HSD consumption can be optimized by increasing the efficiency of HEMM equipment. Also, it was observed no stringent government regulation exists on the optimization of HSD consumption. The policy intervention by government like, incentives to the producers who would reduce HSD consumption or will reduce the idle running time. It can also be optimized by considering the following steps: by reduce the Specific oil consumption by managing the dozers running time in coal yard through HEMM effective utilization, by preventing the energy losses of equipment by minimizing the idle running hours and stop dozers pushing in hoppers, as this consumes more oil.

Further, the below given points can be considered.

Recommendations & Suggestions: ---

- Regular maintenance of HEMM Engine by regular servicing would reduce the HSD consumption, as the older engines that are not timely serviced consumes more oil. Routinely maintenance of equipment enhanced the life of engine and sealing of engine. Break down of equipment should be timely done. When the engine is not in good condition the equipment should be breakdown. The government can intervene by laying down strict policy stating when a HEMM should be break down on the basis of the engine health and life of the equipment. This would also not only help in optimizing HSD consumption but will also help government realize its objective of reducing carbon dioxide and environmental impacts.
- Best practices to upkeep HEMM parts should be adopted. One of them is to conduct condition based monitoring of equipment on a regular basis. Good quality spares increases the life of equipment.
- Skilled driver may save fuel. The idle running time can be reduced if we have skilled driver. Also, training and education of drivers may help for safe driving of equipment and may be economical.
- Empty running of equipment &spontaneous combustion should be prevented by taking regular measures.
- The coal size should be keep in check. The bigger the coal size more is the HSD consumption as it doubles the work. If the coal procured is of desired size it does saves the HSD. Also, use of HEMM equipment may be optimized by managing the coal loading and unloading in a planned way.

  Oil filling through drum by pump to be avoided and to be filled on petrol pump. Sometimes unnecessary use of dozers while pock-lain is sufficient at that place to be minimized and should only be substituted in emergency cases.

As per CERC guide lines --for two units of super critical units operations of 660x2 minimum 4 dozers are required and regular upkeep of machines. HSD consumptions to be optimized by stacking in layers and regular compaction and churning is required to heaps in coal yard and spontaneous combustion to be reduced. Over run of equipments to be avoided. Moisture content in oil to be prevented.

CHAPTER 6

Chapter 6

Optimizing Specific Coal Consumption in Coal Handling Plant of Coal Fired Power Plants

6.1 INTRODUCTION

Coal has an essential role to play in our energy mix. The major proportion of the coal in India is consumed for power generation (Ebinger, 2016). In current scenario the availability of coal & its price hike are the big challenge for thermal power plants. Saving the amount of coal per KWH of electricity generation need to be assessed in a CHP which will have some value addition to the national economy (AYOG, 2015). The Coal Handling Plant is the backbone of the any Thermal Power Plant.

Losses management at CHP is the application of proactive strategy to plan, lead, organize, and control the wide variety of fuel & energy losses that are woven into the fabric of a power sector’s daily and long-term functioning. The coal when bought to the power plant is stored in the coal yard. The coal if kept for longer period in the yard leads to spontaneous combustion of the coal. As a consequence, this reduces the quality of coal i.e. the gross calorific value of the coal. The combusted coal turns into ashes that also reduce the weight of coal. The reduction in quality of coal also reduces the power generated from the coal, for that we increases the coal consumption i.e. SCC increases with decrease in gross calorific value of coal. Therefore, we need to optimize the coal yard management in order to efficiently use the existing coal resources. The objective of this study is to control the losses of fuel & energy at CHP of power sector. The implication of this study is that a lot of fuel and energy in terms of revenue for the organization and to the nation can be saved. Today the coal & Energy scenario in India as well as in internationally global village level become more critical and the fuel cost is too much high. The consequences is, the fuel cost have got increased drastically, which impact on the generation cost and getting break-even point from business to power producers. The power purchase agreements (PPAs) are signed on the fixed price and at this time the scenario is entirely different in just with effect from 2011 onward. The GDP growth in global recession became drastically moved downward on global level and the hike in the coal prices playing the crucial role are not in control of the electricity/power producers. So the fuel cost as well as surface coal, fuel &energy losses cost need to be reduced and generation cost to be minimized in order to make the super critical power units sustainable in power generation.

The function of Coal analysis is very important in SCC –Specific Coal Consumption finding the constituent of coal ingredients like (TM) total moisture (FC) fixed carbon (VM) volatile materials (GCV) Gross calorific value (AC) ash content to transport and transfer the coal from yard to coal Hopper to adjacent hopper points & finally send coal to bunkers through conveyor belt for electricity generation through Mills boiler and Turbine generator. There are several systems in Coal sampling system, auto Coal sampling, Manual coal sampling system, Coal stacking & reclaiming system, Coal crushing & bunker feeding system. Dust controlling system Ventilation system and others. The objective of the study is to study the nature of specific coal consumption (SCC) through total moisture (T.M.), Ash Content , Volatile material (VM) , fixed carbon (FC), Gross calorific value (GCV), different coal in Super Critical Units of coal based power plants.

6.2 METHODOLOGY AND DATA SOURCE

In this study we need to estimate the specific coal consumption by studying the impact of various independent variables that affects the coal consumption. Thus in order to estimate SCC function, we have identified the independent factor that is GCV and total volatility matter, moisture content and ash content on the SCC. The SCC function can be written as given below:

$$SCC_{it} = \beta_1 + \beta_2 GEN_{it} + \beta_3 GCV_{it} + \beta_3 CQI_{it} + u_{it} \qquad \ldots\ldots (6.1)$$

Where the variables used in the eq. 6.1 are defined in Table-6.1:

Table 6.1: Variables for estimation of SCC

Variables	Name of the variables	Definition
Dependent	SCC	Specific Coal Consumption
Independent	GEN	Generation at plant level
Independent	CQI	Coal quality Index
Independent	GCV	Gross Calorific Value of the Coal

Source : Variables estimation of SCC by author

In order to form the coal quality index different coal qualities were used. The coal properties that were used to form the index were: total moisture (TM), volatility matter (VM), ash content (AC) and FC. On the basis of data available on Indonesian/Domestic coal from the coal testing lab report and data by authorized agencies like IGI, SGS, & MSK we found out TM ranges around 30% of the Indonesian coal, ASH ranges varies around 10-40%, VM ranges approximately around 21% and FC around 9%. Thus, the formula for our coal quality index is as follows:

$$CQI = \left(\frac{TM - \overline{TM}}{TM_{max} - TM_{min}}\right) \times 0.3 + \left(\frac{VM - \overline{VM}}{VM_{max} - VM_{min}}\right) \times 0.21 + \left(\frac{ASH - \overline{ASH}}{ASH - ASH_{min}}\right) \times 0.4 + \left(\frac{FC - \overline{FC}}{FC_{max} - FC_{min}}\right) \times 0.09 \quad .....6.2$$

We have normalised SCC GEN and GCV data due to the large variance observed in the date set. The formula used to normalize the above variables is as follows:

$$SCC_{normalised} = \left(\frac{SCC - \overline{SCC}}{SCC - SCC_{min}}\right) \quad ....6.3$$

$$GEN_{normalised} = \left(\frac{GEN - \overline{GEN}}{GEN_{max} - GEN_{min}}\right) \quad .....6.4$$

$$GCV_{normalised} = \left(\frac{GCV - \overline{GCV}}{GCV_{max} - GCV_{min}}\right) \quad ....6.5$$

We aim to study the above function i.e. equation 5.1 using panel data. The data of 3 plant units serve as our cross- sectional units. The three plants that are undertaken in our study is as follows:

Plant 1: Adani Power Ltd. Mundra, Gujarat

Plant 2: Adani Power Ltd. Tiroda, Maharashtra

Plant 3: Adani Power Ltd. Kawai, Rajasthan

The Data for individual plants on the preceding variable are collected from primary survey and log books of respective plants. The data is available on a monthly basis for a period of 36 months from April 2014- March 2017. Thus, there are three cross- sectional units and 36 time periods. Thus, we have 108 observations in total.

The panel data gives us freedom to study the data of these five plants over a period of time. The panel data is suited to study the dynamics of change as it allows us to study the repeated cross section of observations.

In eq. 6.1 (OLS regression), the differential dummies are introduced for the three plants. The introduction of dummy variable in the model allows the intercept to vary between the plants. (Brand, 2010) This means it allow us to study the impact on SCC when all the independent variable is zero for each plant.

The econometric specification of eq. 6.1, thus, can be modified as follows:

$$SCC_{it} = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \beta_2 GEN_{it} + \beta_3 GCV_{it} + \beta_3 CQI_{it} + u_{it} \quad \ldots (6.6)$$

Here,

The plant dummies are as follows:
D1= 1 if the observation belongs to plant 1, 0 otherwise
D2= 1 if the observation belongs to plant 2, 0 otherwise
D3= 1 if the observation belongs to plant 3, 0 otherwise

In order to avoid the problem of dummy variable trap we have not introduced dummy for plant 1. It forms as the comparison plant. Therefore, α_1 represents the intercept of plant 1 and α_2, α_3, the differential intercept coefficients, tell by how much the intercepts of plant 2, plant3, differ from the intercept of plant1 respectively.

SCC_{it} = Specific Coal Consumption of i-th plant at t-th time period

GEN_{it} = Generation of i-th plant at t-th time period

GCV_{it} = Gross Calorific value of i-th plant at t-th time period

CQI_{it} = Coal quality index of i-th plant at t-th time period

Since, not only intercept for all the plants vary but the slope of the independent variable also varies across different plants. It can be inferred that the OLS-2 model also allow us to study the difference in the relationship of APC and BUF across the 5 plants.

The econometric specification of eq. 6.6 can again be modified as follows:

$$APC_{it} = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \alpha_4 D_{4i} + \alpha_5 D_{5i} + \beta_2 BUF_{it} + \gamma_1 (D_{2i} BUF_{it}) + \gamma_2 (D_{3i} BUF_{it}) + \gamma_3 (D_{4i} BUF_{it}) + \gamma_4 (D_{5i} BUF_{it}) + u_{it} \quad \ldots (6.7)$$

To check for the unit root problem the, phillip perron unit root test and augmented dicky fuller unit root test was conducted.

Further, we have also introduced a new variable and tried to estimate the impact of that relation on SCC. The variable introduced was: GEN_GCV i.e. generation per unit of GCV.

$$\mathrm{GEN_{GCV}} = \frac{GEN}{GCV} \quad \ldots (6.8)$$

Where,

GEN= generation at plant level

GCV= gross calorific value of coal

The econometric specification of eq. 6.1 can be modified to:

$$SCC = \beta_1 + \beta_2 GEN\_GCV + \beta_3 CQI + u_i \quad \ldots (6.9)$$

6.3 Descriptive data analysis:-

SCC:--Specific Coal Consumption:--Coal Quantity required to produce 1 unit of energy. For a thermal power plant, it is calculated by dividing Plant Heat Rate by GCV of Coal. SCC i.e. the specific coal consumption is a strong function of moisture content ash content & fixed carbon. Literature suggests that unburned combustible losses are efficiency losses from incomplete combustion of fuel in the boiler. These losses are generally influenced by both fuel properties (fuel volatility) and operations practices (excess air level, fuel fineness) that further effects the coal consumption and hence the revenues. (Shail, 1994)

T.M.: Total Moisture:--SCC Specific coal consumption is a strong function of moisture content. The change in the moisture is proportional to that GCV & generation, i.e. if moisture is increased specific coal quantity i.e. specific coal consumption will be increased. Increase in the moisture content increases the jamming during coal receiving and discharge chutes of coal handling plants. If it is improved then jamming is reduced that further optimizes the APC. (Sh.Mesroghli, 2009)

V.M.: Volatile Material: -- The magnitude of volatile material contribution was found to be directly related to the mineral composition of coal. The change in the VM % is proportional to that coal quality and GCV i.e. if VM is more then it will increased the auto ignition in coal heaps and bunkers also. VM will increase flame in furnace during generation in the plant. VM increase the coal volatility and ignition property. (J.H.Slaghuis, 1991)

AC: Ash Content: -- SCC Specific coal consumption is a strong function of ash content. Ash content of coal is the non-combustible residue left after coal is burnt. From the values of ash concentration, it can be seen that the coal might cause less environmental and health destruction. The input set of "carbon, hydrogen (exclusive of moisture), nitrogen, oxygen (exclusive of moisture), sulphur, moisture and ash" can be used as the best and most reliable input for the prediction of coal gross calorific value. The change in the ash % is proportional to that coal consumption i.e. if ash content is more then it will increased the SCC specific coal consumption as ash content increases jamming in CHP and consequently SCC. (Mahamudul Hashan, 2013)

F.C.: Fixed Carbon:--SCC Specific coal consumption is a strong function of fixed carbon. The change in the FC % is proportional to that coal quality and GCV i.e. if FC is more then, it will increase the ignition in coal quality. FC also increases flammability of coal during generation in the plant. FC is high in carbon content and ignition property. (Milan RAdovanovic, 1986)

The input set of "carbon, hydrogen (exclusive of moisture), nitrogen, oxygen (exclusive of moisture), sulphur, moisture and ash" can be used as the best and most reliable input for the prediction of coal gross calorific value.

SUMMARY STATISTICS

Table 6.2: Summary statistics of all the variables

Variables		Observations	Mean	Std. Dev	Min	Max
SCC	OVERALL	36	-.0014818	57.34119	-77.32	120.28
	BETWEEN			51.16927	-59.08667	29.54111
	WITHIN			39.06622	-95.26259	90.73741
GCV	OVERALL	36	.0037039	60.53789	-126.2	172.8
	BETWEEN			13.77622	-7.95	15.91111
	WITHIN			59.47379	-142.1074	156.8926
GEN	OVERALL	36	-.0030402	953.1816	-1471.32	1708.68
	BETWEEN			877.0136	-853.9869	898.3556
	WITHIN			625.2954	-2369.679	810.3214
GEN_GCV	OVERALL	36	.3789125	.1932561	.0583428	.7308665
	BETWEEN			.2250708	.1593962	.6091544
	WITHIN			.0567554	.09926	.5121119
CQI	OVERALL	36	.1870668	.0428372	.0584596	.2863632
	BETWEEN			.0156916	.1689477	.1961263
	WITHIN			.0408576	.0765787	.2773037

Source: Table developed by author based on the logbook data from Super Critical Units

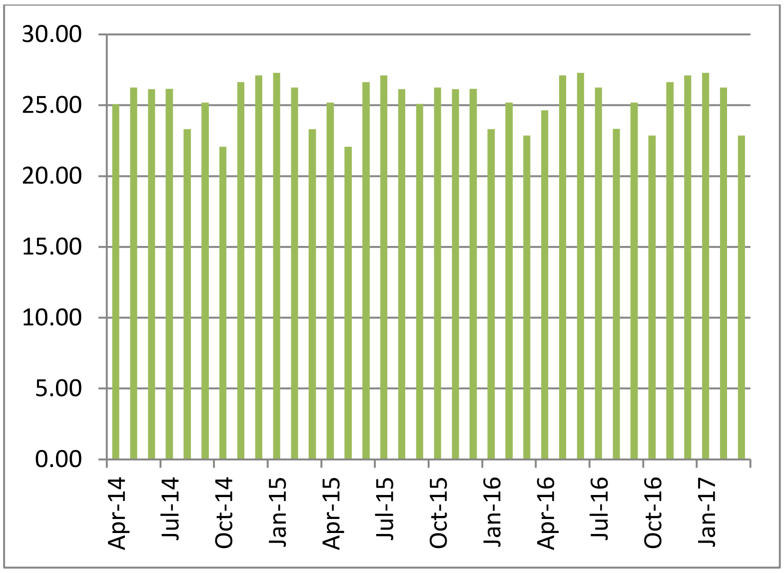

Fig 6.1: Total Moisture of Plant1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.1 shows the monthly average total moisture content of coal used in Plant1. from April 2014 to March 2017. The highest moisture content was observed in the month of Jan &July 2015 27.88 and also it is noticed in the month of Jan 2017 and the lowest being in Oct 2014 & May 2015 is 22.06%. It is further observed that annually T.M. for plant 1 is not more than 27.28%.

