Improving Energy Efficiency of paint industry by systematic energy mapping and standardizing specific power consumption of production process

Major Project Report

Submitted in Partial Fulfilment of the Requirements for the degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Energy System)

By

Chintan M. Shah
(13MEEN08)

DEPARTMENT OF ELECTRICAL ENGINEERING
INSTITUTE OF TECHNOLOGY
NIRMA UNIVERSITY
AHMEDABAD-382481
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Certificate

This is to certify that the Major Project Report entitled “Improving Energy Efficiency of paint industry by systematic energy mapping and standardising specific power consumption of production process” submitted by Mr. Chintan Mukeshbhai Shah (13MEEN08) towards the partial fulfilment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Energy System of Nirma University is the record of work carried out by him/her under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Annexure VI

Undertaking for Originality of the Work

I, Chintan M. Shah, Roll No. 13MEEN08 , give undertaking that the major project entitled, “Improving Energy Efficiency of paint industry by systematic energy mapping and standardising specific power consumption of production process” submitted by me, towards the partial fulfilment of the requirements for the degree of Master of Technology in Electrical Engineering of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

Chintan Shah
Date: 27-April-2015
Place: Ahmedabad

Endorsed by

Prof. D.M Mehta
Faculty Guide

Acknowledgement

This project would not have been accomplished without the presence of following people.

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g) Nirma University for providing me platform and opportunity to adding my contribution as a smallest bit towards Energy Conservation.

My whole hearted thanks to all of you.

-Chintan Shah

Abstract

Paint industries of India are Rs. 280 billion industries (FY13) that contribute significantly to Indias economy. The industry is expected to grow up to Rs. 500 billion in FY18. Research and development of an energy model by energy metering and mapping that can improve its efficiency is therefore significant. However, energy mapping by means of manufacturing process mapping is done solely by kWh consumption of total plant and not of individual processes. So it faces irregularities and difficulties for approaching the solution. No standard basis for the paint industry's product manufacturing energy consumption have been done up till now in India. Modelling an energy consumption review of paint industry after detailed energy mapping will be carried out in this project. The objective of this project is to standardize specific power consumption of one of the different processes commonly followed in all the paint Industry by designing a generalised energy mapping pattern comprising of each variable and constraint affecting the product process and its production cycle.

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List of Abbreviations

CFM Cubic Feet per Minute. 22–29

CH Charging Hopper. 40, 42, 44

CHW Chiller Water. 12

DCS Digital Control System. 42

DG Diesel Generator. 6

DM Dimeneralised. 6

DS Desuperheating Station. 12

EB Emulsion Block. 15, 27

ETP Effluent Treatment Plant. 16, 27

F & A From and At. 31

FD Forced Draft. 12

FIBC Flexible Intermediate Bulk Container. 21, 37, 41, 45, 46

FY Financial Year. 1

hp Horse Power. 20

HSD High Speed Diesel. 13, 30–33, 35

kcal Kilo Calorie. 10, 30

kL Kilo Litre. 36, 48

kVA Kilo Volt Ampere. 19

kW Kilo Watt. 15–17, 19, 21, 23–25, 29, 47, 48

kWh Kilo Watt Hour. 10, 13, 18, 29, 36, 46–48

MCC Motor Control Centre. 11, 15–17

MCR Maximum Continuous Rating. 9

NPSH Net Positive Suction Head. 6

PAT Perform Achieve Trade. 1

PCC Panel Control Centre. 11, 15–17

PID Proportional Integral Derivative. 45

PRV Pressure Reducing Valve. 12

RAL Rotary Air Lock. 38

RMG Raw Material Godown. 15, 16, 27, 37

RO Reverse Osmosis. 6

RPM Revolutions Per Minute. 6, 7, 22, 23, 42–44

SFD Screw Feeder Drive. 39

SME Small And Medium Enterprises. 1

SOP Standard operating Practice. 42

SPB Solvent based Paint Block. 15, 17–19, 26

SPC Specific Power Consumption. 25, 36, 45, 47, 49, 50

TFH Thermic Fluid Heater. 9, 11

TPH Ton Per Hour. x, 9, 31, 32

TSD Twin Shaft Disperser. 6, 7, 15, 17, 40

VFD Variable Frequency Drive. 6, 15, 17, 22, 23

WH Weighing Hopper. 42, 44

WPB Water based Paint Block. 16–19, 26–29

Chapter 1

Introduction

Paints manufacturing facilities of India are one of the large scale chemical industries that account to total of 2.3 % of India's total industrial energy consumption. The industries are expected to grow on much large scale considering the revamp in government's policies to enhance industrial growth in the period of Financial Year (FY) 2013 to 2017 [1]. In a competitive market positions for endorsing the products the paint manufacturers seek to provide technologically improved features in paints and solutions at an economically affordable price rates. To reduce a price of a product keeping in mind unchanged government policies on export, transportation and retails the manufacturers tend to focus on improving energy efficiency in manufacturing. Standardization of requirement of energy for a paint product is therefore required. Large scale industries may tie up with Small And Medium Enterprises (SME)s following the Perform Achieve Trade (PAT) scheme and can help establish energy efficient processes to manufacture paints categorized in same strata.

1.1 Objective of Project

Following are the major objectives of this project:

a) To reduce the specific power consumption for the designated paint manufacturing facility.

b) To develop an energy monitoring system for one of the paint production process.

1.2 Scope of Work

This project includes following in the scope of work:

1. To realize the general paint manufacturing process and associated energy consumption for the same.
2. To evaluate energy consumption pattern of generic utilities in a designated paint manufacturing facility.
3. To develop energy efficient solutions for power and energy consuming equipment that are found inefficient.
4. Process mapping and energy mapping of one of the water base paint manufacturing processes.
5. To calculate and benchmark specific power consumption for paint products following the studied process.

1.3 Literature Survey

Important Paint Processes, paint technology handbook: online excerpt, Rodger Talbert

Basic theory and concepts related to paint technology were studied from a comprehensive excerpt available at scribd.com. The author familiarises the chemical technology after explaining paint composition and its chemical elements. But later part of the excerpt focuses more on process engineering which will be useful for field specific research taken at higher levels.

Energy efficiency guide for thermal utilities, Bureau of energy efficiency Book

During summer internship and industrial training the fundamentals on thermal utilities and thermodynamics concepts were revised. The fundamentals later helped build an approach to understand a system operated at optimal performance and methods to improve that performance. Concepts on fuels and combustion, boiler system, steam system and heat recovery methods were studied from this book.

Energy efficiency guide for electrical utilities, Bureau of energy efficiency Book

Basic concepts on pumping system, compressed air system,fans and blowers, etc. were revised from this book. It has greatly helped during the establishment of detail audit performed at Paint facility in Khandala, Pune.

1.4 Field Study

The field survey of paint manufacturing plants of same company at different locations in India was carried out. Working philosophy of each plant under visit was learnt. From general observation it is found that for certain common production processes, the designed equipment, and operating practices were different from plant to plant. The power consumption of plants varied based on the production capacity, equipment size, operating methodology and range of products. From these observations it is concluded that the methodology of implementing the project must be restricted to a single plant under same company[1].

1.5 Methodology Adopted

For fulfilling the commitments under scope of work, project planning has been formulated. This planning methodology is described in figure 1.1.

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[1] The name of company is kept confidential due to company‘s confidentiality policy

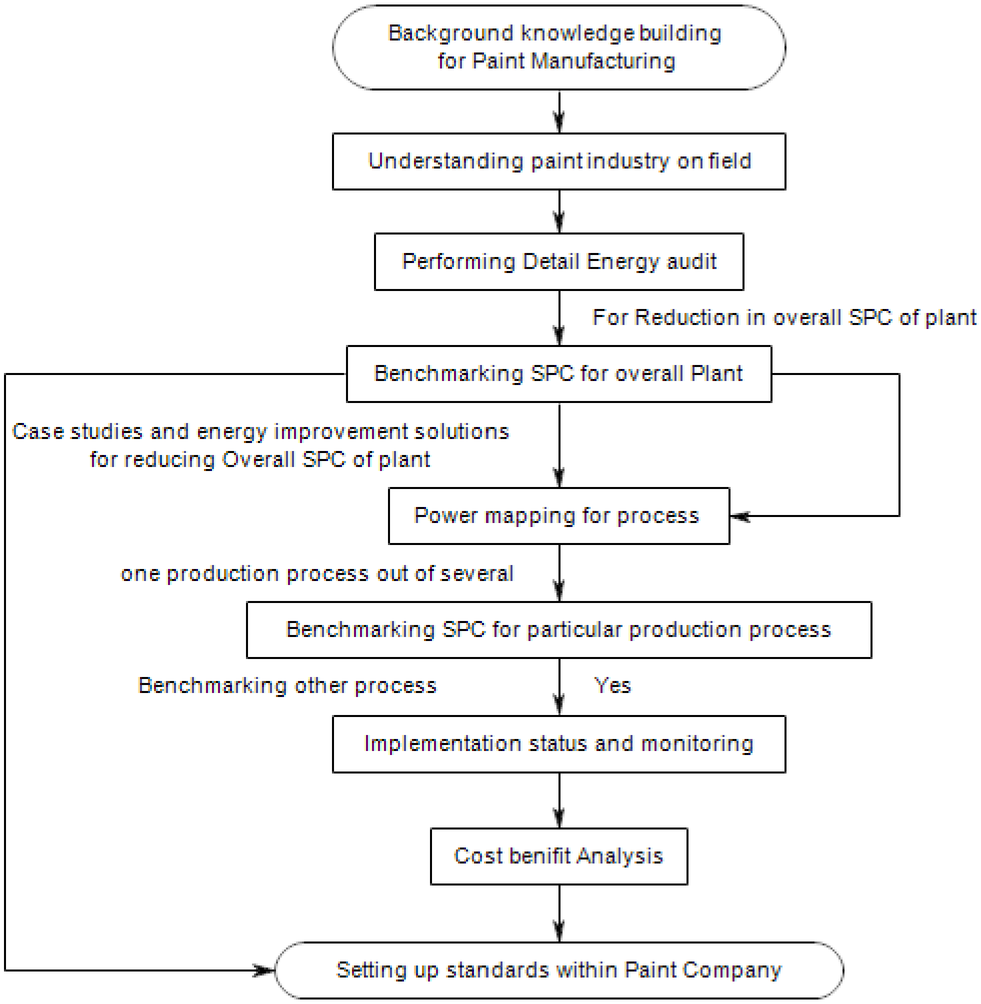

Figure 1.1: Project Working methodology

Chapter 2

General Processes in paint manufacturing facility

Paint is mainly comprised of a solute, pigment and a solvent. Other additives in paint for special purposes can be classified in subsidiary process. Catalysts may also be considered in subsidiary process. Solutes can be chemical composites in powdery form chosen according to the properties required in finished product[5]. Pigments are again powdery chemical composites that add colour to paint. For mixing these pigments and solutes a solvent in the form of liquid form is required. The state of composition comprised of solute, pigment and solvent is called emulsion. Based on the selection of solvent paints can be commonly classified in two types.