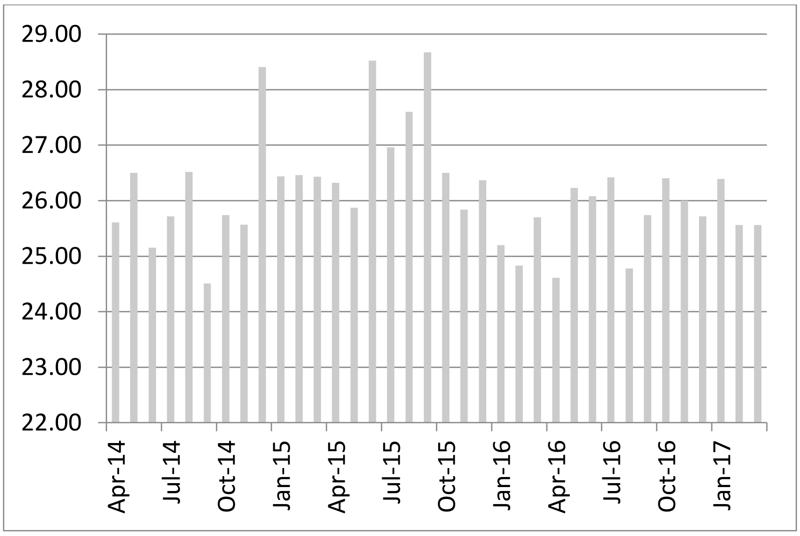

Fig 6.2: Total Moisture of plant-2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.2 shows the monthly average total moisture content of coal used in plant2 from April 2014 to March 2017. The highest moisture content was observed in the month of Sept 2015 is 28.67% and also it is noticed in the month of June 2015 it is 28.52% and the lowest moisture was observed in September 2014 i.e. 24.51%. It is further observed that maximum T.M. for plant 2 is not more than 27.28%. The summary statistics are self-explanatory.

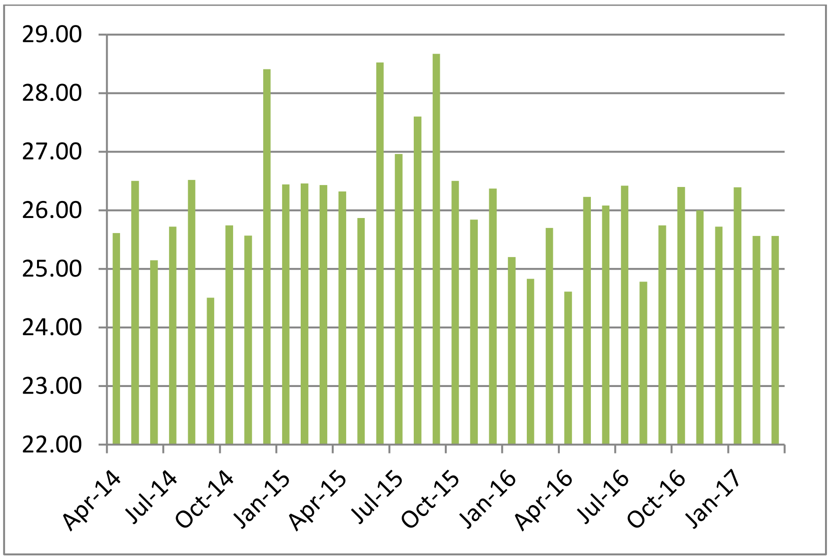

Fig 6.3: Total Moisture of Plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.3 shows the monthly average total moisture content of coal used in plant3 from April 2014 to March 2017. The highest moisture content was observed in the month of September 2015 as 28.67%. In the month of June 2015 & Dec 2014 total moisture content was observes as 28.52 % & 28.41 %, that was 2nd and 3rd highest in the time period respectively. The lowest moisture content was observed in the month of September 2014 and April 2016 i.e. 24.51% & 24.61% respectively. It is further observed that maximum T.M. for plant 3 is not more than 28.27 % but comparatively it has the highest moisture content among all the three plants. This is because of the rainy season which was witnessed by plant 3 during the time period of study.

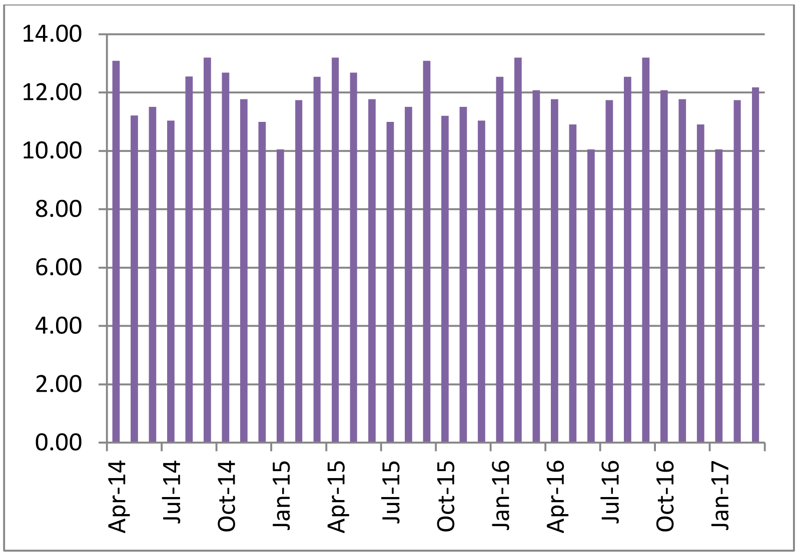

Fig 6.4: Ash content of Plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.4 shows the monthly average ash content of coal used in plant1. The variation in total ash content for the plant was observed month wise from April 2014 to March 2017. The highest ash content is observed in the month of Sept 2014, Apr 2015 & Feb 2016 & Sept 2017 is 13.19 %. Plant 1 is designed on imported coal and imported coal contains less ash content. Thus, the coal. Due to the imported coal and also it is noticed that plant1 is designed on imported coal which content less ash content % than the other two plants. Lowest ash content found about 10.05% in 2014, 2015 & 2017 in month of January 2015, June 2016, and January 2017 respectively.

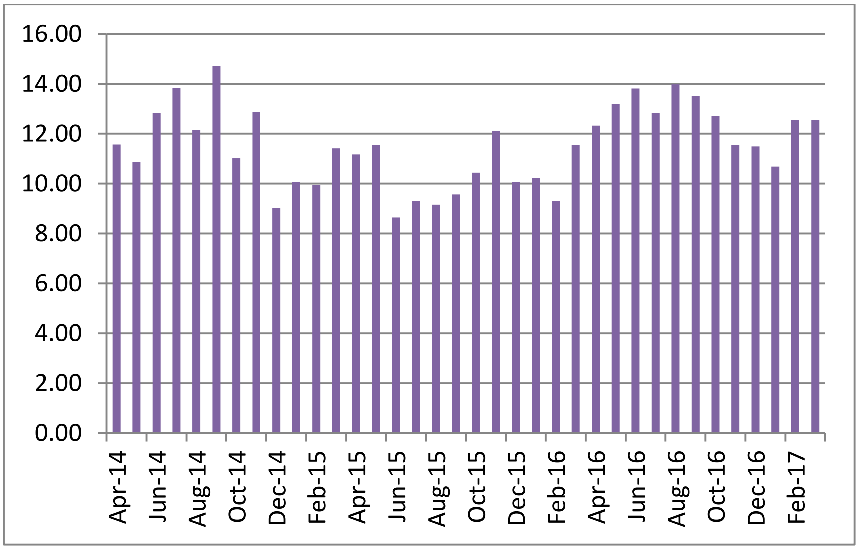

Fig 6.5: Ash Content of plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.5 shows the monthly average ash content of coal used in plant2. The variation in total ash content for the plant was observed month wise from April 2014 to March 2017. The highest ash content is observed in the month of September 2014 i.e., 14.71%. Lowest ash content found about 8.64 % in June 2015. Indian coal is blended with the imported coal in this plant. This plant is designed in a manner that it can use the coal with high ash content coal than that of plant1 or plant3.

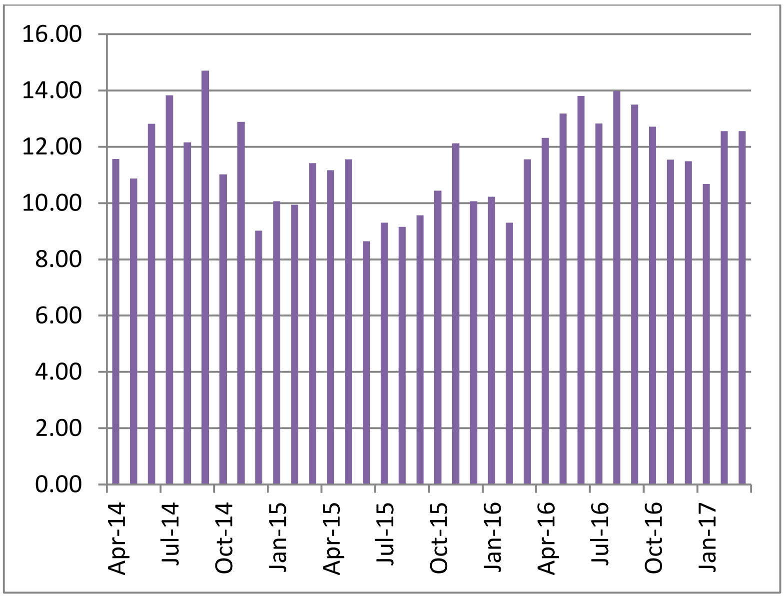

Fig 6.6: Ash content of Plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.6 shows the monthly average ash content of coal used in plant3. The variation in total ash content for the plant was observed month wise from April 2014 to March 2017. The highest ash content is observed in the month of September 2014 due to blending of imported coal with the Indian coal. The plant is designed for the coal with the ash content less than 8.64% and not more than 15%. The lowest ash content was observed in June 2015 & Dec 2014. Less ash content is beneficial for plant due to environmental issues and with the India's adamant participation in COP's has resulted in tighter norms for power plant producers.

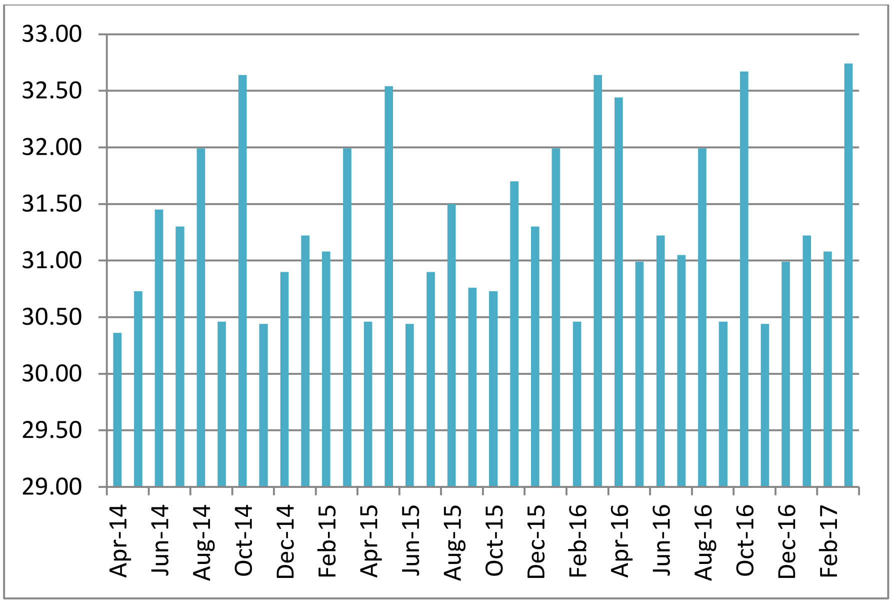

Fig 6.7: Volatile Material of Plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.7 shows the monthly average volatility matter of coal used in plant1. The variation in total volatility matter of the coal for the plant was observed month wise from April 2014 to March 2017. The highest VM is 32.74 % observed in the month of March 2017 & lowest in 30.36% in Apr 2014. Plant1 is designed on the imported coal model. Imported coal has high percentage of volatility matter in it. As a consequent, mill purging is essential for this plant or else fire accidents will be high in the plant due to high VM.

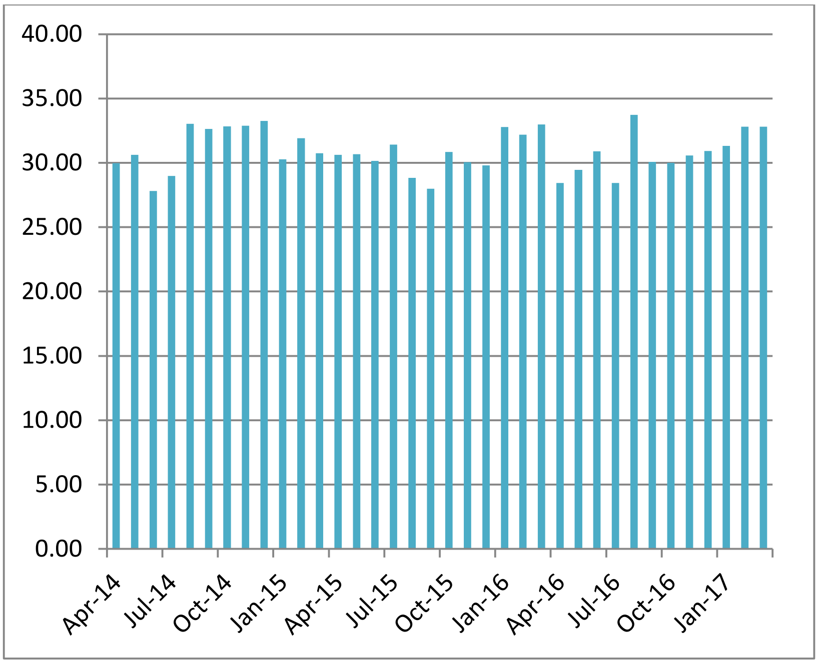

Fig 6.8: Volatility Matter of Plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.8 shows the monthly average volatility matter of coal used in plant2. The variation in volatility matter of coal for the plant2 was observed month wise from April 2014 to March 2017. The highest VM is 33.72 % observed in the month of Aug 2016 & lowest in 27.81% in June 2014 as the plant uses blended coal (imported +domestic coal). The plant is designed on imported mixed coal. But if VM content increases beyond a point there are chances of mill fire**.**

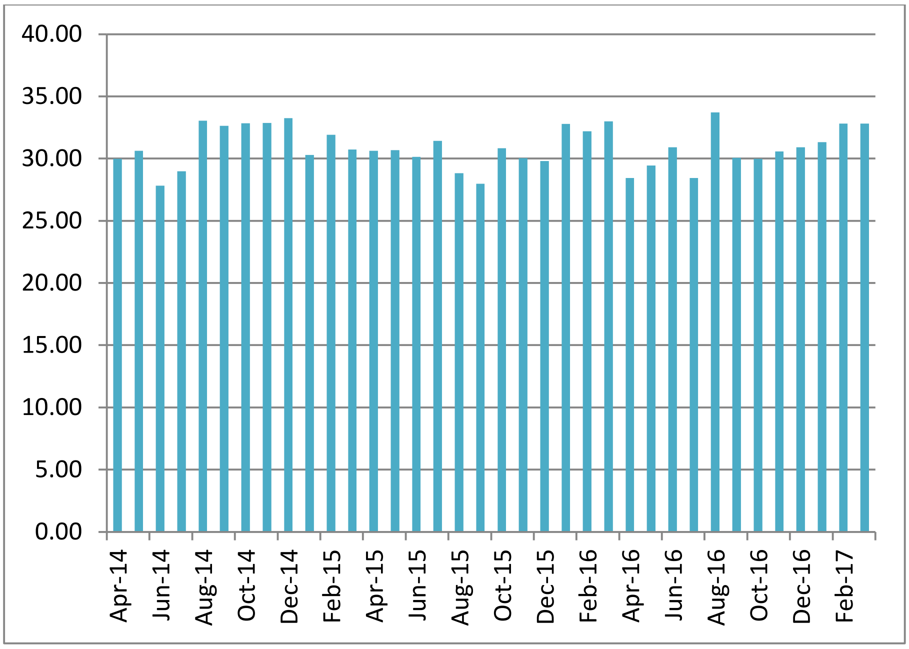

Fig 6.9: Volatility matter of plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.9 shows the monthly average volatility matter of coal used in plant3. The variation in total volatility matter of coal for the plant3 was observed month wise from April 2014 to March 2017. The highest VM is 33.72 % &33.25% observed in the month of Aug 2016 & Dec 2014 & lowest in 27.81% in June 2014.

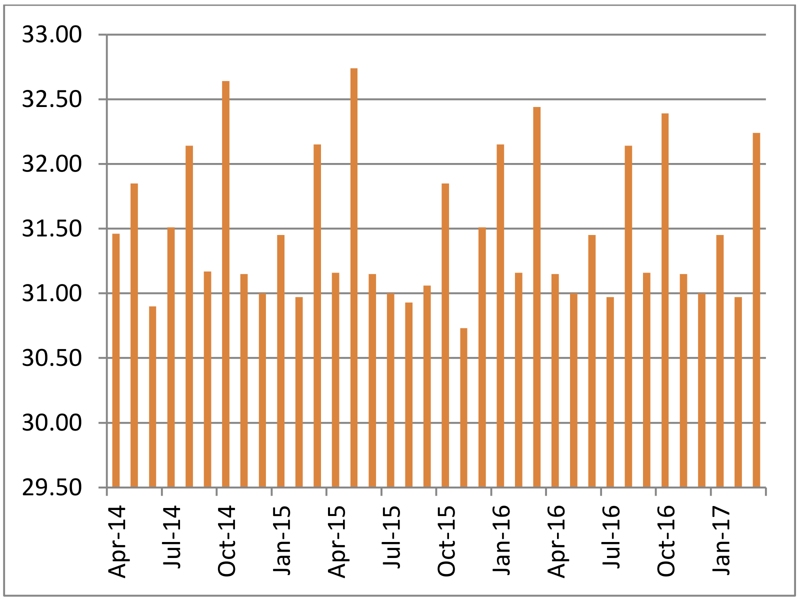

Fig 6.10: Fixed Carbon of plant1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig6.10 shows the monthly average of plant 1 total FC content in coal. The variation in total FC was observed month wise from April 2014 to March 2017. The highest FC is 32.74 % observed in the month of March 2017 & lowest FC in 30.37% in Apr 2014. In SOP mill purging is essential due to FC % high in imported coal that is used in plant1.

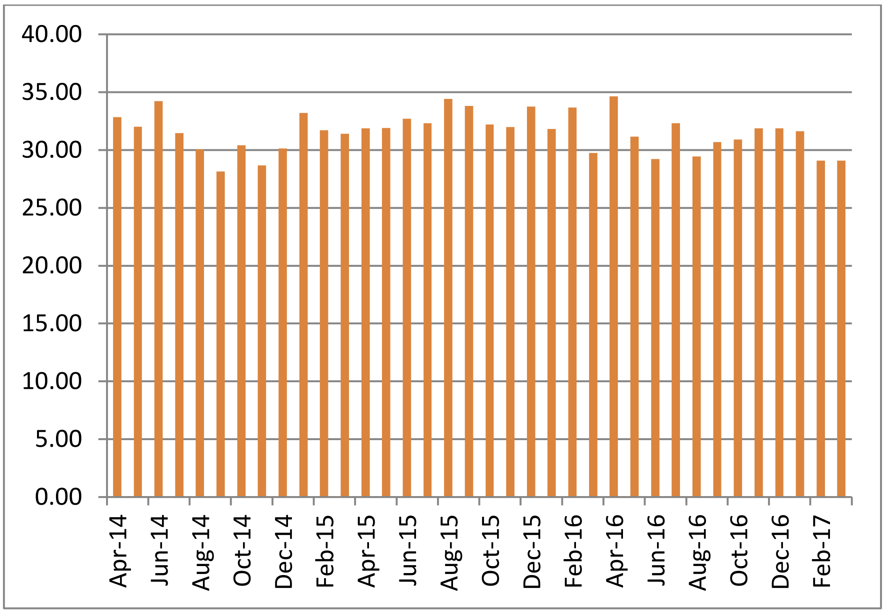

Fig 6.11: Fixed Carbon of plant2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig6.11 shows the monthly average of plant 2 total FC content in coal. The variation in total FC was observed month wise from April 2014 to March 2017. The highest FC is 34.63 % observed in the month of Apr 2017 & lowest FC in 28.14% in Sept 2014.

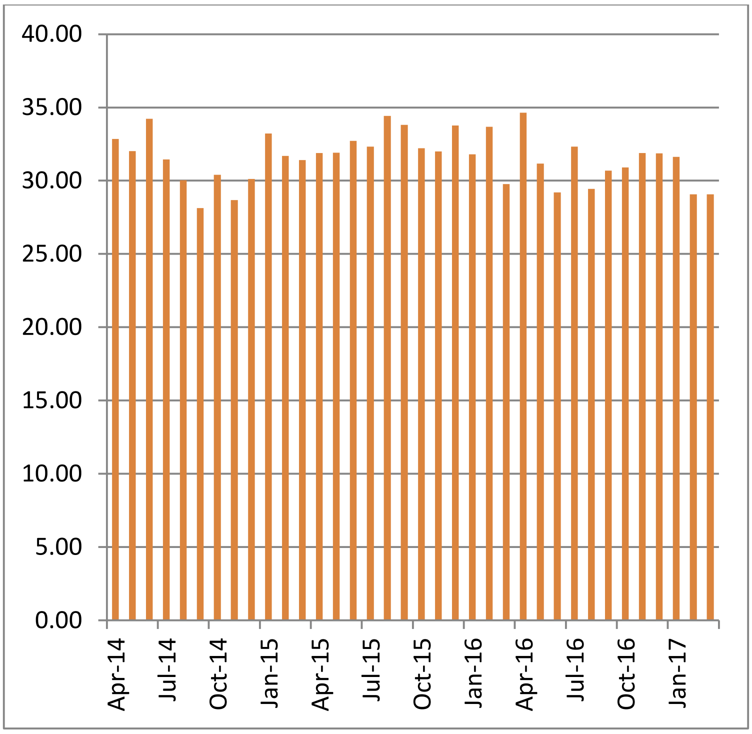

Fig 6.12: Fixed Carbon of Plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig6.12 shows the monthly average of plant 3 total FC content in coal. The variation in total FC was observed month wise from April 2014 to March 2017. The highest FC is 34.63 % observed in the month of March 2017 & lowest FC in 28.14% in Sept 2014. FC increases the flammability of coal during generation in the plant. FC is high in carbon content and ignition property.

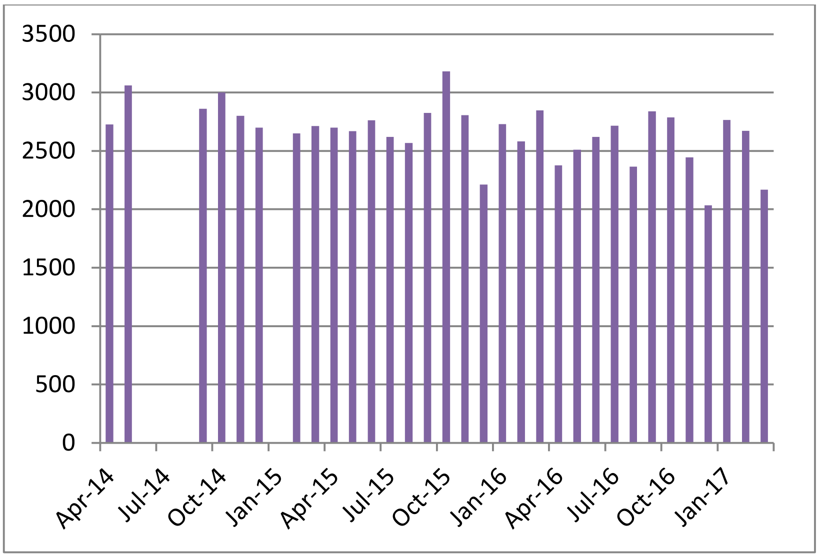

Fig 6.13: Power Generation of Plant 1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.13 shows the monthly average of plant 1's generation in million units. The variation in total generation was observed month wise from April 2014 to March 2017. From May 2014 to September 2014 plant1 was not functional due to unavailability of coal. Generation peak for the period was observed in Oct 2015 i.e. 3180 MU. Plant was also shutdown in Jan 2015. Minimum generation in 2014 to 2017 is 2034 MU.

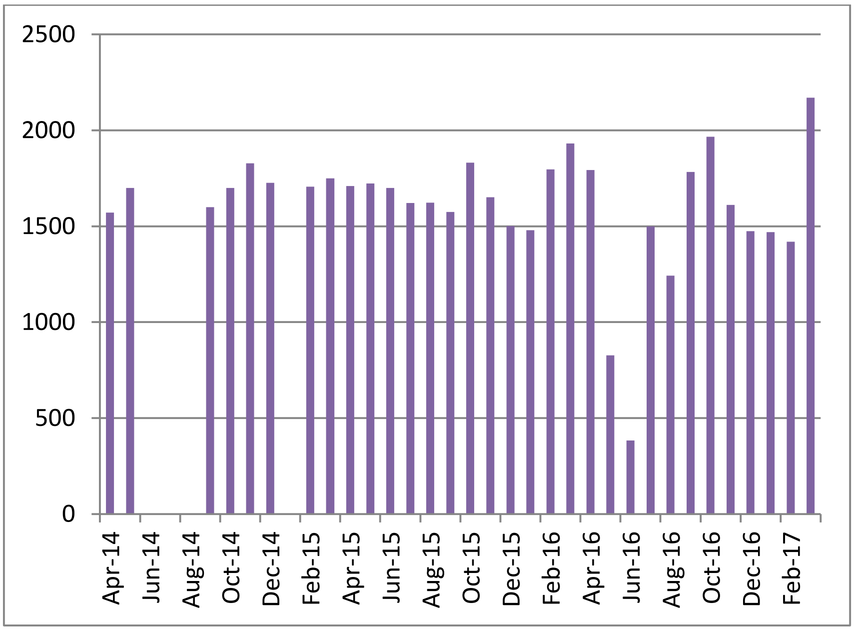

Fig 6.14: Power generation of Plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

The Fig-6.14 shows the monthly average of plant 2's generation in million units. The variation in total generation was observed month wise from April 2014 to March 2017. In Oct 2015, peak generation was observed i.e. 2170 MU. From, June 2014 to Aug 2014 and also in January 2015, generation data is not available as the plant was shut down for the period. Minimum generation in 2014 to 2017 is 383 MU.

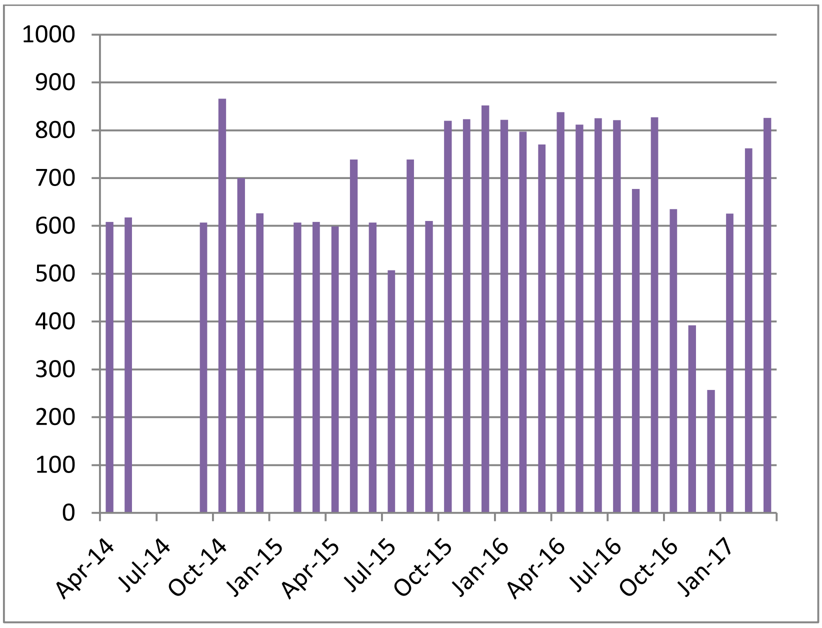

Fig 6.15: Power Generation of plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig-6.14 shows the monthly average of plant 3's generation in million units. The variation in total generation was observed month wise from April 2014 to March 2017. In Oct 2015, peak generation was observed i.e. 866.02 MU. From, June 2014 to Aug 2014 and also in January 2015, generation data is not available as the plant was shut down for the period. Minimum generation in 2014 to 2017 was observed in December 2017 i.e. 257 MU.

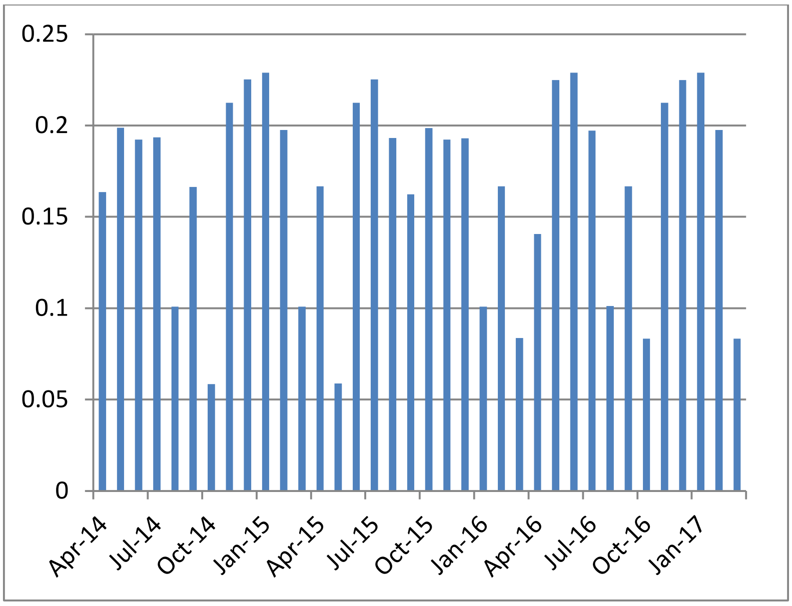

Fig 6.16: CQI of Plant1

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig-6.16 shows the monthly average of coal quality index for the plant1. The variation in CQI was observed month wise from April 2014 to March 2017.

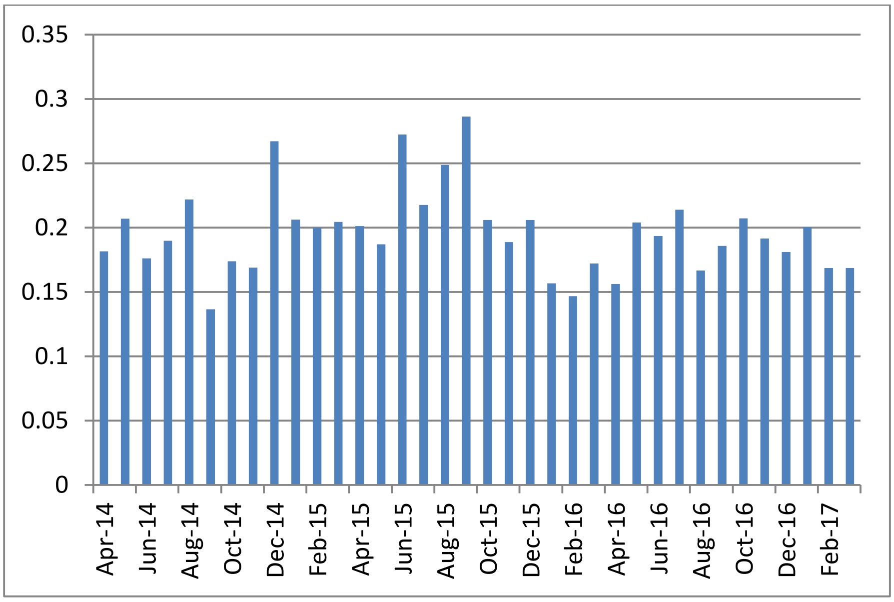

Fig 6.17: CQI of plant 2

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig-6.17 shows the monthly average of coal quality index for the plant1. The variation in CQI was observed month wise from April 2014 to March 2017. The index value of plant 2 & plant 3 similar that shows that the same type of coal is used in both the plants while plant 1 index shows different value.