1. Water base paints
2. Solvent based paints (resins, tints,etc.)

The additives used in some paints are typical and are used for serving special purposes like water resistivity, endurance, anti-corrosive, thermal insulation, flexibility and so on. The additives may be in form of powder or in liquid monomer form that can later be processed into polymers at controlled heat and time environment.

The paint of specific strata is generally a batch process. Powdery solutes required for a batch are stored after thorough refinement taking place in Silo and hoppers. These solutes are conveyed to mixers of specific tank volume which is kept clean from all parasites i.e the residue chunks of previous batch. Parallel to this an additive is prepared from its liquid monomer state or powdery state into polymer state and stored in tank farm. The additive may later be used for mixing in the batch. The Solvent is added to the solute in Twin Shaft Disperser that achieves desired viscosity of the emulsion. The emulsion is then dropped into mixing tank for additive mixing maintaining the viscosity. The emulsion is conveyed to the packaging area where the product is packed as per the volume of size planned.

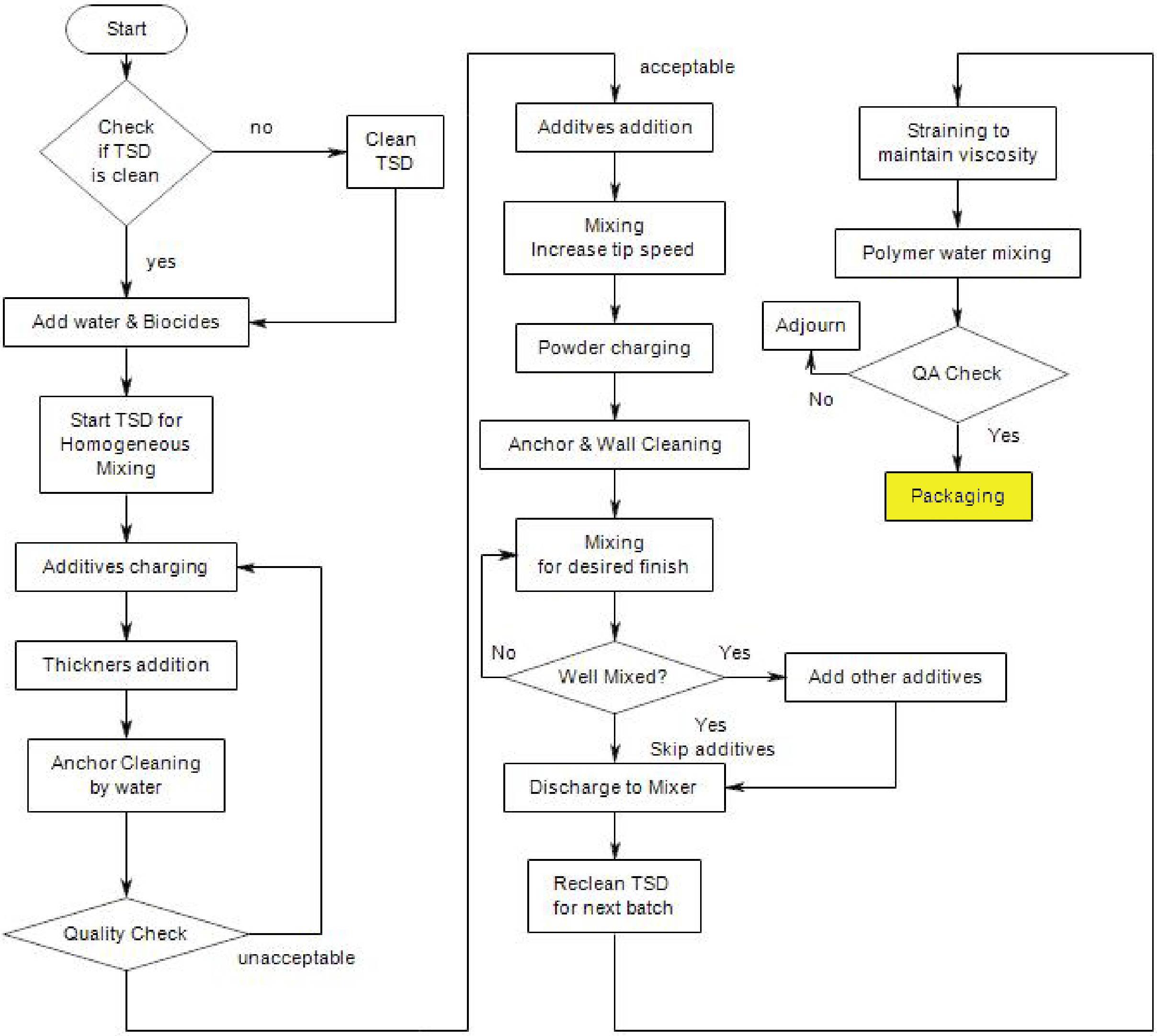

Figure 2.1: Generalised process algorithm for water based paints

2.1 Generic Utilities used in manufacturing

Paint manufacturing is a chemical process that is fulfilled by providing thermal and electrical power at different stages to different machines.

2.1.1 Electrical utilities

Air Compressors, Electrical Pumps, Disperser motors, mixer motors, agitator motors, aeration blowers, conveying blowers, FD fans, Rotary Air Lock (RAL) valves, lighting, etc. are major electrical power consuming equipments in the process. These power requirements are fulfilled by either Diesel Generator (DG) sets or private/government grid power supply or both.

2.1.1.1 Air Compressors:

Compressed air majorly used in air control valves, pneumatic pumps, special diaphragm pumps and robotic packaging. Some facilities may also have nitrogen plant that could be used for blanketing the resin batch.Nitrogen is known to be inert and and cooling media so its best use in resin blanketing is to make the surface suave. Compressed air may be used at control valves for effluent treatment. Use of Variable Frequency Drive (VFD)s for air compressor is more energy efficient application for variable air flow demand in the industry. Air compressors are used with dryers in facilities placed at high humid geographic locations to remove moisture/water from compressed air.

2.1.1.2 Electrical Pumps:

These are extensively used in facilities for various functions and can be called heart of the fluid transport system. Pumps with required head and NPSH are used for supply and return of water used in cooling towers. Pumps are used to push effluent waste, RO and DM water throughout the facility. Pumps are used for supply and return of chiller water that may be used for maintaining cold storage of some raw materials.

2.1.1.3 Disperser Motors:

These are used in Twin Shaft Dispersers (TSDs). Two motors are used for each TSD. The inner mixer is rotated at higher RPM while its torque requirement is less. The outer mixer is constructed in a manner that it requires high torque and low RPM. Based on the volume of TSD size of motors is decided.

2.1.1.4 Mixer motors:

Based on the size of mixer tank volume size of motor is selected. Mixers are used to mix the emulsion further after being collected from TSDs. The mixing speed is kept constant and so these motors do not require speed control.

2.1.1.5 Agitator motors:

Motors are coupled with pumps for jet cleaning of mixer tanks, TSDs and storage tanks.

2.1.1.6 Transfer Blowers:

These are high torque high RPM blowers that are used for transporting raw chemicals in powder form. The Silo is constructed in such a manner that the powder from these blowers is uplifted and added into the tanks. Blowers require high capacity motors so as to push solid powder at larger distances.

Others electrical loads are comparatively low power consuming units and are used only for a while in certain batch. Lighting load is considered constant load for the specific shift hours. Manufacturing facilities are more concerned on achieving desired quantity in batch and so important electrical machines are in pair wherein one is standby while other is running.

2.1.1.7 Chillers:

These are cooling utilities working on principle of Vapour compression refrigeration. Hot emulsion may be required to cool down at a required temperature for which a chilled water is circulated in the closed jacket. The chilled water after gaining heat from process is then passed through the chiller heat exchange and after heat transfer, heat removed is dissipated in environment in cooling tower. Chillers are rated based on heat load to be extracted from process with rated evaporation ratio, condensation ratio, condensing temperature and evaporating temperature. The chiller size may be dependent on the flow rate to which the refrigerant must circulate. Most of the chillers used R-22 or R-134/R-134a as refrigerant. Power of each of these electrical devices was tracked and measured along with their running cycle time. Instantaneous power consumption of each device at each stage of chemical process was measured using power analyzers. Process Cycle time must be provided by the production managers to measure the overall power consumption.

2.1.2 Thermal utilities

Chillers, Incinerators, Boilers and thermic fluid heaters are generally the thermal utilities that utilized for controlled batch heating and cooling purposes. These utilities may be used for maintaining storage temperature, steam heating, vessel cleaning; preheating of batch, providing required temperature for catalytic action and so on.

2.1.2.1 Incinerators:

Residues after each batch is collected at a place. The residue may be harmful to environment and must not be dumped without processing. For such reasons incinerators are used to dispose the residue. The chemical properties of the residue are changed after which they carefully handled and sunk.

2.1.2.2 Boilers:

Steam is an important source for providing direct/indirect heat to any process. Large paint facilities producing tints, varnishes and resins utilize steam for process heating and cleaning vessel. The clinks, parasites of earlier batch are to be cleaned directly with the help of superheated steam at temperatures higher than 390 °C. Polymer blocks at certain facilities utilize steam for preheating the vessel as well as polymer heating upto 160 °C.