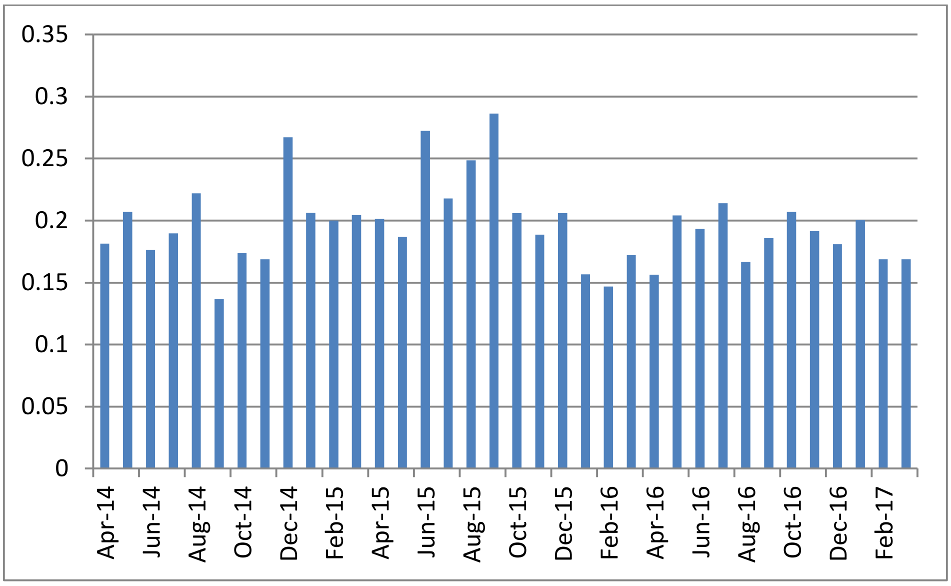

Fig 6.18: CQI of plant 3

Source: Primary data collected and compiled by authors from the Log Book of respective CHPs

Fig-6.18 shows the monthly average of coal quality index for the plant3. The variation in CQI was observed month wise from April 2014 to March 2017. The index value of plant 2 & plant 3 similar that shows that the same type of coal is used in both the plants while plant 1 index shows different value. The highest value observed during the time period is 0.286363239 while CQI is 0.136611094.

6.4 RESULT AND DISCUSSION

Unit Root Test

The panel data involves cross-sectional and time series data both. It is necessary to ensure that the time-series is stationary in order to generalize the relationship between the dependent and independent variables over the period of time (Nielsen, 2005). For our analysis, we conducted Augmented Dicky fuller test and Phillip-perron unit root test. The results are given below in the table 6.3 and table 6.4:

Table 6.3 Result of Unit test without drift

	Augmented Dicky Fuller				*Phillip-Perron*			
Variable name	*Inverse chi-squared(6)*	*Inverse normal*	*Inverse logit t(19)*	*Modified inverse chi-square*	*Inverse chi-squared(6)*	*Inverse normal*	*Inverse logit t(19)*	*Modified inverse chi-square*
	P	*z*	*L**	*Pm*	*P*	*z*	*L**	*Pm*
SCC	*35.6097*	*-4.8067*	*-5.8277*	*8.5476*	*35.6097*	*-4.8067*	*-5.8277*	*8.5476*
GCV	*60.3669*	*-6.6032*	*-9.8835*	*15.6944*	*60.3669*	*-6.6032*	*-9.8835*	*15.6944*
CQI	*29.8557*	*-3.1001*	*-4.6189*	*6.8865*	*29.8557*	*-3.1001*	*-4.6189*	*6.88l65*
GEN	*35.9423*	*-3.0843*	*-5.4116*	*8.6436*	*35.9423*	*-3.0843*	*-5.4116*	*8.6436*

Source: Table developed by author based on the logbook data from Super Critical Units

Table 6.4 Result of Unit Test with drift

All the variables are significant at 1% level,

Source: Table developed by author based on the logbook data from Super Critical Units

It can be inferred from table 6.3 and table 6.4 all the variables used in the model are

	Augmented Dicky Fuller			
Variable name	**Inverse chi-squared(6)**	**Inverse normal**	**Inverse logit t(19)**	**Modified inverse chi-square**
	P	z	L*	Pm
SCC	45.9853	-5.7228	-7.5304	11.5428
CQI	36.4482	-4.5461	-5.9449	8.7896
GCV kcal kg	59.9538	-6.7121	-9.8182	15.5751
GEN	35.3430	-4.2839	-5.7356	8.4706

free from the unit root problem as the variables are significant as per both the tests. Therefore, our data set is stationary

Table 6.5: Result of SCC Estimation Using OLS Regression

SCC	***OLS-1***	***OLS-2***	***OLS-3***
GCV	0.0152411 (0.1217567)	.0192507 (.0699106)	-.1292978** (.0979321)
GEN	*0.0226731**** *(0.006694)*	.0081302** (.0060863)	.0002306* (.00739)
CQI	*307.6512*** *(188.7216)*	156.8664** (101.835)	-21.1075* (168.7687)
D 2		92.48832*** (11.08437)	70.77144** (51.31463)
D3		99.07061*** (14.20249)	107.4897*** (53.17131)
D2 GCV		-	.4444253** (.2357577)
D2 GEN		-	.0057561 (.0139099)
D2 CQI		-	98.66501 (262.2275)
D3CQI		-	164.7055 (263.2395)
D3GEN		-	.0586398* (.0266736)
D3GCV		-	.4018676* (.2236371)
_cons	*-58.07526*** *(35.52282)*	-93.19899*** (19.86585)	-53.67047* (31.84035)
Number of obs	*72*		*108*
F(11, 96)	*6.33*		*13.24*
F(5, 102)		*25.30*	
Prob > F	*0.008*		*0.0000*
R-squared	*0.2182*	0.5536	*0.6026*

Adj R-squared	*0.1837*	0.5317	*0.5571*
ROOT MSE	*52.514*	39.241	*38.161*

*1) ***indicate sig. at 1% leve*

Source: Table developed by author based on the logbook data from Super Critical Units

*l, ** indicate sig. at 5% level and * indicate sig. at 10% level. 2) In parenthesis standard errors are given*

In table 6.5, column OLS 1, GEN and CQI is highly significant as the p-value of the variables is extremely small. GCV or the gross calorific value is statistically insignificant as its p value is large. Thus, in model OLS-1 GCV is not impacting the SCC s. As per the results received, the independent variables generation and coal quality index are effecting SCC positively. The results received for GCV differ from the existing literature. Whereas the literature suggests, CQI and SCC has a negative relation i.e. more the CQI less the coal required to produce the same unit of energy. Also, CQI index defines the coal quality on the basis of its properties. The more the index the better should be the coal quality and less should be the SCC. The limitation of our study is that the results estimated for CQI biased as per CQI.

Generation has a positive effect on the SCC that signifies more the generation more coal is required to increase the generation. It can be inferred that with 1 unit change in the GEN increase the SCC by 0.022 unit. To solve for the limitations of OLS-1, OLS-2 was considered but the results received were similar to that of OLS-1. The limitation of the model OLS 1 was not resolved by OLS -2 model but the model OLS-2 help us understand the dependent variable in the absence of significant independent variables. It can be inferred from the table 5.4 that the intercept value for the Plant 1is -93.1989. The average intercept value of each plant depicts what the SCC of each plant is in the absence of all the GCV, GEN and CQI. On an average the intercept value of plant 2 is 92.48832 more than that of plant 1. While that of plant 3 is 99.076 more than the plant 1. The differences in the intercept is observed because in plant 1 the fully imported coal is used to generate the power whereas plant 2 and plant 3 uses blended coal. The imported coal is better in quality than the Indian coal. The same unit of power can be produced using less imported coal because of high carbon content in the imported coal. Therefore, the SCC of plant 2 and plant 3 is more than that of plant 1.

In table 6.5, column OLS 3 regression, the differential plant dummies are interacted with the independent variable: GEN, GCV and CQI. The differential intercept and all the differential slope coefficients are statistically significant; we can conclude that the Auxiliary power consumption function is different for all the five plants. Here, GEN*D2, GEN*D3, CQI*D2, CQI*D3, GCV*D2, GCV*D3 are differential slope coefficient. OLS 3 solves the limitation of OLS 1 and OLS 2.

The independent variables are highly significant as the p- value of all the variables GEN, GCV, CQI is extremely small. GCV has a negative effect on SCC i.e. with 1 unit increase in the GCV of the coal the SCC decreases by 0.129 units. This signifies that better the gross calorific value of the coal, less will be the coal required to generate same amount of power. GEN has a positive impact on the SCC i.e. with 1 unit increase in generation keeping other things constant the SCC increases by 0.0002306 units. Since, the stringent government intervention to optimally utilize the existing resources and increase the efficiency of the existing resources is absent, therefore, with a unit increase in generation the specific coal consumption also increases. CQI has a negative relation with SCC. This is because more the CQI better will be the coal quality and less will be the consumption. It can further be inferred with 1unit increase in CQI the SCC decreases by 21.1 units.

It can further be inferred that average intercept value of the plant 2 and plant 3 is 70.77144 and 107.4897 (respectively) more than the plant1's intercept. The difference in the intercept term is attributed to the coal quality used in these plants. Plant 1 uses imported coal which is better in quality and more efficient than the blended coal that is used in plant 2 and plant 3.

Further, it is seen that on an average with 1 unit change in the GCV of plant2, the change observed in SCC is 70.77144 more than that of plant1's SCC. Similarly, on an average with 1 unit change in the GCV of plant3, the SCC of plant2 on an average increase by .4018 units than that of plant1's SCC. The differences is observed because during the time period taken for the study better quality coal was imported for plant 2 and 3. With GCV, SCC is increasing for these plants as generation was more for both these plants owing to better tariff rates and better revenue generation from plant2 and plant3.

It can be inferred that on an average with 1 unit change in the GEN of plant2, the change observed in SCC of plant2 in comparison to that of plant1 is not significant. Whereas, on an average with 1 unit change in the GCV of plant3, the SCC of plant3 on an average increase by .4018 units than that of plant1's SCC. The differences are observed in the generation of plant1 and plant3 is because the PLF of plant3 during the time period was more than that of the plant1.

The interaction dummies for CQI are not significant for plant2 and plant3. We can conclude that CQI of all the 3 plants is similar to each other for the time period taken in the study.

Table 6.6: Result of SCC Estimation Using OLS Regression

*1) ***indicate sig. at 1% level, ** indicate sig. at 5% level and * indicate sig. at 10% level.*
2) In parenthesis standard errors are given

As per the literature, CQI and SCC has a negative relation i.e. more the CQI less the coal

SCC	*OLS-1*	*OLS-2*
GCV	*0.0152411 (0.1217567)*	-
GEN	*-0.0226731*** (0.006694)*	-
GEN-GCV		*-180.1551*** (24.9271)*
CQI	*307.6512** (188.7216)*	*231.1812** (110.0818)*
-cons	*58.07526** (35.52282)*	*27.48513** (25.10894)*
Number of obs	*72*	*96*
F(2, 93)		*34.37*
F(3, 68)	*6.33*	-
Prob > F	*0.008*	*0.0000*
R-squared	*0.2182*	*0.4250*

required to produce the same unit of energy. Also, CQI index defines the coal quality on

Adj R-squared	*0.1837*	*0.4126*
Root MSE	*52.514*	*45.423*

the basis of its properties. The more the index the better should be the coal quality and less should be the SCC. However, in table 6.6, column OLS 1, and significant independent variables i.e. generation and coal quality index are affecting SCC positively which is different from that of business as usual model. This is the limitation of our study is that the results estimated for CQI and GEN is biased as per OLS-1. To overcome the limitation we have introduced OLS-2 in table 5.6 that solves our limitation of OLS-1. It can be inferred the independent variable GEN_GCV is significantly impacting SCC i.e. with 1 unit increase in the generation per unit of gross calorific value of the coal the SCC will decrease by 180.1551 units. It is seen that if we put our resources to optimum utilization and use them efficiently we can optimize the SCC.

6.5 Concluding Remarks:

Findings:--

It can be concluded that specific coal consumption depends upon the coal quality index, generation and the generation per gross calorific value. When ash content is less, then SCC will be less. Also, when GCV will be high then SCC will come less. When the GCV is same for each plant then there will be small variations in the SCC. The variations depend upon the variation of constituents of coal like, percentage of VM, TM, FC, ash content. It can be optimized by improving the coal quality index.

Recommendations and Suggestions:--

The following measures can be taken in order to ensure better CQI:

- Moisture content of the coal should be minimized (Y.J.LIAO, 2015). It can be minimized by using tarpaulin. Coal in the yard should be cover by the tarpaulin. For the rainy season there should be proper arrangements for the coal shed which will prevent the moisture content to increase in the coal.
- Volatile material enhances the fire in mill that causes huge loses. In order to avoid such loses purging should be done regularly even when the mill is not functional.
- Fixed carbon affect the SCC and when in coal yard the spontaneous combustion I stakes place the coal quality is detoriated and GCV i.e. the gross calorific value of the coal reduces significantly. As a consequence, the SCC is increased. In order

to avoid this situation, the regular compaction, churning action by dozer and pock lain to be done in yards for the coal heaps.

- In order to avoid spontaneous combustion water should be spread near the coal storage during the morning and evening time. The temperature of the coal storage should regularly be checked through infrared thermometers in order to avoid accidents be spontaneous combustion.
- The equipment where the fly coal is spread during the coal handling should be timely wash. If the equipment are not timely washed due to volatility material, the conveyor gallery will catch fire. As a consequence, SCC will increase and will impact the generation and the revenue of the company.
- Heat rate in each month to be calculated and according to that SCC is designed and ash content to be monitored properly. Timely and proper monitoring of the heat rate will help us plan the consumption in a better manner.
- The government intervention is necessary in order to maximize generation and optimize the coal consumption.

As per CERC Recommendations –

CHP in a coal based thermal power unit covers coal unloading, storage crushing bunker filling etc. activities. Design of CHP depends on coal source station capacity and coal transportation mode. Topography and area geometry of CHP-System.

Capacity of station is depend on CHP capacity how much coal can handled by CHP. The unit size of 500 MW and above 600&660MW supercritical units one coal handling plant is provided to cater for two units running ,if plant size is more than 660MW and more than two units then extra CHP is required.

Regarding quality of coal & coal source super critical units may vary, for example imported coal indigenous run of mines coal indigenous washed coal

Quality of coal (HGI- High Grindability Index, GCV-Gross Calorific Value MC-Moisture Content). For blending of imported and indigenous coal in layers on belt while feeding coal to bunkers these coal layers got mixed while falling into the bunkers and in 2nd method coals are blend in yards and 3rd method for blending is through the mills operation depend upon coal quality and coal type. Different transportation means such as merry go round -MGR conveyor belting, by ships through ports and coal rakes by Indian railway networks.

Ship type of transportation system is preferred if coal mine or port is nearest to the power plant. The coal received plant may be unloaded by help of track hopper or truck tipplers or by wagon or combination of all depending on the type of wagons (BOBR or Box-N wagons) in the coal rakes /trucks received at the power station.

CHAPTER 7

Chapter 7

Summary and Conclusion

The study analyse the need to mitigate under-utilization of equipment's at Coal Handling Plants of Super-Critical Thermal Units as it is critical to the company's revenue. The study analysed three major areas in the CHP that need to be optimally utilized, that includes auxiliary power consumption, high speed diesel consumption and specific coal consumption. The following conclusions can be drawn from the above study:

A. APC & BUF are two major components that effects the smooth functioning of coal handling plant. The optimization of the above two components can helps us minimize the financial losses to the business at the micro level. Whereas, at macro level it help us optimally utilize our existing resources and capacity. The study reveals that no organization at present has on an average achieved more than 67% BUF. The optimization of BUF can result in reduction in APC which can further increase our revenue and save our existing resources. The BUF can be optimized of we take some measures regularly. Some of them are discussed below:

i) The belt utilization factor can be optimized by increasing the belt loading points. The increase in the number of belt loading points will ensure more loading on the conveyor belt that further improves the BUF which will further improve the APC.

As we know the conveyor must work on its designed capacity 100% but when if loading points is less i.e. on one place then when truck tippler/ wagan tipplers are unloading the coals at one points then the coal flow will not be continue on belt in designed capacity and the amount of coal required to go on belt will not fulfil the 100% requirement and capacity of belt may not be fully utilized. This is why, if loading points will be more than one then only simultaneously coal flow will be continuous from two or more points and rated capacity may be optimized and the belt loading capacity may be obtained and BUF may be increased and APC will be decreased due to capacity enhancement & running hours of belts will decreased which may resulted in APC reduction.

ii) The studies have observed that coal unloading time and timely availability of equipment for coal loading has a major impact on the BUF. Thus, by decreasing the unloading time of coal on the conveyor belt, can increase the BUF. The various measures can be taken to ensure reduction of unloading time. The coal should be stored near to the conveyor belt. The minimum distance between the two ensures that the conveyor belt is not empty for a longer duration at any given point of time. This will further cut down running of empty conveyor belt. Thus, reducing the APC and utilizing the belt capacity more optimally.

iii) BUF can further be optimized by ensuring reliable and proactive maintenance of equipment like, conveyor gearbox and motors with zero breakdown. The timely maintenance of the conveyor gearbox increase the belt availability that in turns increases belt utility capacity factor. The maintenance of pock lain, Dozers and bob-rain rake to be made on a regular basis so that coal can be pushed easily and timely on the hoppers and further on the conveyor belts. Big boulders also delays the unloading process of coal on the conveyor belt. The big boulders clogs the grizzly. They are evacuated from grizzly, crushed and then unloaded on the belt. By avoiding big boulders on grizzly, we will be able to reduce the coal handling time and speed up the unloading of coal on the belt. Thus, better BUF can be achieved by decreasing the unloading time. The coal plant with trucks should minimize the turnaround time (TAT) of rake and hydraulic trucks to be minimized to maximize BUF for better capacity utilization. Reduction in TAT increases the coal on the belt that cut downs the empty running of the conveyor belt. (Somanath Ojha, 2016)

Generally it has been seen by us that when we operate the unit we did not found the predefined and designed coal regularly generally in running plant 0-100mm size is acceptable in track hopper 20to 30% size coal boulders of size 100-200mm is also incorporated and sometimes >300 mm size coal is comes into the hoppers because we are using coal raw coal of mines and sometimes there is no control of size ad more than >300&400mm size to up to 800mm size coal we received from trucks due to surface minors etc issue in mines end. This stone and coal boulders creates problem to us and clogged the track hoppers grizzly and not allowed to pass coal from the grizzly to hoppers and to the belt . its consequences is less amount of coal is delivered to belt and belt running hours increased and APC is increasing due to continuous belt is running to pass the coal into the hoppers to go to the belt. APC in increased and BUF decreasing due to not capacity of belt fully utilized so size of coal 0-200 mm must be received in plant.

iv) Further, use of LED lighting should be promoted in the coal yard. High Mast lights should be substituted by LED lighting to save power consumption as LED light consumes less power than the normal bulbs that improves our APC. In order to optimise APF we also need more stringent policy interventions by government.

As we know that Supercritical thermal plants came into existence from 6-10 years earlier and first super critical unit 660 MW is started in India at Mundra location and previously conventional lighting work has been done in each plant and we know that when we use one no 100 watt bulb for lighting and it consuming 2400 watts in a day =2.4 kwh in 24 hrs in lighting while for the same illumination level of lux if we use LED bulbs of 10 watt for 24 hrs then it consumed only 240 wats in 24 hrs . It is clearly reflecting the 10times saving of auxiliary power consumption pattern if we replace it. You may understand that if we take only one bulb example then we can save 24x100=2400wats and if we are using LED the only 240 Watts electricity is consumed in 24 hrs so from one bulb replacement you can save 2160 watt the electricity cost by consuming same time for same illumination by new technological advancement . it recommendation for the energy consumption saving point of view and CHP lighting APC reduction may be done. Government is also focusing on it to save energy. In CHP there are 5 high mast and one high mast consumed 17 KW /Hour so you can imagine how APC may be optimized.

Thus, by adopting the above measures we can optimize our BUF that will help us to improve revenue

B. The HSD oil consumption may be optimized by proactive management of HEMM. The optimization of HSD consumption will save the business revenue losses per annum. HSD consumption can be optimized by increasing the efficiency of HEMM equipment. Also, it was observed no stringent government regulation exists on the optimization of HSD consumption. The policy intervention by government like, incentives to the producers who would reduce HSD consumption or will reduce the idle running time. It can also be optimized by considering the following steps: by reduce the Specific oil consumption by managing the dozers running time in coal yard through HEMM effective utilization, by preventing the energy losses of equipment by minimizing the idle running hours and stop dozers pushing in hoppers, as this consumes more oil. Further, the below given points can be considered:

i)

Regular maintenance of HEMM Engine by regular servicing would reduce the HSD consumption, as the older engines that are not timely serviced consumes more oil. Routinely maintenance of equipment enhanced the life of engine and sealing of engine. Break down of equipment should be timely done. When the engine is not in good condition the equipment should be breakdown. The government can intervene by laying down strict policy stating when a HEMM should be break down on the basis of the engine health and life of the equipment. This would also not only help in optimizing HSD consumption but will also help government realize its objective of reducing carbon dioxide and environmental impacts.

As you know in normal human tendency when anybody goes for the vehicle purchasing generally he thinks about its ECG—Engine Clutch and Gears why because these are the heart of the vehicle so our concerns in HEMM is same if Heavy earth movers machineries regular maintenance will not been done continuously its parts will be damaged and the consumptions of fuel will be more and average will be reduced so regular CBM, PM and BDM is carried out. Government has strict ruling on environment pollution impact to minimize CO2 so regular maintenance to be carried out to up keep the health of HEMM maintenance. Therefore regular serving and spares managements on running hour’s basis to be managed by the contractors and plants who kept the HEMM in possession.

ii)

Best practices to upkeep HEMM parts should be adopted. One of them is to conduct condition based monitoring of equipment on a regular basis. Good quality spares increases the life of equipment.

It has been observed that local spares parts are utilized and for some times equipment’s become normal but its life is found less & damaged asap due to inadequate quality of spares purchased and used in HEMM by the contractor/agency involved in maintenance . its consequences is that in few hours running or operations it parts got damaged . It is only done for economizing or optimizing the cost but due to this repetitive breakdown the equipment’s down time got increased so do not compromised for genuine spares parts. It may be costly but life of equipment is better in long run and reliability got increased.

iii) Skilled driver may save fuel. The idle running time can be reduced if we have skilled driver. Also, training and education of drivers may help for safe driving of equipment and may be economical.

Here I am not telling about the manpower head count I am just appraising for the Quality of drivers operational smartness of skill for fuel saving . For Example when we go in traffic it has been seen that when we stop for traffic signal more than one minutes we stop our two or Four wheeler engine to save fuel but in power plant it has been seen practically that generally operators start dozers or HEMM equipments are kept start when it is not in use , its affects the fuel /HSD consumption more and you know that a dozer which consume oil 35-38 liters per hour so to save the HSD fuel we have to check and monitor it regularly.

iv) Empty running of equipment &spontaneous combustion should be prevented by taking regular measures.

It has been found practically in power plant that coal is kept in such a way that it spread in long distance and dozers are moving around it and approaching it from long distance and due to long distance of coal stacked the dozers running hours are increased and HSD consumption is increased . It is also seen if coal is kept more than one month duration at one place then it catch fire and if there is volatile material in coal quality index is more in the coal then it caught fire within a week by self-ignition property so thermography of heaps of stacked coal quantity is taken regularly and its weekly monitoring at adequate interval so that we can know it in the better way that if there is any chances of spontaneous combustion in heaps so we can control it , the spontaneous combustion and using of dozers and HEMM use reduced and HSD consumption may be reduced.

v) The coal size should be keep in check. The bigger the coal size more is the HSD consumption as it doubles the work. If the coal procured is of desired size it does saves the HSD. Also, use of HEMM equipment may be optimized by managing the coal loading and unloading in a planned way.

As in objective 1 we have seen that if coal size is not adequate then we will suffer in APC reduction and similar way due to big size boulders we have to use more than two three pock lain and fir stuck boulders are to be removed from the grizzly then spread it on hard surface and dozers about 10 times crush the big boulders then only it can pass through the grizzly after becoming lower sized -100mm. therefore the HSD consumption is also depend on size of coal received from Rom coal raw coal of mines.

vi) Oil filling through drum by pump to be avoided and to be filled on petrol pump.

It is also seen in power plants due to availability of HEMM equipments dozers are deployed while pock lain is idle and it may do better in confined space as well as open spaces. Dozer is consuming 38 liters while pock lain consuming 15 liters so where we can do better by pock lain but we use dozer so HSD consumption becomes more to taken care to save HSD. In HEMM oil fill pumps are available in power plant but due to hurry people store in drum the HSD oil and fill through local pump and huge amount of oil is fallen down so it will belter if Petro pump is used in for filling HSD

vii) Sometimes unnecessary use of dozers while pock lain is sufficient at that place to be minimized and should only be substituted in emergency cases.

It is also seen in power plants due to availability of HEMM equipments dozers are deployed while pock lain is idle and it may do better in confined space as well as open spaces. Dozer is consuming 38 liters while pock lain consuming 15 liters so where we can do better by pock lain but we use dozer so HSD consumption becomes more to taken care to save HSD. In HEMM oil fill pumps are available in power plant but due to hurry people store in drum the HSD oil and fill through local pump and huge amount of oil is fallen down so it will belter if Petro pump is used in for filling HSD.

C. It can be concluded that specific coal consumption depends upon the coal quality index, generation and the generation per gross calorific value. When ash content is less, then SCC will be less. Also, when GCV will be high then SCC will come less. When the GCV is same for each plant then there will be small variations in the SCC. The variation depend upon the variation of constituents of coal like, percentage of VM, TM, FC, ash content. It can be optimized by improving the coal quality index.

The following measures can be taken in order to ensure better CQI:

i) Moisture content of the coal should be minimized (Y.J.LIAO, 2015). It can be minimized by using tarpaulin. Coal in the yard should be cover by the tarpaulin. For the rainy season there should be proper arrangements for the coal shed which will prevent the moisture content to increase in the coal.

Generally there is misconception to people who has not really worked in CHP that in the imported coal rain water is not penetrated but practically it have been observed that water is percolated inside the coal and during rainy season huge amount of coal becomes wet and chutes jamming in coal handling occurred frequently so generation is affected and LDO is taken into service due to furnace flame is become disturbed. Therefore, tarpaulin should be used to minimize the moisture content which will reduce the SCC consumption & further it may be studied. Now days for smooth operation of Coal handling plants for rainy season a big coal shed like stadium covered type shed is made to prevent moisture to be incorporated but it is costly affair so generally co are not involved in this matter. Financial burden due to CHP comes for smooth run of plant so it is recommended.

ii) Volatile material enhances the fire in mill that causes huge loses. In order to avoid such loses purging should be done regularly even when the mill is not functional.

It has been observed practically in three to four super critical unit mills that due to imported coals using in generation due to volatile materials issue Purging is very important phenomena otherwise mill will be pressurized and due to mill out let temperatures its blast may occurs in the equipment so Mill Purging is most important factor to save the machine and operators life at Super critical units.

Fixed carbon affect the SCC and when in coal yard the spontaneous combustion is takes place the coal quality is detoriated and GCV i.e. the gross calorific value of the coal reduces significantly. As a consequence, the SCC is increased. In order to avoid this situation, the regular compaction, churning action by dozer and pock lain to be done in yards for the coal heaps.

iii) Fixed carbon affect the SCC and when in coal yard the spontaneous combustion I stakes place the coal quality is detoriated and GCV i.e. the gross calorific value of the coal reduces significantly. As a consequence, the SCC is increased. In order to avoid this situation, the regular compaction, churning action by dozer and pock lain to be done in yards for the coal heaps.

For smooth functioning of Generation of Super Critical Units SCC is defined & linked with the GCV and if spontaneous combustion is occurred and coal quality is detoriated due to spontaneous combustion then the Quality coal index constituents FC - fixed carbon will affect the SCC so to avoid this situation, the regular compaction, churning action by dozer and pock lain to be done in yards.

iv) In order to avoid spontaneous combustion water should be spread near the coal storage during the morning and evening time. The temperature of the coal storage should regularly be checked through infrared thermometers in order to avoid accidents be spontaneous combustion.

As it is observed that some power pants storage/stacked coal got burnt out and coal has self-ignition property and for any fire three things required Heat, Oxygen, Fuel &chemical reaction which are self-content in coal the oxygen is taken from the atmosphere coal is fuel and self-heat and calorific value so there may be self-ignition property in coal so spontaneous combustion is takes place .therefore infrared camera are installed and thermography is recommended to measure the heaps temperatures.

v) The equipment where the fly coal is spread during the coal handling should be timely wash. If the equipment are not timely washed due to volatility material, the conveyor gallery will catch fire. As a consequence, SCC will increase and will impact the generation and the revenue of the company.

Generally imported coal fines is very high and more than mess size 200 is passed in mill is -200 microns so due to very fines in coal is spread in conveyor galleries during handling through transfer point to another transfer points so to prevent fire in cables washing of conveyor galleries is required and huge amount of coal is spread over the cable tray where current is flowing and when cable is heat and coal have self-ignition property so there is consequences of catching fire and SCC may be affected. and SCC may impact on generation and revenue of the company.

vi) Heat rate in each month to be calculated and according to that SCC is designed and ash content to be monitored properly. Timely and proper monitoring of the heat rate will help us plan the consumption in a better manner.

Heat rate is main parameter of any power plant and the revenue calculation is done due to heat rate which is designed earlier on coal quality index and coal GCV. The coal quantity consumed with coal quality index measurement plays significant role to measure the SCC nd heat rate. This is essential. it is done by operation efficiency department people. Therefore , Timely and proper monitoring of the heat rate will help us plan the consumption in a better manner

vii) The government intervention is necessary in order to maximize generation and optimize the coal consumption.

Government has emphasized to maximize the generation and minimize the SCC –specific coal consumption as per heat rate designed. It is only possible when good GCV coal is received from mines and PPA is signed with Govt. bodies.

Contribution to Literature:

Outcome of this unique research will help power plants and power plant policy makers to take the appropriate decision on energy regulatory policies and to adopt the suitable power plant structure and design of equipments in India and abroad. As of now supercritical power units in India are regulated by CERC and CEA on uniform basis.

1. The present research work will help in optimizing BUF while enhancing Auxiliary Power Consumption, High Speed Diesel and Specific Coal Consumption in any super critical or sub critical units of power plants in India.
2. SCC - Specific coal consumption mainly depend on the GCV & Total moisture. The result obtained for optimization of SCC contributes to the literature as it has not been previously analyzed. It would be further useful to conduct research for usage of coal w.r.t Gross Calorific Value and Coal Quality.
3. Results obtained from Optimization of High Speed Diesel in the present research work are applicable to address the issues w.r.t Heavy Earth Movers Machinery (power plant and other similar industries) in the industry.

Limitation of This Research:

The limitations of the study are mentioned below;

1. Data Limitation: Availability of the Operational Data for the study period (Jan 2014- Dec 2016): First round of super critical units started in India in 2010-11 at Mundra power plant. Full load operation of super critical unit started in 2013-14.
2. A few power plants were not operational for certain specific number of weeks during the study period. Had there been operating, may results would have been different. As these plants continue the operations for significant time period (7-10 years), perhaps would be good time to analyze/revisit the results again.
3. Limitation of availability of data restricted the application of econometric tools in the study.