2.1.2.3 Thermic Fluid Heaters:

TFHs are used in alternate to boilers. For indirect heating at comparatively very low pressure and high temperature than steam, these TFHs are equipped. They are mostly used in process heating for solvents. They can also be used for sublimation type of filtering. Thermic fluid has a closed cycle of mineral/synthetic oil which is used as heat transfer media.

Boilers of Maximum Continuous Rating (MCR) less than 3 Ton Per Hour (TPH) can be used if TFHs are installed. Boilers may be gas fired or oil fired that may have efficiency as high as 85-92 % depending on its operational duty. TFHs circulate special type of oil that has high specific heat as well as available in the open market.

Chapter 3

Detail Energy Audit and Case Studies

3.1 Brief Description on Detail Energy Audit

It has been learnt that energy audit may well be defined according to the objective set by top management and auditing team. The scope and objective of each energy audit should be predefined. Detail energy consumption is the total energy consumed in Kilo Watt Hour (kWh) or Kilo Calorie (kcal) per kg of product in present situation and process for particular product. Any change in the process parameter will result "corresponding change" in detail consumption For establishing baseline for any process it is important to map the utilization of each energy consuming element. Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish and investigate energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time at nights and at weekends as well as during normal daytime working hours to ensure that nothing is overlooked.

To evaluate the efficiency of each step of the manufacturing process and means of improving these efficiency will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed.

3.2 Methodology of Conducting Detail Energy Audit

The methodology applied to conduct detail energy audit is described by the flowchart in figure3.1.

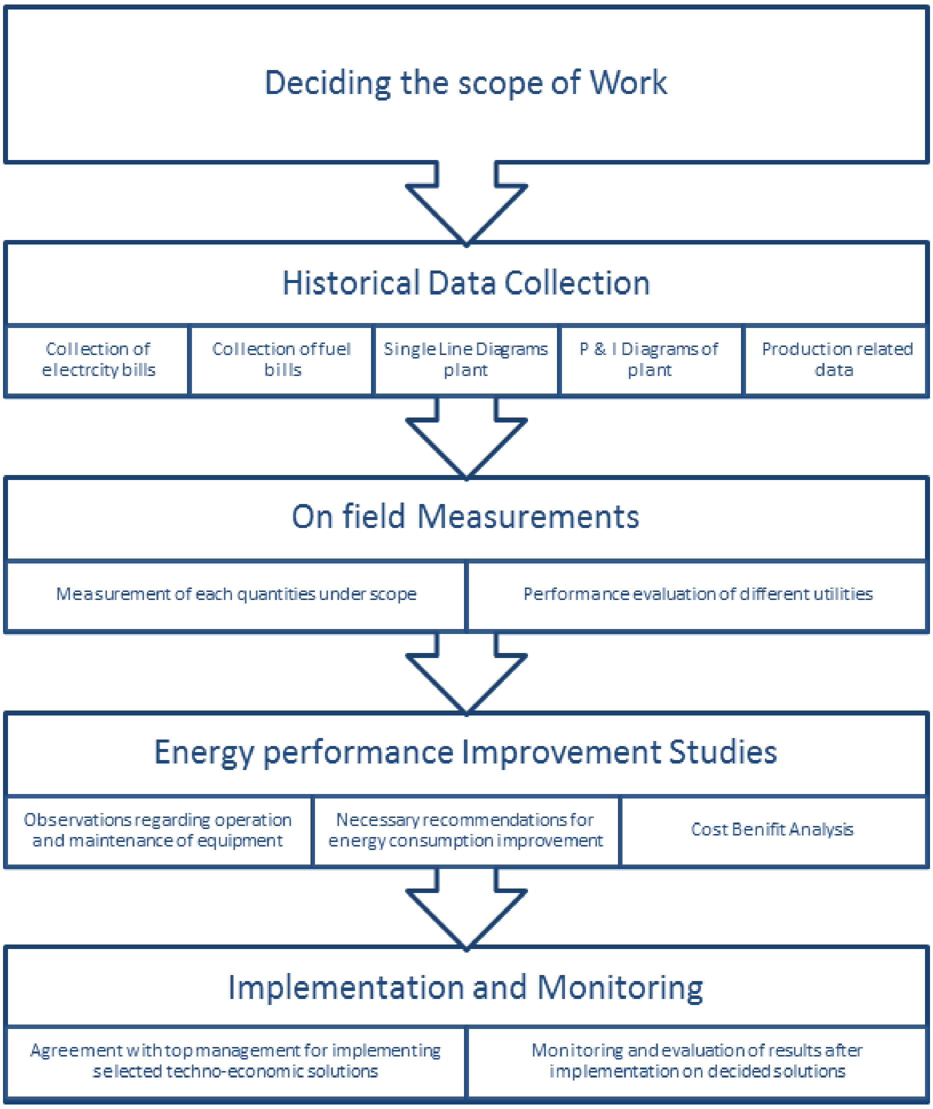

Figure 3.1: Energy Audit Methodology Flowchart

The information collected during the detailed audit at a paint manu-

facturing facility is:

1. Energy consumption by type of energy, by department, by major items of process equipment, by end-use
2. Energy cost and tariff data
3. Process and material flow diagrams
4. Generation and distribution of common utility services (eg. compressed air, steam, thermic fluid heating, chilling/cooling)
5. Sources of energy supply (e.g. electricity from the grid or self-generation)

With the data collected from the planning and production team ,the process cycle time, batch running time, boiler running hours, compressor running hours and daily lighting load were measured at this paints manufacturing facilities at Khandala, Pune. For detail energy audit, it becomes essential to provide and implement energy efficiency solutions for reducing the specific energy consumption.. The thermal and electrical utilities are targeted and their operating performances are measured and validated. At Plant following actions were carried out.

1. Power Cycles measurement at- Main Incomer/Panel Control Centre (PCC)s/Motor Control Centre (MCC)s
2. Transformer Study/Capacitor Measurements/Harmonics
3. Data Collection & Electricity Bill Analysis
4. Lighting System Study/Lux Measurement at various process plants and shops
5. Performance Study of Boilers – Indirect efficiency measurement method
6. Steam distribution system/Utilization
7. Performance Study of TFH – Indirect efficiency measurement method
8. Thermic Fluid distribution System/Utilization

9. Study of Chillers with auxiliaries
10. Study of Secondary Chiller Water (CHW) pumps
11. Study of Compressed air systems
12. Study of water system

3.3 Activities carried out for Detail energy at Paint facility in Khandala, Pune

Following activities were carried in accomplice with other DESL team members.

1. Measurement of air velocity of Forced Draft (FD) fans to calculate the air volume
2. Measurement of flue gas exit temperature and its composition by flue gas analyzer
3. Surface temperature at each point on boiler body and hotlines carrying steam thermic fluid system
4. Hourly fuel consumption when the boiler is running at its full load condition
5. Hourly feed water utilization against fuel consumption to calculate evaporation ratio
6. Inlet/outlet temperature of air preheater
7. Flue gas damper system
8. Hourly working pressure and temperature of steam from its outlet
9. Setting of Pressure Reducing Valve (PRV) and Desuperheating Station (DS) valves
10. Thermal losses at piping due to worn out insulation

11. Condensate discharge and flashing at valves
12. pumps and Fan performance of cooling towers

Table 3.1 forms the basis on current energy demand of the plant (dated: 28-Aug-2014)

Baseline Parameters		
Particulars	Unit	value
Unit Cost	Rs./kWh	7.72
Operating Days	days	330
HSD Cost	Rs./litre	65
Operating hours	hours	24
Annual Electricity Consumption	kWh/annum	21281209
Annual Fuel (HSD) Consumption	kL/annum	1069
Annual Electricity Bill	Lacs/annum	1644
Annual Thermal Bill	Lacs/annum	695
Total Energy Bill	Lacs/annum	2339

Table 3.1: Baseline parameters of energy consumption

Due to lack of proper coordination between planning and production/operation department, some discrepancies were observed during actual process study, which results in energy in-efficient operation of utility equipments like working on partial load, redundancy and idle running etc. Some feasibility case studies for energy improvement were made along with team of DESL.

3.4 Electrical system

3.4.1 Electrical Power Distribution System:

A single line diagram for the electrical power distribution system across the paint manufacturing facility is shown in figure 3.2 **Load Description** Description of major load connected in the facility is shown in table 3.2