Scope for Future Scope:

The present research work has further scope;

- **i.** The study can be extended further on the variables when data is available for adequate number of years.
- **ii.** The present study is limited to coal handling plant of the power plant which can be applicable to the power generation plant.
- **iii.** This study can be extended to other industries where similar operational factors are contributing to the business.

Annexure-1

CBM--Condition Measurement Techniques:			
Parameter	**Instrumentation**	**Positions**	**Description**
Vibrations	Vibration analyzers/data collectors, hand held overall meters	Transducer placed in path of vibration transmission i.e. bearing housings	Crushers & Pulley Bearings, Gearbox, Crusher Rotors
Vibrations	Detection meters, Shock pulse etc.	As close to source of vibrations.	Crushers & Pulley Bearings, Gearbox, Crusher Rotors
Temperature (Contact)	Thermocouples, RTD	Surface or internally mounted	Crushers & Pulley Bearings, Gearbox
Temperature (Non-Contact)	Infra-red cameras, Pyrometers, Laser Thermometer	Surface	Crushers & Pulley Bearings, Gearbox
Lubricants (Condition)	Analytical lab or Portable lab kit	Any lubrication sample	Gearbox, Fluid Couplings
Lubricants (Wear Debris)	Spectrographic analysis, On-line systems Ferro graphy	Wear Debris in lubricant used between wear surface via magnetic plugs	Gearbox, Fluid Couplings
Speed and current Relations	Taco generators with current transformer	Mounted on shafts	Fluid Couplings
Current	Load cell with Current Transformer	Below the conveyors and in panels	Electromagnetic vibrating feeders

Source: M. Joshi

Annexure 2

Table 4.5: Hausman fixed random model

Coefficients	buf
(b) fixed	0.0190748
(B) random	0.0128869
(b-B) Difference	0.006188
Sqrt (diag (V_b-V_B)) S.E.	0.0011086

Where b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(1) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 31.15

Prob>chi2 = 0.0000

To decide between the two effects: fixed or random we run Hausman test. The null hypothesis is that the preferred model is random effect model in comparison to the fixed effect model. Since, the prob>chi2 value is less than 0.05, we reject the null hypothesis and can conclude that the fixed effect is the preferred model. (Torres-Reyna, 2007)

Annexure 3

CERC Standard Design Criteria / Guidelines studies for BOP –CHP more than 500 MW Capacity and for Supercritical units 660 MW.

For BOP--Balance of Plant of) Thermal Power Plant/ Project (Central Electricity Authority):

Introduction:

The CHP in coal based supercritical units' covers the coal unloading, coal crushing and boilers bunkers feeding. The Design of CHP is according to site location specific and depends on following aspects.

- Station Capacity
- Mode of Transportation of Coal
- Coal Quality and Coal Source
- Geometry of area of CHP System and topography of area for CHP.

Station Capacity--How much quantity of coal to be handled in the station, is called station capacity as determined and according to that only. Coal unloading system, crushers, conveyors and other equipment's designed for super critical units. Generally one coal handling system is provided which may be suitable for two units of super critical units of 660mw.coal conveying system may cater to not less than 3 units to limits the outages of super critical units in the case of any failure in the CHP. All CHP must be interconnected to the separate CHP. If the plant consists non identical units in terms of size means 500mw. 600mw 660 MW , 800mw then separate CHP requirement should be there to cater the bunker filling due to non-uniform size of coal and bunkers levels .Similar system must be there and it should be equipped with coal loading, coal unloading , coal crushing and feeding to bunkers facilities.

Brief Description of Coal Handling Plant –CHP System: Coal transportation mode: --The coal received at power station may be unloaded by means of wagon tippler in track hopper or by Truck tipplers or by combination of all three depending on the type of coal rakes/trucks to be used for the transportation of coal to the station. Generally coal rake consists of 58-60 wagons, each wagon carrying pay load of 60 tons. Coal trucks are of weight 15 MT to 30 MT.

Unloading system through Track hopper

Track hopper system: Belt weigher scales are provided on the conveyor system in gallery for the measuring the coal flow rate to know the capacity utilization .and flow rate measurement. Paddle feeders are installed under track hoppers conveyors to scoop the coal and feeding onto reclaim hoppers inside underground. The coal is received through BOBR--Bottom Opening Bottom Release wagons. The Wagon rakes are unloaded in the underground RCC track hopper.

Unloading through Wagon Tippler : When the coal is received at plant from the box –n wagon, it is unloaded in the Reinforce Cement Concrete - RCC hoppers which are in underground by help of rota side type wagon tipplers tables .for placement of wagons side arm chargers are employed and removal of empty wagon from after tippling and it is going on .Apron feeders are provided under each wagon tipplers table for extracting the coal from the wagon tippling hopper and coal feeding onto underground coal reclaiming hoppers.

Coal Source & Coal Quality:--Due to shortage of Indian coal, there is need of facilities to blend the imported and indigenous coals to meet out the challenges. Sometimes coal blending is also done due to environmental issue to combat the coal dust. Blending can be done in several ways. First case--Coal imported may be spread over the ground of one layer of 300mm and then 2^{nd} layers of indigenous coal layers of 200mm then 3^{rd} layer of imported on 2^{nd} layer then 4^{th} layers of indigenous coal layer may be done in definite ration for proper mixing and by the help of dozer on the ground hard surface, its blending may be done. Another method of coal blending through the mills, in 2 mills indigenous and in 6 mills imported coals is kept alternate and its mixing done 70:30, 80:20 &90:10 according to designed and according to load condition and stability of furnace and ash content bearable to ash handling unit which is installed in existing system . It may be in use to dedicate one mill for firing the imported coal and then adjusts the mill parameters to achieve the maximum heat load of the burners.

Coal Crushing, Stacking And Reclaiming In Coal Stock Yard: -- According to the layout of the CHP , Coal is unloaded from the wagon tippler hoppers to track hopper and it is conveyed to crusher house through the conveyor belt via pent house or TP-transfer point .In Pent house suspended magnet is provided to remove the tramp iron being hanging over on the conveyor belt structure . Before crushers metal detectors are also provided to detect the non-ferrous materials present in the coal. In case the sized coal is received 0-20 or 37 mm size , then the coal is sent directly to coal stock yard and the crusher is stopped /by-passed. The Conveyors leading to crusher house is having facility for manual stone picking, at a suitable location after penthouse stone picking hoppers are provided.

ILMS-In line magnetic separators are provided at discharge chute end of conveyors for removal of remaining metallic ferrous tramp /iron pieces from the coal before it reaches the crushers. Coal sampling unit is provided to take sample of the uncrushed coal of raw coal of mines - ROM. The size of the coal received is normally (-) 300 mm which may, however, depend on coal linkage agreement tie up from mines. The received coal is sized in crushers (ring granulators) from (-) 300 mm to (-) 20-37 mm according to crushers design. Vibrating Screens (vibrating grizzly type or multi roller screens) provided upstream of the crushers screen out (-) 20 to -37mm coal from the feed and (+) 20 to -37 mm coal is fed to the crushers. A set of rack & pinion gates and rod gates is provided before screens to permit the maintenance of equipment downstream without affecting the operation of other stream. The crushed coal is either fed to coal bunkers of the boilers or discharged on to conveyors for storage in coal stockyard through conveyors and transfer points.

Coal Stacking & Reclaiming at Stockyard:--When coal bunkers are full with the crushed coal then coal is sent to stockyard. Stacking/ reclaiming of coal is done by stacker-cum- reclaimer by bucket wheel type which moves on the rails. The stacker-cum reclaimer can stack coal on either sides of the yard conveyor. During stacking mode the coal is fed from conveyors to the boom conveyor and boom conveyor discharges the coal on the yard conveyor while in reclaim mode, for feeding the coal to bunkers through conveyors and transfer points. The coal yard conveyor can be reversible type depending on layout requirement of the plant. When direct unloading from rakes is not in operation in supercritical units, coal is reclaimed by the stacker –cum-reclaimer and fed to the coal bunkers hoppers. Reclaim hopper can be provided to reclaim coal by dozers when stacker –cum- reclaimer is not in operation. When Coal stockpile is provided the emergency reclaim hopper can also be used for coal blending on conveyors in ration as per plant requirement in Supercritical coal based units..

Dust Control System and Ventilation system

In the CHP transfer points, feeders, crusher's etc locations, the dust control system is required for control of fugitive dust emissions. From generation point's view, dust control can be achieved by extraction system & dust suppression system .Dust suppression is achieved by two methods e.g. Dry Fog Type Dust Suppression System & Plain Water Dust Suppression System.

Ventilation Fan is provided for all the working areas/ locations/ buildings/ underground structures of CHP. The actual ventilation is achieved by mechanical ventilation system/ pressurised ventilation system depending on the area requirement. The pressurized ventilation system is capable of pressurizing slightly above atmospheric pressure to prevent ingress of dust from outside. The MCC/switchgear room areas of coal handling plant are provided with pressurised ventilation system while other areas have mechanical ventilation. RIO (Remote Input/ Output) room are provided with air conditioning system along with the control rooms, office room.

Miscellaneous facilities at Coal Handling Plant

At the underground suitable locations, in the buildings to drain out the water is also provided with sump pumps in the Coal Handling Plant. Necessary monorails with manual or electric hoist are provided for handling various equipments of CHP. Necessary service water, potable water and cooling water system is provided in CHP area as per requirement. Flap Gates or Y Chutes are provided at transfer points for dropping the coal from one conveyor to other conveyor and also for changing the coal flow stream.

The coal may contain shale and sand stone as high as 20% due to open cast method of mining involved,. Also occasionally metal pieces like , brake shoe, wires ,broken shovel teeth etc., may also come along with coal from open cast mine The coal "as received" shall contain varying percentage of fines. Coal with such fines may tend to form adhesive lumps, particularly during monsoon when surface moisture is at its maximum value.

For all other purposes viz. for stresses/ load on structures, torque calculations the bulk density of the coal shall be taken as 1200 kg/ m3. For the purpose of volumetric computation, the bulk density of the coal shall be taken as 800 kg/m3. Therefore, for calculation of belt conveyor capacity, their drives and drive motors kW requirement, and sizing (volume calculations) of chute, hoppers etc. the above bulk density shall be considered.

The gear boxes, motors, couplings and pulleys for conveyors shall be standardized and no. of types shall be limited to minimum possible. All hoppers and tunnels shall be provided with sump pumps (1 operating + 1 Standby). The drive motor of all the sump pumps shall be mounted at least 1.0 metre above the floor / ground level. The sump pumps shall be suitable to handle coal slurry and impeller shall be of non-clog type. For slurry purpose and long life mud pumps are also suitable for <35mm slurry.

The Coal Unloading System shall be capable of unloading the rake within the time as stipulated in the latest Commercial Policy (Freight) of Indian Railways. The currently applicable Policy of 2007 stipulates 7 hours unloading time for a coal rake for BOX, BOX-N, BOXNHA etc type wagons and 2 hours 30 min for BOBR type wagons.

Wagon Tipplers

The wagon tippler shall be 'rota side' type suitable to unload a coal wagon by lifting and rotating it sideways. The angle of tip shall be at least 150° giving 60° angle to the side of the wagon for emptying the coal contents into the hopper below.

The wagon tippler design shall conform to latest edition of G-33 and its amendments issued by RDSO. The tippler shall be designed to allow passage of all standard broad gauge (1676 mm) Indian Railways diesel locomotives over tippler table at creep speed. The tippler shall be designed to accommodate 150 Tons locomotive as per G-33 requirement.

Wagon tipplers shall be suitable to handle any type of wagons being used by Indian Railways as on date for transportation of coal as per IS-10095 (Latest edition) and shall conform to all stipulations with regard to suitability for handling wagons having width, height and length over coupler faces as indicated by RDSO at the time of approval of wagon tippler drawings.

An electronic static weighing system shall be provided as recorder the quantum of coal, wagon wise on the wagon tippler table before & after tippling. It shall have a minimum accuracy of 0.5 to 1% of the gross weight of the wagon.

Side arm charger

The side arm charger shall be suitable to handle 59 nos. of loaded wagons weighing 110 Tons. Thus, side arm charger shall be used for indexing forward the rake of 59 nos. loaded wagons, placing decoupled wagons on the tippler table and out hauling the empty wagons.

Wagon Tippler Hopper

For effective volumetric capacity computation of the hopper, the angle of repose of coal shall be considered as 37°. The minimum valley angle of the hopper shall be considered as 60°. The wagon tippler hopper shall be of RCC construction and adequately sized to accommodate the coal load for at least three (3) nos. 8 wheeled wagons (180 tons) of RDSO design used by Indian Railways. The hopper and gratings shall be designed for movement of front end loader/bulldozer over them. Bull-dozer weight shall be considered as about 35T. Steel gratings of mesh size 300 mm x 300 mm over wagon tippler hopper shall be provided.

Track Hopper

Track Hopper is underground RCC structure and gunited with 50mm thick guniting with effective coal holding capacity of 4500 Tonnes. The valley angle shall not be less than 60 deg. Track hopper complex shall be provided with covered structural shed. Track hopper shall be 200 m long with one maintenance bay of 15 meters on each side of track hopper with hatches & monorail with hoist. Provision shall be made for compressed air connections for opening / closing the wagon doors during unloading. Track hopper shall have removable type steel grating cover with opening of 300 mm x 300 mm. In case of coal supply by Indian Railway wagons, the track hopper capacity may be 6000 MT with hopper length of 300 meters in line with Railway guidelines. Track hopper capacity of 6000 MT with hopper length of 250 m is also acceptable but the invert level of track hopper shall increase in such a case.

For effective volumetric capacity computation of the hopper, the angle of repose of coal shall be considered as 37°. For maintenance, there shall be electric hoist / manual hoist for handling of the equipment. The path way of monorail shall be close enough for easy handling of the equipment to be lifted. Extension of the monorail outside the building shall be minimum three (3.0) meter from the outside of the wall / column of the building.

Apron Feeder

Apron feeders shall be of robust construction and designed for handling ROM coal as specified and without any choking particularly during rainy season when coal is wet. A dribble conveyor shall be provided below apron feeder for proper clean up.

Paddle Feeder

The carriage shall automatically reverse its motion, when two paddle feeders operating on the same track come within a predetermined distance. Each paddle feeder shall have capacity to scoop out coal at the guaranteed capacity in both forward and reverse motions with no indication of wheel slipping. Suitable anti-collision device (infrared and mechanically operated limit switch type) shall be provided. Rope actuated stop switches shall be provided along the traveling structure for emergency use.

Metal Detector

Metal detectors shall have high reliability with enough sensitivity to detect 25mm aluminium sphere below the burden of coal in case of synthetic belting. However, for steel cord belting the sensitivity shall be 40 mm. It shall also detect other metals, like brass, copper, stainless steel, manganese steel, bars, scraps etc. It should ignore magnetite/iron and shall distinguish between metal pieces and magnetite/iron.

Electronic Belt Weigher

The electronic belt weighers for measurement of coal flow rate and quantity shall be provided at following locations. Unloading conveyors to determine the coal receipts rates. The electronic belt weigher shall be complete with flow rate indicator, ERH belt conveyors to know the quantity of coal reclaimed/blended. Boom conveyor of stacker-reclaimer to know the coal reclaim rates. Conveyors feeding bunkers to know fuel feed rates to coal bunkers.

Control Panel & Totalizer: -- These shall be designed for continuous automatic weighing, metering and printing of coal flow rate. Belt weigher shall be designed for a range of 20% to 120% of rated capacity with an accuracy of at least (+) 0.25 percent throughout its range. Belt weigher provided on Stacker Reclaimer Boom Conveyor shall have accuracy (in them horizontal position of Boom) of (+) 1 percent for the range of 20% to 120% of boom conveyor rated capacity.

In-line Magnetic Separator and Suspended Magnet

The magnet shall be able to separate M20 bolts & nuts, and 50 kg MS plates / MS bars of L/D (length /diameter) ratio of less than 5. Strength of magnet at the specified mounting height shall not be less than 1050 gauss (at the centre point of belt). Mounting height shall be >450mm in the conveyors carrying uncrushed coal & >400 mm in the conveyors carrying crushed coal measured between top of conveyor belt or bottom of falling material trajectory and the surface of magnetic separator belt. The magnetic separator shall be located such that it picks-up tramp iron from coal trajectory after it has been discharged from head pulley.