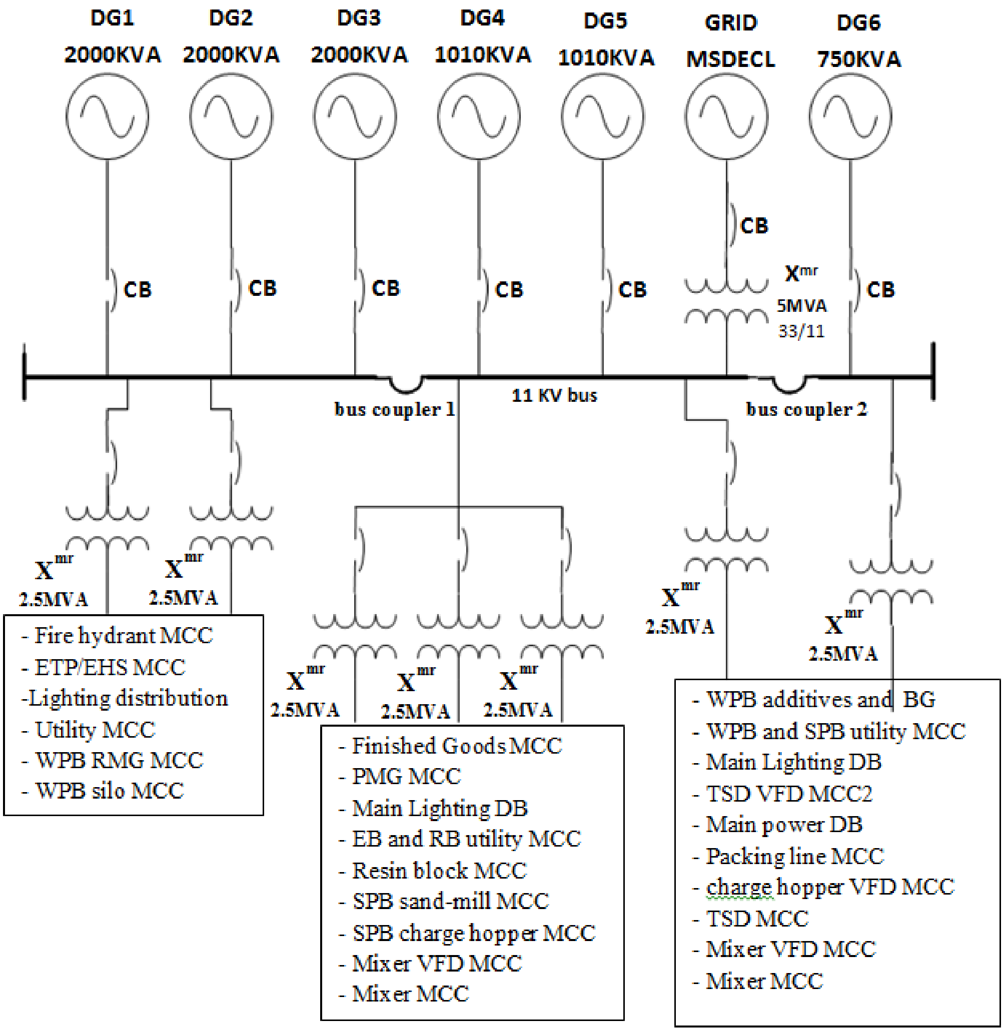

Figure 3.2: Electrical power distribution network

Sr No	**Load Description**	**Connected Load (kW)**
	SPB PCC Load Details	
1	SPB TSD VFD MCC	1252
2	MIXER MCC	806
3	MIXER VFD MCC	670
4	PACKING MACHINE MCC	232.7
5	SPB CHARGE HOPPER MCC	350
6	SAND MILL MCC	487
7	MISCELLANEOUS POWER LOAD	350
8	LIGHTING LOAD FOR SPB	630
9	PMG MCC	1282.5
10	PMCC IN RMG FOR EB & RB	1400
11	PMCC FOR RMG & BG of SPB AND TANKFARM	2177
12	EMULSION BLOCK MCC	712
13	RESIN BLOCK PMCC	722.5
14	FEEDER FOR UTILITY MCC FOR EB & RB	1605
15	FG MCC	1385.4
	TOTAL LOAD (kW)	**14062.1**

Table 3.2: Load Description I

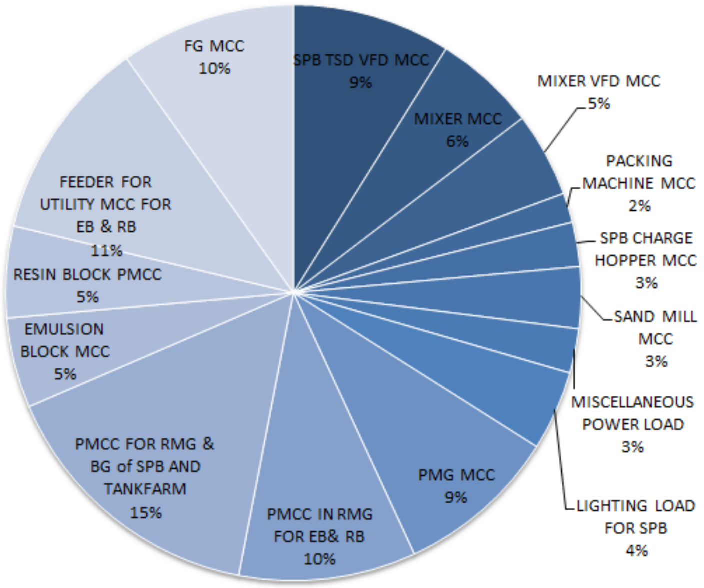

Figure 3.3: Load Sharing I

Sr No	**Load Description**	**Connected Load (kW)**
Utility PCC Load Details		
16	WPB SILO MCC-1	2227.35
17	WPB SILO MCC-2	2000.9
18	WPB RMG MCC	1372.36
19	ETP EHS MCC	285.98
20	FIRE HYDRANT MCC	515.5
21	UTILITY MCC	532.1
22	LIGHTING LOAD	400
23	MISCELLANEOUS POWER LOAD	250
	TOTAL LOAD (kW)	**7584.19**

Table 3.3: Load Description II

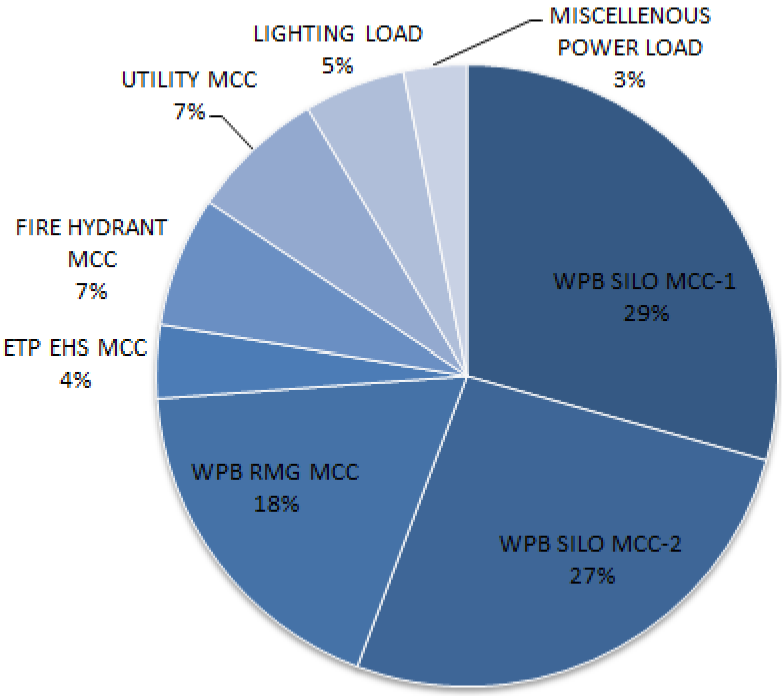

Figure 3.4: Load Sharing II

Sr No	**Load Description**	**Connected Load (kW)**
WPB PCC		
24	MIXER VFD MCC	726
25	TSD MCC	495
26	PACKING LINE	474.9
27	MPDB	275
28	TSD VFD MCC 1	2075
29		150.5
30	TSD VFD MCC 2	1245
31		301
32	MIXER MCC	1468.5
33	CHARGE HOPPER VFD MCC	647
34	LIGHTING LOAD	300
35	UTILITY MCC FOR WPB & SPB	1075.5
36	WPB ADDITIVES AND BG	614.3
	TOTAL LOAD (kW)	**9847.6**
	Total Connected Load (kW)	**31494**

Table 3.4: Load Description III

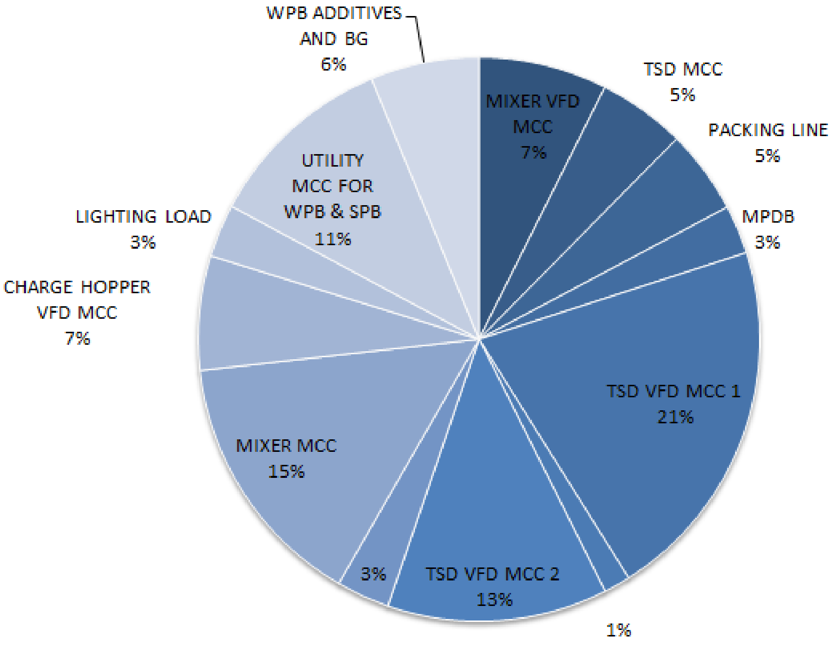

Figure 3.5: Load Sharing III

To understand the load pattern of plant, power analyzer was connected to the main incomer for 24 hours. Following is the summary of 24 hours load cycle. A total of 61960 kWh was recorded for that day.

Parameters	**Maximum**	**Minimum**	**Average**
Voltage (kV)	35.7	32.3	33.9
Ampere	60.8	8.58	45.5
MW	3.42	0.5	2.57
MVA	3.51	0.5	2.7
Power Factor	1	-0.995	-0.91 to 0.98
Frequency	50.3	49.6	49.9
THD (V) %	1.3	0.3	0.6
THD (A) %	12.3	2.84	5.3

Table 3.5: Power pattern of main incomer

3.4.2 Transformer Performance analysis

Being a static device, the losses of transformer are very low thus giving very high efficiency. The transformer losses comprise of two parts viz. (1) No load losses (Iron losses), which are assumed to be constant. (2) Variable losses (copper losses) which vary as square of load. However, it is well known that transformer efficiency is highest at about 50 % load. Actual load cycles of the individual transformers are measured by logging for a period of one hour for distribution transformers and 24 hour logging at main transformer connected at incomer to the plant, efficiency of individual transformers are calculated and summarized at average condition.

Observations

1. It is observed that main transformer is loaded more than 50 % of the rating.
2. Water based Paint Block (WPB) transformer4 is loaded in the range of 42-46 %
3. Solvent based Paint Block (SPB) transformer7 is loaded to about 40 %.
4. Transformer2 & transformer3 are loaded in the range of 10-15 %.

Particulars/ Rating	5000 kVA	2500 kVA (Utility HT Side)	2500 kVA (WPB HT Side)	2500 kVA (WPB HT Side)	2500 kVA (SPB HT Side)	2500 kVA (Utility LT Side)	2500 kVA (WPB LT Side)
Primary Voltage (kV)	66	11	11	11	11	11	11
Secondary Voltage (kV)	11	0.44	0.44	0.44	0.44	0.44	0.44
% Impedance	7.48	7.53	7.49	7.59	7.37	7.44	7.33
No Load Losses (kW)	4.53	2.27	2.27	2.15	2.17	2.27	2.15
Cu Losses (kW)	22.3	17.2	17.1	17	16.9	17.2	17
Operating load (kVA)	2669	348	288	1163	979	386	1050
Operating PF	1	0.99	0.99	0.98	0.99	0.99	1
Percentage Loading at average load (%)	53.38	13.92	11.52	46.52	39.16	15.44	42
Operating Load Loss (kW)	6.35	0.33	0.23	3.69	2.59	0.41	3.01
Total operating load loss (kW)	10.89	2.6	2.49	5.84	4.76	2.68	5.16
Power Output (kW)	2669	345	285	1140	969	382	1050
Power Input (kW)	2680	347	288	1146	974	385	1055
Efficiency (%)	99.59	99.25	99.13	99.49	99.51	99.3	99.51

Table 3.6: Transformer performance study

3.4.3 Motor load study

Most electric motors are designed to run at 50 to 100 percent of rated load. Optimum efficiency is usually near 75 percent of rated load. Thus, a 10 horsepower (hp) motor has an acceptable load range of 5 to 10 hp; peak efficiency is at 7.5 hp. Under-loaded motors, below 50 percent of rated load, are inefficient and exhibit low power factor. Low power factor results in increased electrical distribution system losses. Replacing under loading motors with correctly sized motors improves efficiency and raises power factor. Over loaded motors can overheat and loose efficiency. Following two options can save the energy according to the motor loading [2].

Table 3.7 shows the actual power measurements of motors and derived percentage loading based on installation details provided. Providing star-delta converters for under loaded motors, timer control for motors wherever it is feasible to avoid idle running of motors was suggested.

Suggestions for under performing motors

1. Replace oversize motor by proper sized high efficiency motor.
2. Convert under-loaded motors into permanently star connection
3. Using Energy saving devices like Auto Star Delta Converter, Variable frequency drives, Soft Starter etc.

Sr. No.	Description	Motor kW	Measured Load Volt	Ampere	PF	kW	% LOAD
1	Transfer Blower 1221	110	415	121	0.8	67.4	52.08
2	Transfer Blower 1209	110	415	118	0.71	60	46.36
3	Transfer Blower 6" line (Non Rutile) for 360	110	414	153	0.81	84.6	65.37
4	Transfer Blower 6" line for 660 SILO Blower 1214	75	415	82.2	0.67	39.3	44.54
5	Transfer Blower FIBC Non Rutile Blower 1206	75	415	71.6	0.66	34	38.53
6	Transfer Blower FIBC Non Rutile Blower 1210	75	413	73.8	0.6	31.9	36.15
7	Transfer Blower FIBC Line for 660 SILO Blower 1215	75	416	105	0.77	58.6	66.41
8	Mixer M106	55	418	42.2	0.58	17.9	27.66
9	Mixer M117	55	418	36	0.39	10.4	16.07
10	Mixer M114	55	416	53.3	0.72	26.2	40.49
11	Mixer M115	55	421	54.2	0.75	34	52.55
12	Mixer M217	9.3	422	9.3	0.17	1.12	10.24
13	Mixer M231	9.3	424	10.1	0.33	2.43	22.21
14	Mixer M605	9.3	423	8.57	0.55	3.3	30.16
15	CT509	11	416	19.9	0.35	5.06	39.1
16	CT507	11	416	24.8	0.38	6.83	52.78
17	CT508	11	417	26.4	0.34	6.46	49.92

Table 3.7: Motor load study

3.4.4 Compressed air System

Paint manufacturing facility has installed air cooled screw compressors for its compressed air requirement. Compressed air generated through compressors are passed through refrigerated air driers and collected in main receiver tank near compressor house having capacity of $12m^3$. From this receiver compressed air is distributed to different blocks of the plant, at the user end also receivers are installed of different capacities as per requirement to create buffer so that substantial pressure drop is avoided at the point of application [2].

Compressed air is generated at unload pressure of 6.8 bar from two of the compressors having capacity of 1000 CFM, whereas third compressor which is running on VFD operates at 7.9 8.0 bar at this pressure compressor RPM at variable speed to cater load fluctuations.

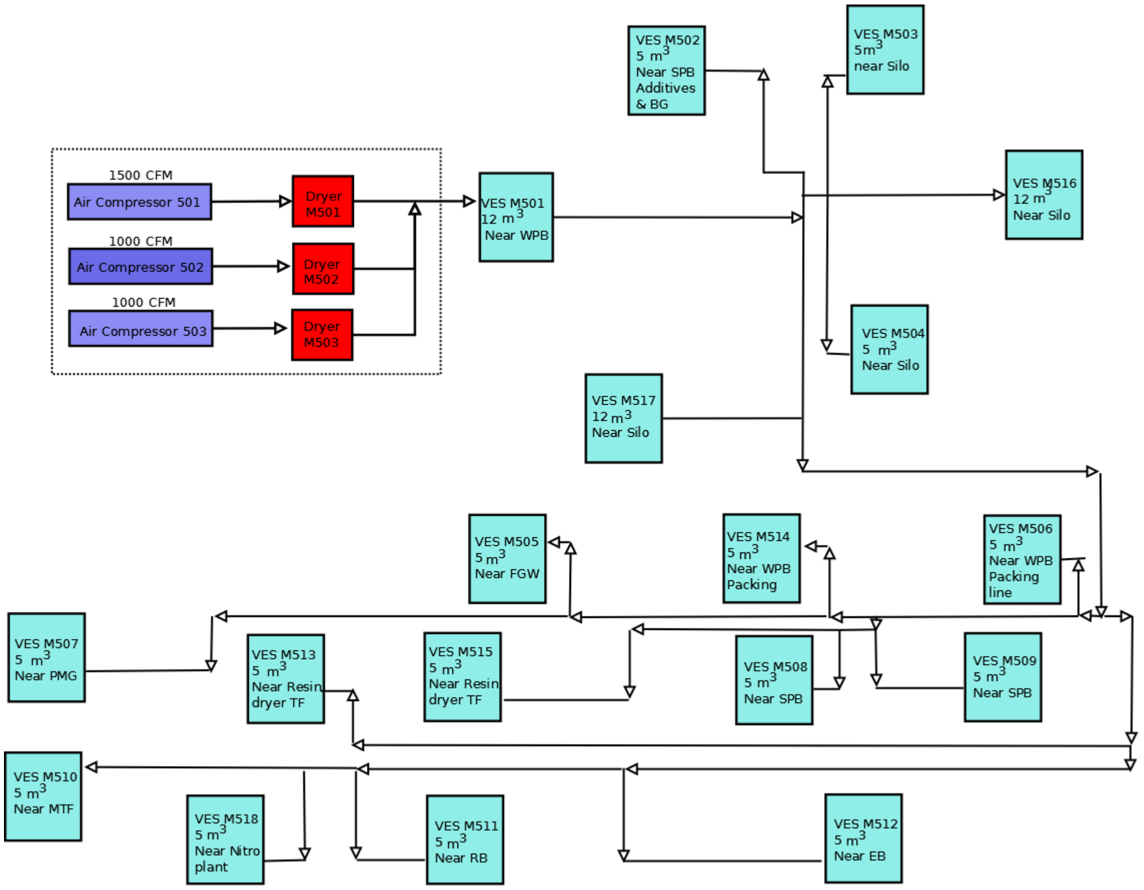

Figure 3.6: Compressed Air Network

Capacity Free Air delivered:

$$FAD\left(\frac{m^3}{s}\right) = \left(\frac{P_1 - P_0}{P_{atm}}\right) \times \left(\frac{v}{t}\right) \tag{3.1}$$

where,

P_1=Final Pressure setpoint (bar)

P_0= Initial Pressure setpoint (bar)

P_{atm}= Atmospheric pressure (bar)

v= volume of receiver tank and piping up to receiver (m^3)

t= time taken to reach P_1 to P_0 (sec)

Particulars	**Unit**	**Compressor 501**	**Compressor 502**	**Compressor 503**
Rated Capacity	CFM	1500	1000	1500
Rated Speed	RPM	1500	1500	1500
Maximum Working Pressure	bar	8.5	8.5	8.5
Rated Power	kW	250	160	160
Year of Manufacturing	year	2011	2011	2011
Make		Kaeser	Kaeser	Kaeser
VFD		Yes	No	No

Table 3.8: Installation details of compressors

3.4.4.1 Leakage test of compressed air network

In order to find if the compressed air supplied is utilized purposefully or is leaked at different points in the plant, leakage test is performed.