Coal Sampling Unit

The coal sampling units suitable to give “Samples” conforming to ASTM-D-2234 shall be provided for taking samples from any of the two streams running at guaranteed capacity. The normal input feed size shall be considered as (-) 300 mm for coal sampling unit before coal crusher. However occasionally (-) 400 mm lumps may also arrive. Coal lump size after crusher (as fired coal) shall be (-) 20mm. However occasionally (-) 50 mm lumps may also arrive in crushed coal.

Vibrating Grizzly Screen:- The screen shall be capable to segregate the (-) 20 mm size of coal along with coal dust, any muck & muddy coal (which is likely to be encountered during rainy season) etc. The segregated material shall be directly fed onto the corresponding belt conveyors/feeders through separate hoppers/chutes provided under each screening feeder. The width of vibrating screening feeder shall match to feed the material uniformly over the entire length of crusher rotor without any deflectors in the feeding chute.

Crushers:

Ring granulator type crusher shall be provided for sizing the input coal to (-) 20 mm size. Crusher shall be supplied complete with accessories and subsystems. The crusher shall be capable of delivering the normal rated output even when handling damp sticky coal having maximum moisture content. No clogging or building up of material on the crushing element shall develop. The entire inside surface of crusher coming in contact with coal shall be provided with abrasion resistant steel liners of requisite thickness.

Stacker – cum- Reclaimer

Stacker-cum-reclaimer shall operate on rail track running for adequate length to cover the entire coal stockyard. The wheel load of stacker-reclaimer shall not exceed 27.0 tonnes. The ratio of boom length (as specified) to the rail track gauge shall not exceed 5. Top of rail level shall be maintained at 0.7 m above the ground level, i.e., coal pile base level unless specified otherwise. Suitable number of rail scrappers shall be provided. The minimum track gauge for Stacker-cum-Reclaimer shall be 7 m. Buckets shall be sized for 125% of rated capacity. Rate of bucket discharges shall not exceed 55 per minute.

Stockpiles

The stockpiles of coal will have adequate storage for at least as per the table given below and the coal consumption for this purpose shall be based on normative heat rate and average GCV of design and worst coal.

In Plant location Coal stock (in terms of no. of days of coal consumption)

a. Pit head 15 days stock requirement

b- Load centre 30 days stock requirement

c. Coastal 30 days stock requirement

Maximum coal stockpile height shall be 10 meters.

Drains shall be provided around the stockpile. Angle of repose of stored crushed Coal shall be 37 degree. A coal pile run off pit shall be provided close to the stockpile area. During monsoon, the rain water from the coal pile would be collected in drains and led to the coal pile run off pit. The size of the pit would depend on the intensity of rainfall in the area and size of the stockpile. Pit shall be of RCC construction with a baffle wall in the middle. Coal particles in water collected in the pit would settle down in the first compartment and relatively clear water would flow to the second compartment. The water would be pumped from them second compartment to guard pond for further utilisation. Coal particles shall be removed from the pit using backhoe and trucks. Suitable ramp for the movement of backhoe shall be provided. This coal will be dumped in coal stockpile.

Chutes and Hoppers

The minimum valley angle of chutes shall be 60 degrees from horizontal. Hoppers and Chutes shall be made of minimum 20 mm/25 mm thick Mild Steel/ TISCRAL / SAILHARD /LSLAS07 or equivalent material. Sliding zones & adjacent sides shall be 20 mm thick, while non striking/ non sliding zones shall be 10 mm thick MS. In case of vertical chute (valley angle more than 80 degree) complete chute work shall be 20mm thick MILD STEEL /TISCRAL / SAILHARD / LSLAS07 or equivalent. Transfer chutes shall be adequately sized and sloped to ensure smooth flow of coal without any accumulation anywhere. Minimum cross sectional area of chute should be 5.0 times the area of cross load of the preceding conveyor. Direct impact of material on conveyor belt shall be avoided by providing an inclined surface at 60 degrees valley angle at the feeding point to guide the material in the direction of belt travel called deflectors for coal flow in centre of belt. Further, chute construction below flap gate shaft shall be such that there will not be any accumulation of coal dust between chute and flap gate in that zone.

Drive Selection

The motor rating for belt conveyors shall have a minimum margin of 20% over the required kW. For all other drives, a minimum margin of 10% over the required kW shall be taken. All equipment drives except crusher drive shall be capable of starting on full load. The service factor for selection of gearboxes, flexible couplings, brakes, etc., shall be minimum 1.5 on the motor rating.

Single LT drive motors shall be used for conveyor drive ratings up to 155-160 kW. For conveyor drive rating >160 kW, single HT drive shall be used for conveyors. However for boom conveyor drive and intermediate conveyor drive on stacker reclaimer, single

LT motor may be used above 160 kW also. For the bunker conveyor (tripper conveyors) drives only, single snub LT drive motor shall be used up to 200 kW rating.

The type of high speed coupling between motor and gear box shall be as follows:

- Traction type fluid coupling/ Delayed fill type fluid coupling
- For motor rating up to 30 kW- Resilient type flexible coupling For LT motors of above 30 kW
- For HT motors - Actuator operated scoop type fluid coupling

Belt Conveyor System

Belt conveyor system shall be designed as per the latest edition of as per IS: 11592. Or 'Belt Conveyors for Bulk Materials' published by CEMA-Conveyor Equipment Manufacturer's Association' Slopes of conveyors, wherever applicable, shall not exceed 16 degree depending on the lump size and other governing factors. The conveyor shall be horizontal at the feed point as far as possible. In case the same is not possible, the inclination at the feed point shall be limited to 6 degree.

Hold Back:--The hold back is a device for preventing the running back of the conveyor belt in case of conveyor being stopped in loaded conditions due to power failure or during normal operational delays shall be provided to give positive protection.

The hold back shall instantaneously engage without shock and be capable of protecting equipment and personnel. It shall be released instantly when 'power' resumes or the 'delay' is removed. The holdback devices shall be integral with gearbox.

Conveyor Belting

The belting shall be of either synthetic fabric such as Nylon-Nylon/ Polyester-Polyamide, Steel Cord. etc. with rubber covers of adequate flexibility to give a troughing angle of 35 -45 deg.

Fire resistant covers shall be provided for all conveyors belting breaker fabric shall be provided for all belts. The covers shall be FR Grade conforming to CSAM422M87 type-C / Equivalent DIN 2.2 to 3 of Canadian Bureau of Mine specification belting for surface installation. The belt shall have 5 mm top cover & 3 mm bottom cover (min). Minimum number of plies shall be four (4). Ratio of calculated maximum working tension to rated belt tension shall not exceed 0.8 accordingly belt selection shall be done.

The flame test shall be carried out as per ISO 340 stipulation. l) All over ground and overhead conveyors shall be located in suitably enclosed bridge structure. The conveyor bridge shall have permanently colour coated steel sheeting covers on roof and both sides, properly screwed or locked to steel structure as required. Adequate provision of windows shall be kept. A continuous slot opening of 500 mm shall be provided on both sides just below the roof sheeting.

Belt Protection Equipment

Pull chord type (manually reset type) emergency stop switches shall be located on both sides of belt conveyors at a spacing of 20 m along the walkways for the entire length of conveyors for emergency stopping of conveyor.

Belt sway switches of self-resetting type shall be provided at a spacing of 45 m to limit belt sway to permissible extent. Zero speed switch shall be non-contact (proximity) type electronic switch.

One no. chute blockage switch of proven type shall be provided at a suitable height on each leg of the conveyors discharge chute,

Vibrating screens by pass chutes, crusher feeding chutes, tripper discharge and feeding chutes nearest to the skirt boards.

Chute blockage switch shall trip the feeding conveyor in case of chute blockage and protect the feeding conveyor equipment.

Chute blockage switch shall also be provided at each leg of mobile tripper and shall trip the tripper conveyor.

Stone Picking

Manual Stone Picking arrangement at a suitable location in the conveyor gallery before the crusher house shall be provided complete with platforms, overhead lighting, hand railings, suitable seating, safety hook & holding arrangement for manual pickers, disposal chutes to ground level etc.

Dust Control (Dust Extraction and suppression) System:--Design and construction features of Dust control system shall be generally in conformity with the recommendation of "American Conference of Governmental Industrial Hygienists". Type of dust suppression system to be provided at various locations shall be as given below: Around the track hopper and wagon tippler – Plain water dust suppression. Wagon Tippler hopper complex - Dry fog type dust suppression system Crusher receipt and discharge points - dry fog type dust suppression for all transfer points - Dry fog type dust suppression system for stock pile - Plain water type dust suppression system with swivelling nozzles. Boom belt discharge of stacker – reclaimer - Dry fog type dust suppression System

Plain water type dust suppression system:

Pressure at inlet (Plain water) shall be 2.5 kg/sq. cm for Track Hopper and 4.5 Kg/sq. cm for wagon tippler, coal stock piles. Spray heads shall comprise of swivelling type spray units spaced at an interval of approximately 40 meters around each coal pile.

Dry fog type dust suppression system: Spray head pressure at inlet (dry fog) shall be min. 0.5 kg/cm2 for water and min 5 kg/cm2 for air. Dust extraction System shall be provided at following locations:

For Bunker floor for crusher house: -- The dust extraction system shall be of Venturi scrubber system. One independent dust extraction system for each stream shall be provided. The dust collection efficiency shall be 95% down the 10 micron size.

Ventilation System --Ventilation system shall be designed and installed conforming to "Industrial Ventilation" (American Conference of Governmental Industrial Hygienists/Committee on Industrial Ventilation). The MCC/switchgear room areas shall be provided with pressurised ventilation system while other areas shall have mechanical ventilation.

The pressurized ventilation system:--It shall be designed considering 15 air changes per hour to maintain these areas pressurised slightly above atmospheric pressure to prevent ingress of dust from outside. The air quantity for mechanical ventilation system shall be estimated based on equipment and solar heat loads and the temperature rise inside the building. Necessary air filters shall be provided to supply only clean air into building. Exhaust air shall be discharged at a suitable height above building. No. of air changes per hour shall not be less than 10 supply air changes & 7 exhaust changes for over ground building. No. of air changes per hour shall not be less than 15 supply air changes & 7 exhaust air changes for underground areas.

Instrumentation and Control

Control System for coal handling plant shall be Programmable Logic Controller (PLC) based or shall be implemented through micro-processor based distributed control system (DCS) covering total functional requirements of sequence control, interlock & protection, monitoring, alarm and data logging. Remote I/O cabinets shall be provided wherever required depending upon distance/location.

It shall be possible to select any coal flow path from the Operator's work station located in the CHP control room viz.

a) Wagon tippler/ track hopper to coal bunkers b) Wagon tippler/ track hopper to crushed coal storage via stacker cum reclaimer c) Wagon tippler/ track hopper – one stream to crushed coal stockpile and other stream to coal bunkers d) From crushed coal stockpile to coal bunkers via stacker cum reclaimer e) From crushed coal stockpile to coal bunkers via emergency reclaim hoppers iii) Entire CHP shall be controlled from following points: a) CHP control room near crusher house consisting of Operator Work Station (OWS) and Large Video Screen (LVS) for the control of entire CHP. Some I/O may be located remotely in Wagon tippler MCC room and on bunker floor. b) OWS for the control of each stacker cum reclaimer. c) OWS for the control of wagon tipplers/track hoppers. d) Dust extraction / suppression system shall be operated from the respective control panel provided locally with the equipment / system. Dust extraction/suppression system shall operate when the coal conveying system is in operation and bunker ventilation systems shall operate round the clock. DE / Dust suppression system shall be provided with remote operation from main CHP control room except for Bunker floor DE operation which will be local. e) Control system for stacker cum reclaimer, wagon tipplers, dust extraction / suppression system shall be interfaced to the CHP control room. f) Local start/stop push button stations, de-interlock switches to be mounted near each equipment for start / stop during maintenance of the system. iv) For design requirements of Control & Instrumentation system, Section 8 of this document may be referred to. Civil Works For design requirements of civil works, Section 9 of this document may be referred to. Layout and Maintenance Requirements

i) the sizes of the junction towers, transfer points and crusher house and the floor Elevations shall be finalized considering a minimum clear walkway space of 1200 mm around the equipment in each floor. The clear distance between the floors shall be minimum 3000 mm and the headroom shall be suitable for handling / removing the equipment at the head end and tail end.

ii) Adequate space around the crusher in the crusher house shall be provided for opening the cage of the crusher and for removal of the shaft. Partitions with slide doors shall be provided in the crusher house between the crushers to enable maintenance of standby crusher when the other crusher is operating. Adequate maintenance space and handling facilities shall be provided on both sides of the partition wall

iii) All transfer points shall have separate debris disposal chute upto last operating floor.
iv) Minimum clearance between the bottom of the tail pulley and floor in junction tower / crusher house / transfer house / tunnel shall be 600 mm.

v) Wherever the conveyor crosses the road, a minimum clearance of 8 M shall be provided below the structure. At the rail crossings, this clearance shall be as per the Indian Railways requirement.

vi) Side and central walkways for double stream conveyors shall be 800mm and 1100mm wide respectively. The side walkways for single conveyors shall be 800 mm on one side and 1100mm on the other side.

vii) Provision shall be kept with platforms and ladders for crossing over the conveyors at approximately every 100m intervals of route length and minimum one per conveyor.

viii) Cage ladder at every 100M shall be provided to approach / escape from the galleries from ground. Spacing of monkey ladders on trestles shall be as given below:

(a) Where height of conveyor gallery (walkway level) is 10 m or more: every trestle. (b) Where height of conveyor gallery (Walkway level) is less than 10m: On alternate trestle

PERFORMANCE REQUIREMENTS

System Performance Requirements--The coal handling system and equipment shall perform satisfactorily to meet the guarantee requirements as stated hereunder:

.i) After the coal handling system is ready, the same shall be tested at rated capacity to prove the performance of the system and equipment. The guarantee requirements shall be met without undue vibrations in the conveyor supports, junction towers, crusher house, transfer houses, etc.

ii) Each crusher shall be capable of crushing rated capacity with specified maximum lump size of coal even while handling damp and sticky coal having 20% moisture (including surface moisture) during monsoon season. The largest size of output particles shall not exceed those specified in the specification.

iii) Screens shall screen out 95% of material having dimension of (-) 20 to -37nmm even during rainy season.

iv) Stacker / reclaimer shall be stable under specified design condition and shall meet all the requirements specified. The bucket wheel reclaimer shall reclaim coal at the rated capacity specified while handling well compacted, damp and sticky coal during rainy seasons. The capacity shall be arrived at on working for 4 hours over complete cross, section of the stockpile. Also, the stacker shall stack coal at the rated capacity specified.

v) All drive motors shall be suitable for direct-on-line starting and capable of starting fully loaded conveyors / feeders.

vi) Noise level produced by any rotating equipment (other than crusher) individually and collectively should not exceed 85 dba at a distance of 1.5 metres from it in any direction under any load condition.

vii) Vibration level of equipments at bearings shall not exceed the following limits for different equipment. Vibration levels shall conform to the limits specified below and shall be measured as per VDI 2056 / BS 4675.

Equipment Peak to peak limit: At the bearing of drive pulley, motor and gear box for the following equipment:

i) Boom conveyor of stacker/ Reclaimer ii) All other equipment/ : Conveyors/feeders etc. 115 microns 75 microns . On the floors and columns of junction towers, Crusher house and conveyor, Gallery walkways 200 microns Crusher 160 microns for speed of, 750 rpm . At the outlet of the dust extraction system, the dust concentration shall not exceed 100 mg/Nm3. Simultaneous operation of both the paths in conveyor streams at rated capacity shall also be demonstrated to confirm healthiness of the system.

Performance Guarantee Tests

Before conducting Performance Guarantee test, the coal handling plant shall be on trial operation during which necessary adjustments can be made to enable full capacity range operation. The duration of Trial Operations of the complete equipment shall be fourteen (14) days with minimum twelve hours daily operation. For successful Trial Operation, the trial shall necessarily include steady operation of the plant at its rated flow path capacity for at least one hour duration per day on an average. Normal duration of the P.G. test shall be four hours. However, minimum one (1) hour continuous & steady operation shall be required to establish the guaranteed capacities. Power consumption measurement shall be done only for one hour after the conveyor flow rate stabilizes at the guaranteed capacity.