Pump Up Test for Air Compressors				
Parameters	**Unit**	**Compressor 501**	**Compressor 502**	**Compressor 503**
Receiver Volume	m^3	12	12	12
Piping Volume	m^3	0.962	0.816	0.816
Total Volume	m^3	12.962	12.816	12.816
Initial Pressure	bar	8	6.8	6.8
Final Pressure	bar	6.9	6.2	5.8
Time for Receiver fill up	secs	21	17	30
Capacity	m^3/hr	2412.94	1607.45	1533.33
Rated Capacity	**CFM**	**1500**	**1000**	**1000**
Capacity Delivered	CFM	1420.01	945.98	902.36
Measured Power	kW	271	160	170
Specific Power Consumption	**kW/CFM**	**0.1908**	**0.1691**	**0.1884**

Table 3.9: Pump up test for air compressors

Based on 24 hour power cycle, average air demand is calculated. Calculated air demand includes air leakages in the plant. Air demand calculation is represented below:

Air Demand Calculation from Power Cycle				
Parameters	**Unit**	**Compressor 501**	**Compressor 502**	**Compressor 503**
Total Cycle Time	hours	24	24	24
Total On time	hours	24	24	24
Total Off time	hours	0	0	0
Average Power from Cycle	kW	262	164	175
Capacity Delivered	m^3/hr	2413	1607	1533
Capacity Delivered	m^3/day	57911	38579	36800
Capacity Delivered	ft^3/day	2045094	1362396	1299574
Average Air Demand	CFM	1420	946	902
Average SPC	kW/CFM	0.1846	0.1729	0.1935
Average Air Demand	**CFM**	**3269**		

Table 3.10: Air demand calculation

The leakage test at various locations and their summary is as shown in table 3.11, 3.12, 3.13 and 3.14:

Leakage test at different locations				
Particulars	Unit	WPB	Entire Plant except WPB	Header Leakage Test
Load Time T	secs	90	197	53
Unload Time t	secs	71	377	49
% Leakage	%	0.56	0.34	0.52
Compressor for Trials	Tag	Comp. 503	Comp. 501 & Comp. 502	Comp. 502
Compressor Measured Capacity	CFM	902.36	2366	945.98
Calculated Leakage	CFM	503.4	1744.6	491.4

Table 3.11: Leakage test at different locations: I

Leakage test at different locations					
Particulars	Unit	SPB Process (Receiver 506)	SPB Packing (Receive 504)	SPB Robotics (Receiver 509)	WPB Robot + WPB Packing + FG (Receiver 514)
Load Time T	secs	209	69	81	111
Unload Time t	secs	36	53	48	52
% Leakage	%	0.85	0.56	0.63	0.68
Compressor for Trials	Tag	Comp. 502	Comp. 502	Comp. 502	Comp. 502
Compressor Measured Capacity	CFM	902.36	902.36	902.36	902.36

Table 3.12: Leakage test at different locations: II

Leakage test at different locations					
Particulars	Unit	Receiver 516,518,505,517 RMG1, SILO, ETP, EHS	WATF + BG1 (Receiver 508)	PMG (Receiver 502)	RMG3 (Receiver 507)
Load Time T	secs	126	75	126	62
Unload Time t	secs	71	43	39	42
% Leakage	%	0.64	0.64	0.77	0.6
Compressor for Trials	Tag	Comp. 502	Comp. 502	Comp. 502	Comp. 502
Compressor Measured Capacity	CFM	902.36	902.36	902.36	902.36
Calculated Leakage	CFM	84.9	83.2	199.1	46.5

Table 3.13: Leakage test at different locations: III

Leakage test at different locations				
Particulars	Unit	MTF Tank-farm (Receiver 510)	RB	EB
			(Receiver 512)	(Receiver 515)
Load Time T	secs	78	160	116
Unload Time t	secs	44	41	42
% Leakage	%	0.64	0.8	0.74
Compressor for Trials	Tag	Comp. 502	Comp. 502	Comp. 502
Compressor Measured Capacity	CFM	902.36	902.36	902.36
Calculated Leakage	CFM	85.5	226.9	172.5

Table 3.14: Leakage test at different locations: IV

Following observations were drawn from the leakage test for different locations.

1. Entire compressed air system leakage is calculated at 2248 CFM.

2. WPB has leakage of 503.4 CFM.

3. Entire plant leakage except WPB is calculated at 1744.60 CFM.
4. Header leakage when all the distribution end receiver inlets/outlets valves were closed was calculated at 491.4 CFM.
5. Compressed air leakage is 64
6. Numbers of leakage points were shown to APL team during the field visit.
7. it was also observed that numbers of solenoid valves were passing air in the plant area

3.4.4.2 Retrofitting and cost benefit analysis

Table 3.15 describes how savings in compressed air network is possible by stopping leakage points

Compressed Air Leakage Reduction		
Particulars	**Unit**	**Values**
Compressed air leakage in WPB block	CFM	503.38
Compressed air leakage in entire plant except WPB	CFM	1744.6
Total Leakage	CFM	2247.99
Specific Power Consumption for saving estimation	kW/CFM	0.18
Saving Potential Available	kW	404.64
Percentage total compressed air generation	CFM	3268.36
Existing Leakage percentage	%	68.78
Percentage Leakage to be plugged	%	75
Leakages to be plugged - proposed	CFM	1685.99
Saving Potential to be achieved	kW	303.48
Operating Days	days	330
Operating Hours	hours	24
Saving Potential to be achieved	kWh/annum	2403547
Saving Potential to be achieved	Rs./annum	18566970

Table 3.15: Air leakage reduction and Cost Benefit Analysis

Other studies in the formation of detail energy audit include water pumping system, Cable losses calculation, Harmonics analysis,cooling tower performance and performance of chillers. The findings have been excluded since it were carried out by other members of team DESL.

3.5 Thermal System

Thermal system includes mainly the thermal energy and temperature required for process and material heating. This heat is provided by two main utilities namely boiler and TFH

3.5.1 Boiler system

The main unit of the paint facility is divided in to the four different blocks mainly Water base paint, Solvent base paint, Resin & emulsion block. The resin & emulsion blocks are the major consumers of the steam, which is coming approximately 1 to 1.5 Ton/hr of steam flow. The current steam requirements of these sections is supplied by two numbers, diesel fired 3 pass fire tube boilers located in utility 2 section of the plant. Both of these boilers operating as one running & one standby, steam generation pressure through boiler ranges from 8 to 8.5 kg/cm^2. The total fuel consumption of these boilers is about 50 to 56 ltr/hr (measured). Fuel used in these boilers is High Speed Diesel (HSD), which is having calorific values as (GCV) 10942 kcal/Kg & NCV 10540 kcal/kg.

3.5.1.1 Performance Evaluation of boilers

Performance evaluation for each boiler with their present running flue gas analysis & Performance analysis by heat loss method is described below:

Performance analysis by Heat loss method		
Boiler No	1	
Location	Utility 2	
Capacity	3	
Input/ Output Parameter	kcal/kg of HSD	% Loss
Heat input	10540	100
1. Heat loss in dry flue gas	384.4	3.65
2. Heat loss due to formation of water from H2 in fuel	824.4	7.82
3. Heat loss due to moisture in fuel	0.4	0
4. Heat loss due to moisture in air	61.4	0.58
5. Heat loss due to partial conversion of C to CO	1.4	0.01
6. Total Radiation & convection loss/Hr	206.4	1.96
Boiler Efficiency	**85.97**	%

Table 3.16: Performance analysis of 3 TPH boiler 1

Performance analysis By Heat loss method		
Boiler No	2	
Location	Utility 2	
Capacity	3TPH	
Input/ Output Parameter	**kcal/kg of HSD**	**% Loss**
Heat input	**10540**	**100**
1. Heat loss in dry flue gas	385.2	3.65
2. Heat loss due to formation of water from H2 in fuel	820.3	7.78
3. Heat loss due to moisture in fuel	0.4	0
4. Heat loss due to moisture in air	61.4	0.58
5. Heat loss due to partial conversion of C to CO	2	0.02
6. Total Radiation & convection loss/Hr	206.4	1.96
Boiler Efficiency	**86**	%

Table 3.17: Performance evaluation of 3 TPH boiler 2

3.5.1.2 Recommendation and Saving potential

Recommendations

- Suggestion of installing online efficiency monitoring system to monitor the flue gas oxygen and fuel optimization for proper combustion.
- Condensate Recovery: Re-use high temperature condensate from process for boiler feed water heating by mixing it with boiler feed water.
- Also provide feed water heating system with temperature controller & one control valve to increase the feed water temperature up to 95 °C.
- Both condensate recovery & feed water heating will increase the boiler output on the same fuel input. (Run the boiler nearer to designed From and At (F & A) which is 100 °C) [2].
- Provide temporary removable insulation to boiler shell opening, so that at the time of boiler inspection it can be removed and fixed again.
- Insulation was not proper at many locations; recommend providing proper insulation to minimize surface heat losses.

Savings potential

This section includes opportunity for fuel saving for the presently working boilers

Saving on Excess air control		
Parameters	**Values**	**Units**
3 TPH Boiler Excess air	55	%
Present Excess air	116.5	%
Proposed Excess air	55	%
Present % heat loss in dry flue gas	3.6	%
Proposed % heat loss in dry flue gas	1.5	%
Saving Percentage	2.1	%
GCV of HSD	10942	kcal/kg
Boiler Running hours	3960	hr
Heat loss Saving	234.9	kcal/kg
Fuel consumption	47	kg/hr
Energy saving	10970.5	kcal/hr
Fuel saved	1	kg/hr
Total Fuel Saving	5293.8	kg/annum
Fuel Cost	65	‘/kg
Total Savings	2.6	‘ Lacs/annum
Investment for Excess air control system	0	‘ lacs
Simple Pay back	Immediate	Months

Table 3.18: Saving on excess air control

The boilers are already equipped with efficiency monitoring system, but this efficiency monitoring system is not tuned in line with boiler operation. This system will control the excess air to the optimum level as per burner requirement & this will help to reduce the present fuel consumption by 5394 kg/annum

Savings on Insulating Boiler shell openings		
Parameters	**Values**	**Units**
Area of un-insulated boiler body	0.25	m^2
Surface Temperature	173.6	°C
Radiation heat losses	2	%
Proposed % heat losses	1	%
Saving percentage	1	%
GCV of HSD	10942	kcal/kg
Boiler running hours	3960	hrs
Fuel Consumption	47	kg/hr
Heat loss savings	104.8015	kcal/kg
Energy Saving	4925.67	kcal/hr
Fuel Saved	0.450162	kg/hr
Total Fuel Saving	2376.854	kg/annum
Fuel Cost	65	‘/kg
Total Savings	1.16	‘ Lacs/annum
Cost of insulating window	-	‘
Simple Pay Back	Immediate	months

Table 3.19: Savings on Insulating Boiler shell openings

Condensate Recovery

The condensate return from process collected at the underground tank near emulsion Block and Resin Block can be recovered at 92-93 °C. The condensate returned to feed water will improve boiler efficiency and saving in cost of feed water (Delivery and Treatment). For recovery option, a well-insulated feed storage tank is to be designed. Tank capacity of 5000 litre is recommended

Assumptions

1. The feed water consumption is taken after warming up of boiler.
2. The fuel consumed during boiler warm up is not considered.
3. Mass flow rate of feed water is kept constant for steam required in every batch.
4. The boiler operating hours does not count warm up period.
5. Boiler running hours 10-11 hours/day

Savings in Steam Condensate and Direct steam Injection		
Option1-I Only Condensate Recovery		
Parameters	**Value**	**Unit**
Feed Water temperature	30	°C
Mass flow rate of feed water	665	kg/hr
Mass flow rate of Condensate	304	kg/hr
Temperature of condensate	92.4	°C
Volume of New tank	2	kL
% Recovery	50	%
Tank feed water temperature after 4 hrs of continuous condensate recovery	68	°C
% Potentially Improved boiler efficiency	3.8	%
GCV of Fuel	10942	kcal/kg
Heat recovery	400.52	kcal/kg
Boiler operating hours	3960	hr
Fuel consumption	46.704	kg/hr
Energy req. from fuel before savings	492260.2	kcal/hr
Fuel Required after savings	44.99422	kcal/hr
Fuel Savings	1.70978	kg/hr
Fuel cost	65	‘/ltr
Total Savings	5.28	‘ Lacs/annum
Investment	76000	‘
Simple Pay Back	Less than 7	months

Table 3.20: Condensate recovery option: I

Case-II Condensate Recovery and Steam injection		
Details	Value	Unit
% Recovery	50	%
Tank Feed Water temperature after 3 hrs of continuous condensate recovery	59	°C
% Steam Injection	13	%
Raise in temp of feed water in tank	80	°C
% Potentially improved boiler efficiency	5	%
GCV of fuel	10942	kcal/kg
Heat Recovery	527	kcal/kg
Boiler operating hours	3960	hr
Fuel consumption	46.704	kg/hr
Energy req. from fuel before savings	492260.2	kcal/hr
Fuel Required after savings	44.48	kg/hr
Fuel Savings	2.224	kg/hr
Fuel cost	65	‘/ltr
Total Savings	6.864	‘ Lacs/annum
Investment	1.12	‘ Lacs
Simple Pay Back	Less than 2	months

Table 3.21: Condensate recovery option: II

Savings on Insulating the steam line		
Parameter	**Quantity**	**Unit**
Total Heat Loss saved by insulation covering	6307	kcal/hr
GCV of HSD	10942	kcal/kg
Rated Efficiency of Thermo-pack	89	%
Saving of fuel in Kg/hr	0.65	kg/hr
Saving of fuel in Litre/hr	0.78	Litre/hr
Specific gravity of HSD	0.83	-
Operating Hours in a year	5280	Hour/year
Fuel saved in Litre/Year	4097	Litre/year
Fuel cost in Rs/Litre	65	‘/litre
Savings in Rs/year	266273	‘/year
Savings in Lac Rs/year	2.7	Lac ‘/year
Insulation cost	0.11	Lac ‘
Payback period	1	Month

Table 3.22: Savings on insulating the steam lines

Other studies in the formation of detail energy audit include performance of thermic fluid system, process steam requirement and reduction feasibility study. The findings have been excluded since it were carried out by other members of team DESL.

3.6 Outcome of Energy Audit

After submission of detailed energy audit report to the concerned authorities the case studies and its saving potential was discussed. The outcome of which resulted in implementation of several feasible solutions that are described in table 3.23.

Proposal	Solution	Implemented	Month of completion
1	Compressor Air Leaks to be sealed at 116 points	Yes	Dec-14
2	Chiller water pumps be replaced with suitable head	No	
3	Cooling tower pumps be replaced with suitable head	Yes	Dec-14
4	Ensure proper air drafting by blower control in TFH	Yes	Nov-14
5	Boiler steam condensate recovery up to 60%	Yes	Under construction

Table 3.23: Implementation status on energy improvement solutions

The impact of implementing the energy improvement solution is observed on the overall SPC of the plant. Table3.24 shows the considerable reduction in SPC.

Month	Production (kL)	Consumption (kWh)	SPC (kWh/kL)
Sep-14	16287.57	2095650	128.67
Oct-14	13269.48	1765223	133.03
Nov-14	15412.66	1960912	127.23
Dec-14	15863.05	1865157	117.58
Jan-15	15702.60	1705455	108.61

Table 3.24: Overall monthly SPC of plant

Chapter 4

Case Study on Process Mapping: Material Charging

Since there are abundant simultaneous processes occurring in the Paint facility at Pune, the domain of this project has been narrowed to the most rigorously complex one which is the Material Charging Process. A systematic process mapping of Material charging was studied on field. The observation, calculation and methodology is discussed in this chapter.

The Raw Material Godown (RMG)s store elementary raw material that is unloaded from trucks and stored by storekeepers. There are 3 RMGs present inside the plant. These are used as primary constituents in both water based and non water base paints. From RMG there are 3 major and 2 minor material transfer stages that are described in next section:

4.1 Process stages

4.1.1 FIBC to silo

In this stage material from Flexible intermediate bulk container (FIBC) is conveyed to respective designated silo number from specific silo group. These FIBCs come in package of 0.1 ton, 0.5 ton or 1 ton. They are lifted to conveyor through hoists. Powder from the conveyor is pulled by created negative draft using transfer blower.

bag thrashes and other impurities in the powder is removed from intermediate stage passing from vibrator to Rotary Air Lock (RAL). Since powder in each vessel/pass is flowing sequentially it obvious that each pass will take same operating time until the charging to silo is finished[4]. There are seven such units present in the plant. unit 1 to 5 comprise of same rating of transfer blowers while rest two are of lesser ratings. There are 13 channels installed to convey any given powder to the desired silo number.

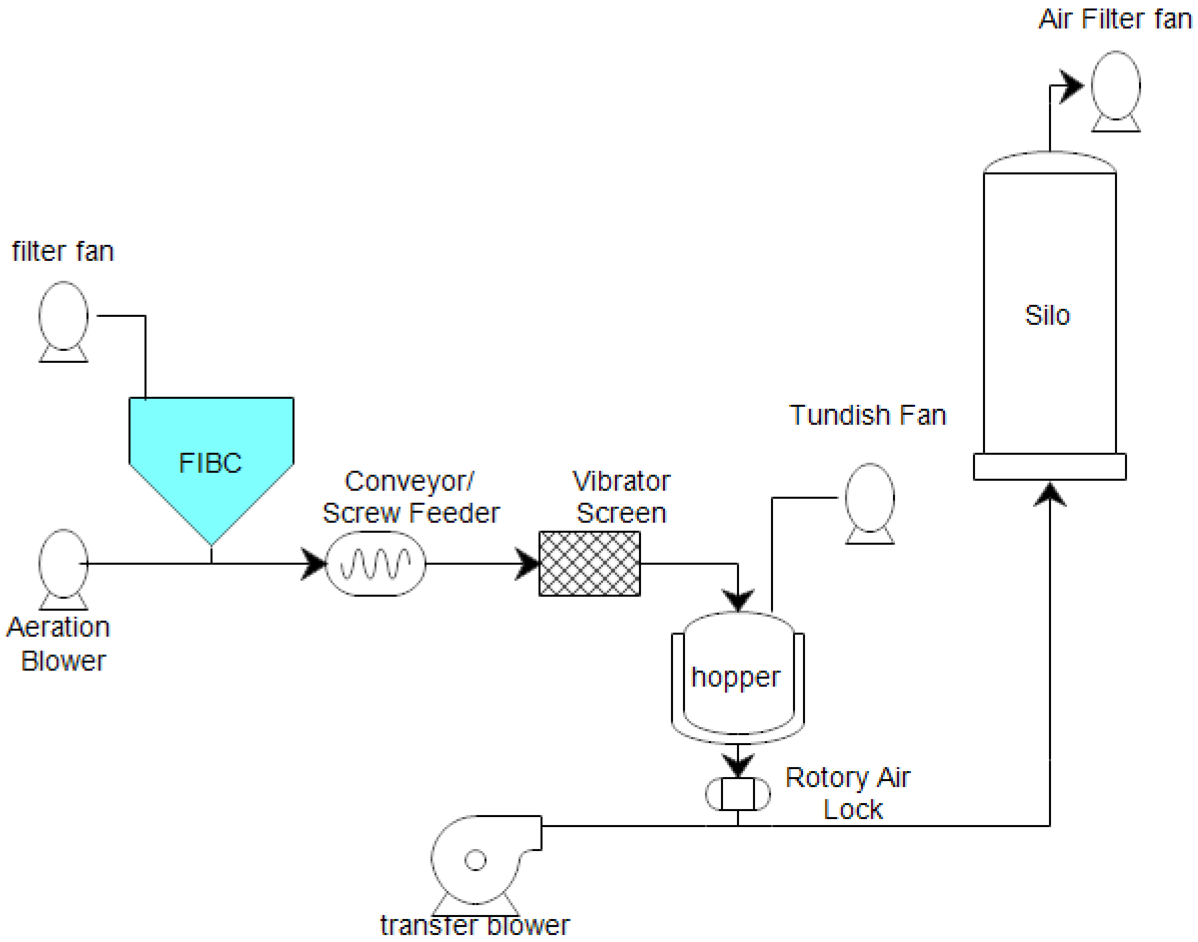

Figure 4.1: FIBC to Silo

4.1.2 Silo to Weighing Hopper

Silos are large vertical storage vessels that contain raw materials in a controlled physical conditions. At present, 46 Silos are installed inside the plant. Based upon the storage size of the silo they are categorised as follows: Based on the formulation of

Silo Group	Silo Capacity	Number of Silo
660	660-600 m^3	12
360	380-360 m^3	12
220	220-200 m^3	14
100	100-80 m^3	8

Table 4.1: Silo Grouping

paint batch, quantity of materials involved are transferred from silo to Weighing Hopper. Components used are Screw Feeder Drive (SFD) (conveyor), Rotoflo, aeration blower,RAL and vent fan (at certain events).