Performance Guarantee Tests shall be conducted in such a way that all the conveyors in both the streams are covered. For this purpose it may be necessary to repeat the Performance & Guarantee tests until all the conveyors are covered. Tests to be conducted shall include:

i) Capacity in T/Hr (equivalent to 100% of rated) of conveyor system including the intermediate equipments for each of the two parallel conveyor streams separately or any combination thereof. For the purpose of conducting guarantee test coal, flow shall be divided into following coal flow paths:

a) Wagon tippler/ track hopper to coal bunkers

b) Wagon tippler/ track hopper to crushed coal storage via stacker cum reclaimer.

c) Wagon tippler/ track hopper – one stream to crushed coal stockpile and other stream to coal bunkers

d) From crushed coal stockpile to coal bunkers via stacker cum reclaimer

e) From crushed coal stockpile to coal bunkers via emergency reclaim hoppers

ii) Guaranteed capacity in T/Hr of the following:

a) Paddle Feeders

b) Apron Feeders

c) Crushers

d) Stacker Reclaimer

e) Wagon tippler with side arm charger

iii) Total power consumption for all the equipments including auxiliaries with single

Stream operation of longest flow path (listed at 2.4.2.i.a) at guaranteed capacity

Except intermittent loads such as lighting, hoists, coal sampling units, sump

Pumps, elevators, dust suppression/elevation, ventilation, service/potable water system.

Codes and Standards

The design, manufacture, inspection and testing of the Coal Handling System shall comply with all the currently applicable statues, regulations and safety codes in the locality where the equipment is to be installed. The equipment shall confirm to the latest edition of the following standards & codes. Other internationally acceptable standards/codes, which ensure equal or higher performance, shall also be accepted.

Belt Conveyor System

IS: 11592: Code of practice for selection and design of Belt Conveyors. “Belt Conveyors for Bulk Materials” published by Conveyor Equipment Manufacturers’ Association.

IS: 7155: Codes of Practice for Conveyor Safety.

IS: 1891 (Part-I) : General Purpose Belting

IS: 8598: Idlers and Idler Sets for Belt Conveyors

IS: 4009 (Part-II) : Conical Head Grease Nipples

IS: 8531: Pulleys for Belt Conveyors.

IS: 226: Structural Steel (Standard Quality)

IS: 4682: Codes of Practice for Lining of Vessels and Equipment for Chemical Processes.

IS: 11592: Code of practice for selection and design of Belt Conveyors.

CAN / CASA - M422 M 87: Canadian standard association.

IS: 2062 Steel for General Structural Purposes - Specification

Drive equipment like gears etc.

IS: 3688: Dimensions for shaft ends

IS: 3681: General plan for spur & helical gears

IS: 7403: Code of practice for selection of standard worm and helical gear boxes

Belt Scales/ Weighers NEMA Standards

NEC For electronic circuit enclosures.

IS: 11547 Electronic weighing in motion system.

Dust Control Equipment

IS: 778: Gun Metal gate, globe & check valves for general purpose.

BS: 5150: Cast Iron Gate Valve for water works purposes

BS: 5152: Cast Iron Globe Valve for water works purposes

BS: 5312: Cast Iron Check Valve for water works purposes

IS: 1239: Mild Steel tubes & fittings.

IS: 2379: Colour for the identification of pipe line.

IS: 3589: Electrically welded steel pipes for water, gas & sewage (200 to 2000 mm)

IS: 5312: Swing check type reflux (non return) valves.

IS: 1520: Horizontal centrifugal pump for clean, cold fresh water.

IS: 5120: Centrifugal pump for clean, cold & fresh water.

BS: 5169 & BS: 1123: Air Receivers.

ANSI B 31.1: Code for pressure piping.

Hydraulic institute Standards of U.S.A

IS: 210 Cast Iron

IS: 318 Bronze

Ventilation equipment

IS: 3588: Specification for electrical axial flow fans.

IS: 2312: Propeller type AC Ventilation fans

IS: 3963: Specification for roof-extractor units

IS: 4894: Centrifugal Fans

IS: 655: Specification for Metal Air Duct

ARI: 210: Standard for Unitary air conditioning equipment.

ARI: 270:

Standard for application, installation and servicing of unitary equipment.

IS: 8183: Specification for bonded mineral wool.

IS: 661: Thermal insulation for cold surfaces.

IS: 4671: Expanded polystyrene for thermal insulation purpose.

IS: 8148: Packaged Air conditioners.

Crushers & Vibrating Screens

IS: 8723 Dimensions for vibrating conveyors and feeders with rectangular or trapezoidal Trough

IS: 286 Austenitic-Manganese Steel Castings - Specification

Monorail and Hoists

IS: 3938: Specification for Electric Wire Rope Hoist

IS: 3832: Chain pulley blocks

IS: 2429: Round steel short link chain

IS: 6216: Short link chain grade 80

IS: 8610: Points hooks with shank for general engineering purposes

IS: 210: Cast Iron Castings

Chutes and Hoppers

IS: 4682: Code of practice for lining of vessels and equipment for chemical processes.

IS: 226: Structural Steel (Standard Quality)

Elevators

IS: 4722 Rotating Electrical Machines – Specification

IS: 325 Three-phase induction motors

IS: 1753 Aluminium conductors for insulated cables

IS: 1554 Specification for PVC Insulated (Heavy Duty) Electric Cables

COAL HANDLING PLANT

SCOPE OF WORK

The scope of coal handling plant typically covers the design, engineering, manufacture, Inspection and testing at manufacturer's works, supply, packing and delivery at project site, unloading, storage and in plant transportation at site, erection, supervision, pre commissioning, testing, successful commissioning, performance testing and handing over of coal handling plant of the thermal power project. Scope of work shall include all mechanical, electrical, C&I, accessories, civil, structural and architectural works to make the system complete. Typical scope of work for 2x500 MW & 2X660MW thermal power project includes: Mechanical

Underground RCC track hopper with four (4) Nos. paddle feeders OR Three (3) nos. rota side wagon tipplers along with side arm chargers and electronic weighing bridges, three (3) nos. wagon tippler hoppers and three (3) nos. apron feeders Note: Stations with track hoppers may also additionally have wagon tipplers to take care of eventuality of non-availability of BOBR wagons. In such a case, two (2) nos. wagon tipplers may be provided with hoppers and apron feeders

Belt conveyors (2x100% streams) from wagon tippler hoppers/track hopper up to crusher house complete with tunnel, conveyor gallery, pent house and transfer points. Covered conveyor galleries with steel trestles shall be provided for all over-ground conveyors. Following shall also be provided on each belt conveyer before crusher house:

a) Suspended magnets for removal of tramp iron pieces b) Metal detectors c) Electronic belt weighers d) Manual stone picking platforms e) Coal sampling unit along with online analysers f) In-line magnetic separators for removal of small and tramp iron pieces escaped from suspended magnets Four (4) nos. vibrating grizzly screens before crushers. Sets of gates each comprising of one rod gate and one actuator operated rack & pinion gate at inlet to each of the vibrating grizzly screens and at inlet to vibro feeders in emergency reclaim hoppers. Crusher house (CH) accommodating four (4) nos. crushers and associated vibrating grizzly screens, gates, passenger cum goods elevator, conveyors, chute work along with actuator operated flap gates, monorails & hoists, hoist maintenance platform, external and internal staircases, hand rails and other equipments such as coal sampling unit, dust suppression, dust extraction system etc. Four (4) nos. crushers including crusher supporting foundations, vibration isolation system with springs & viscous dampers, vibration monitoring system etc. Belt conveyors (2x100% streams) from crusher house up to coal bunkers complete with conveyor gallery and transfer points. viii) Belt conveyors (2x100% streams) from crusher house up to yard conveyor for coal stacking complete with conveyor gallery and transfer points. Reversible Yard conveyor (1x100%) with independent drives for stacking and reclaiming modes. One (1) nos. reversible Stacker cum Reclaimers with electronic belt weighers mounted one on each reversible stacker reclaimer. xi) Emergency reclaims hoppers with vibro feeders and belt conveyors (2x50%) complete with conveyor gallery and transfer points for interconnection with conveyor between crusher house and bunkers. Belt conveyors from yard conveyor complete with conveyor gallery and transfer points for interconnection with conveyor between crusher house and bunkers. Following shall also be provided on each belt conveyer before coal bunkers: a) Electronic Belt weighers b) Coal sampling unit along with online coal analyser c) In-line magnetic separators d) Metal detectors xiv) Complete chute work and motor operated flap gates between various conveyors in all Transfer points and crusher house. xv) Four (4) Nos. motorized traveling trippers, two (2) nos. for each unit. xvi) Two (2) nos. passenger - cum – goods elevators to serve various floors of the crusher house (CH) and one (1) no. passenger – cum – goods elevator in transfer point near boilers. xvii) Adequate number of ventilation equipment for ventilating the track hopper, wagon tippler hoppers, emergency reclaim hoppers, underground tunnels, transfer points, crusher house and bunker bays (housing tripper conveyors) xviii) Pressurised ventilation system for all switchgear rooms, MCC rooms. Exhaust fans in all battery rooms and toilets Air conditioning of main CHP control room, local control rooms for track hopper, wagon tipplers, stacker/reclaimer and office rooms. xxi) Adequate number of sump pumps in hoppers, transfer points complete with individual discharge piping with fittings and valves up to nearest plant drain. xxii) One (1) No. belt vulcanizing machine along with belt jointing facilities Complete dust suppression system for control of fugitive dust in track hopper/wagon tippler hopper, paddle feeder, transfer points, crusher house, coal stock yard complete with enclosed pump houses, water tanks, pumps, drives, hoisting arrangements, piping, valves etc. as briefly specified below: a) Plain water dust suppression around the Track Hopper top and wagon tippler top through fogging nozzles. b) Plain water dust suppression around stockyard through swivelling sprinklers c) Complete plain water dust suppression system with two (2) nos. pumps and one (1) tank mounted on paddle feeder or on trolley including ring header inside track hopper for supplying plain water. d) Complete dry fog type dust suppression system at all Transfer Points, wagon tippler complex, S-R boom conveyor discharge and Crusher House (both at discharge and loading points) including all electrical and accessories. e) Belt sealing arrangement in Bunker bays for control of dust coming out of coal Bunkers. Complete dust extraction system for control of fugitive dust in crusher house and bunker floor with complete water tanks, pumps, drives, hoisting arrangements, piping, valves etc. Service water, potable water system and cooling water system for complete coal handling plant. Monorails and electrically operated hoist blocks as well as hand operated chain pulley blocks for servicing/installation/easy replacement of drive machinery, different types of pulleys for all conveyors and other equipment from ground level to their locations and vice-versa. Four number bull dozers of minimum 400 BHP diesel engine for dosing coal into emergency reclaim hoppers and coal stockpile maintenance xxviii) Drainage of all CHP buildings, track hopper, wagon tippler hopper, emergency reclaim hoppers, tunnels, conveyor galleries and coal stock yard including all civil & structural works. Fire protection provisions to meet TAC and IS – 3034.

Electrical System / Equipment

Two no. feeders shall be provided from 11 kV Station Switchboards for Coal Handling Plant. Further, distribution of power supply at 3.3kV and 415V voltage levels and all other required electrical equipment for putting coal handling plant into successful operation shall be in the scope of work of CHP supplier. The 415V supply shall be arranged either through 11/ 0.433kV or 3.3/ 0.433kV LT auxiliary transformers. However, 415 V supply for boiler floor MCC shall be arranged from respective 415 V unit PMCC. Typically, following electrical equipment shall be included:

i) 11/ 3.3kV and 11/0.433kV or 3.3/0.433kV auxiliary transformers ii) 11kV, 3.3kV and 415V Switchgears iii) HT and LT bus ducts iv) Power and control cables including cables from 11 KV station switchboards and 415 V unit PMCC. v) Cable laying along with cabling accessories, cable trays and termination/ jointing kits of cables, and fire sealing vi) HT and LT Motors vii) 220V DC system comprising of battery banks, chargers and DC distribution boards viii) Complete illumination system for internal and external lighting of associated plant and building ix) Complete grounding and lightning protections and its interconnection with nearest earth mat x) Emergency stop push button for all HT and LT motors

Control & Instrumentation System

(in case of PLC based system) i) Microprocessor based programmable logic control (PLC) system for operation, control and monitoring of the Coal handling plant from the coal handling system control room. Operator Work station housing TFT / keyboard, and Large Video Screen shall be provided in the main control room of CHP along with I/O racks, PLC panels and power supply arrangement. Remote I/Os may be provided depending on distance/location. It shall be possible to monitor the coal handling plant from the main DCS in the Unit Control Room through soft link.

ii) Independent PLC based control system, comprising of OWS, PLC panels, I/O racks and power supply arrangement etc., for stacker cum reclaimers with facility to communicate important signals with CHP control room through hard wiring.

iii) PLC based control system comprising of OWS, PLC panels, I/O racks and power supply arrangement etc.. for coal unloading at wagon tippler/track hopper complex along with static weigh bridges iv) Local control panels for traveling trippers, dust extraction / suppression system. These local panels shall be interfaced to the CHP control room.

v) Communication facility between CHP Control Room and all the strategic workings areas such as Wagon Tippler/track Hopper Control Room, Stacker-Reclaimer Control Cabin, bunker floor, unit control room etc.

vi) Instrumentation and control cables including laying and termination vii) Power supply system for C&I system including redundant UPS system, batteries, charges etc.

viii) All Instruments integral to CHP equipment for control, monitoring and operation of the equipment/plant/ systems such as: a) Belt sway switches b) Pull chord switches c) One No. zero speed switch at tail end for each conveyor. d) Vibration monitoring system for crushers and drives e) Motor overload switches for conveyor drives f) RTDs for conveyor drive motors and crusher motors (for HT motors only) g) Level switches in dust suppression system water tanks and other field devices as required.

Civil Works-- The civil works to be performed shall cover providing all labour, materials, construction equipment, tools and plant, scaffolding, supplies, transportation, all incidental items necessary for successful completion of the work. The work shall involve earthwork in excavation including controlled blasting and very deep underground excavation, extensive de-watering, shoring and strutting, sheet piling, back filling around completed structures and plinth protection, area paving, disposal of surplus excavated materials, piling, concreting including reinforcement and form work, brick work, fabrication and erection of structural / miscellaneous steel works, inserts, architectural items & finishes such as plastering, painting, flooring, doors, windows & ventilators, glass and glazing, rolling shutters etc., permanently colour coated profiled steel sheeting, anchor bolts, R.C.C. trenches with covers, laying and testing of water pipes, sanitation, water supply, drainage, damp proofing, water proofing and other ancillary items. ii) The work shall be carried out both below and above ground level and shall include basements, equipment foundations including vibration isolation systems, grounding, slabs, beams, columns, footings, rafts, walls, steel frames, brick walls, stairs, trenches, pits, access roads, culverts, conveyer galleries, trestles, penthouses, track hopper, wagon tippler hoppers, emergency reclaim hoppers, underground tunnels, crusher house, transfer towers, buildings for switchgear and control room, finishes, complete architectural aspects, drainage, sanitation, water supply (from terminal points to various buildings, conveyor galleries) and all other civil, structural and architectural works associated with the complete Coal Handling Plant. iii) All buildings shall be complete with all electrical, civil, structural, architectural works, cable trenches, fire safety walls, foundation, earth mat, fencing, earthling for transformers. All cables, duct banks, trenches, cable trestles shall be complete with associated civil/ structural work and necessary civil foundations. Buildings to be provided shall include the following:

a) Underground/partially underground transfer points (RCC construction) b) Overground transfer points and Crusher House (steel construction) c) Electrical & control buildings (RCC construction) listed below:• Main switchgear cum central control room building near crusher house• Wagon tippler/track hopper switchgear cum control building near wagon tippler/track hopper complex • Switchgear room for Stacker –cum- Reclaimer.

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