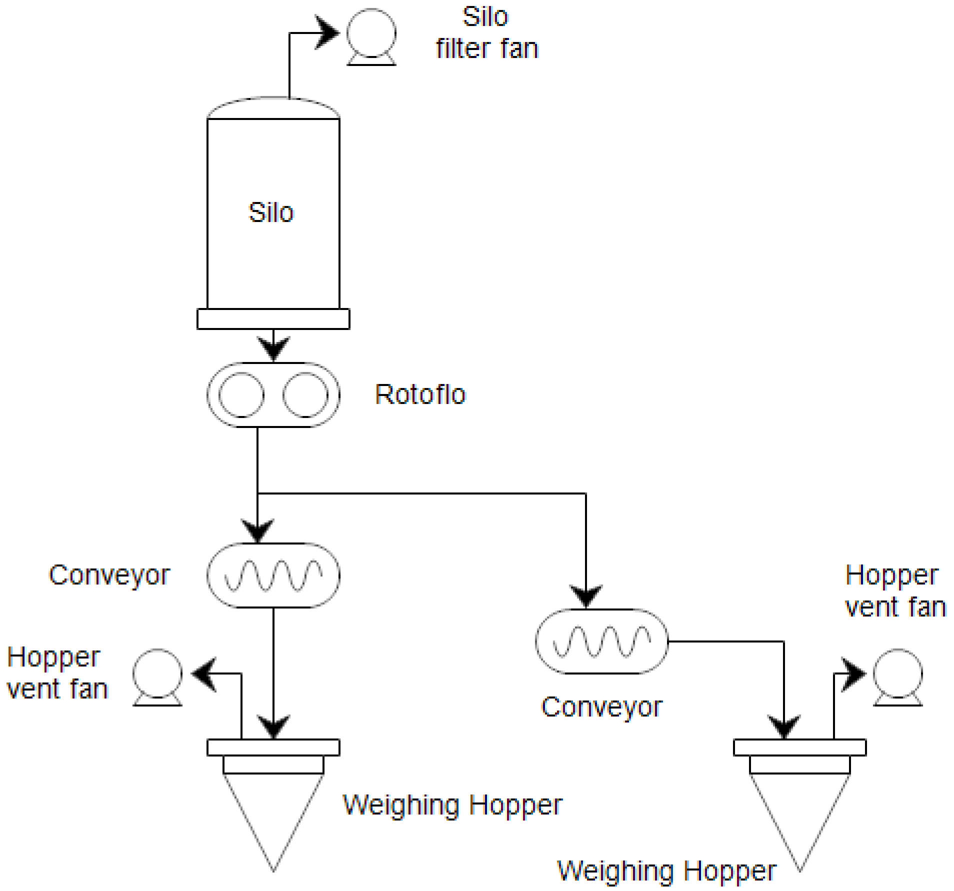

Figure 4.2: Silo to Weighing Hopper

At present there are 12 Weighing Hoppers inside the plant. 8 Hoppers are dedicated to water base paints and others for solvent base paints. All 12 of them can be charged at a same time.

4.1.3 Weighing Hopper to Charging Hopper

Material from weighing hoppers is transferred to charging hopper before starting the grinding in TSDs. Amount of powder for Batch formulation quantity is charged and and is premixed in the charging hopper. Vessels/passes like RAL, screw feeder, aeration blower and vent fan are used simultaneously for transferring.

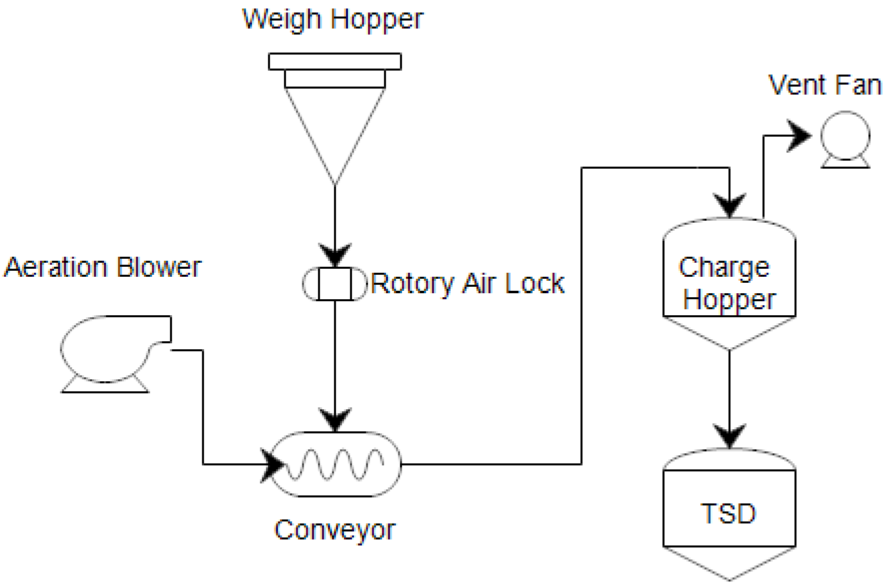

Figure 4.3: Weighing Hopper to Charging Hopper

There are 7 Charge Hoppers installed inside the plant. After adequate cleaning of TSD, powder from Charging Hopper (CH) is dropped in it.

Similar to Charging hoppers there are 5 Minor Charge Hopper (MCH) installed. The methodology of conveying is same for MCH. Apart, from these bulk material transfer there are pigment silos and Daybin (DB) that are used for minor powder charging. The storage and conveying of material in these systems are not considered in the study part since the connected load and power requirement of these systems is very small as to affect the SPC.

Chapter 5

Improvisation in methodology: Material Charging Process

The driving force such as transfer blower, aeration blower in each process stage discussed above are the major power consuming machines. While machines that are used for delivering such as screw feeder and Rotoflo also contribute in power consumption. Following are the key points observed in the methodology of material charging before feedback and suggestion to them.

5.1 Existing Methodology

1. Each record of time taken with time stamp to charge material from FIBC to silo is maintained (material wise).
2. Two or more silos may be used for storing a common material, depending on the demand of the material for producing bulk batches.
3. The silo number does not change for designated powder for 4 months i.e same material is to be stored in the assigned silo throughout the quarter.
4. Loss of material during charging is strictly kept below 0.1 % i.e for 1000 kg of charging loss of material above 1 kg is not tolerated and the operation is halted until the Standard operating Practice (SOP) is retained.

5. The same record of conveying time, filling time and discharge time is maintained with time stamp for process stages like silo to Weighing Hopper (WH) and WH to CH.
6. The quantity of powder to be charged from silo to WH is monitored and controlled by setting the necessary RPM of Rotoflo (primary digital controlled pump) with the Digital Control System (DCS) supervised by production engineer. The same is followed for process stage WH to CH.
7. There are two modes of speed operation of Rotoflo for material charging. These are bulk charging and trickle charging namely. RPM of Rotoflo is kept higher for bulk charging until the quantity reaches near to the desired amount. Trickle charging is for fine delivery of material at lower RPM. Rotoflo RPM and trickle time are variable quantities that can be controlled from DCS by production engineer.
8. Conveying mechanism is started and roused for uncertain time before opening the valves at silo and weighing hopper for material discharge.
9. No provision of standard time of operation for the above mentioned procedures.
10. Unavailability of metering of energy measurement for individual process stage equipment.

5.2 Standard Charging Time

To improvise charging time and hence saving equipment for running unnecessarily a trial method of performance was carried out. This method was earlier performed in the different plant unit of the paint company and is known as “Performance trials by Dennis” [3]. According to the method Standard design time for conveying of material from Silo to WH was tested.

As we are dealing with raw material in powdery form the control of their discharge is done by controlling three main power utilising machines, they are:

1. Pneumatic conveyor

2. Rotoflo
3. Rotary Air Lock valve

Following are the major constraints that affect the discharge of material [3]:

i. Designated Material (kg)
ii. Conveying pressure of silo [high & low] ($mbar$)
iii. Rotoflo full speed set point (%)
iv. Rotoflo trickle speed set point (%)
v. Hopper discharge screw full speed set point (%)
vi. In flight allowance (%)
vii. Conveying pressure for charge hopper filling [high & low] ($mbar$)
viii. Trickle feed allowance (%)

5.3 Calculation of Standard Transfer Time:

Input Control Parameter

Flow rate from Rotoflo (v $(\frac{m^3}{hr})$) by Speed of Rotoflo: N (RPM)

Desired Output

Target mass for batch: m_d (kg)

Error between target mass and actual mass: Error % $\leq$ 0.1 %

Variable

Actual Time taken= $t_a(sec)$

Design Time $t_d(sec)$

$$t_d = t_b + t_t \tag{5.1}$$

where,

t_b = Bulk time for bulk charging and

t_t = trickle time for trickle charging

$$t_b = \frac{m_b}{\rho \times v_b} \tag{5.2}$$

where,

Density of material: $\rho\ (\frac{kg}{m^3})$ and $(v_b \propto N)$

$$t_t = \frac{m - m_b}{\rho \times v_t} \tag{5.3}$$

Hence design time,

$$t_d = \frac{3600 \times m_b}{\rho \times v_b} + t_t \tag{5.4}$$

5.3.1 On field time trials

Trial for each material for Silo to WH and WH to CH was carried out using these equations and changing the set point of Rotoflo for precision charging. Trickle charging is done reduce % error in batch weight; it is obvious that at lower speed the power consumption of equipment also reduces. But since this time is less than 5 % of bulk time, the power consumed can be assumed to be same.

Charge Details			m_d	% Error	N RPM	t_d	t_a	% of t_d
source	Destination	Density kg/m^3						
Sil-M1204	WH-M1204	678	3351.6	0	900	654	1171	179
			1873.6	0.1	1100	194	256	132
			1873.6	0.03	1200	194	246	127

Table 5.1: Performance Trials sample

Design Standard for charging material with density 678 kg/m^3 for process stage Silo to WH is 194 s, best achievable time is 246 s. The exercise was repeated for each material since density of each material is different.

Chapter 6

Benchmarking of Specific Power Consumption: Material Charging Process

Based on the designed connected material charging system for bulk handling, derivation of SPC for certain products was calculated. The methodology applied to calculated SPC is described in this chapter.

6.1 methodology

For process stage Silo to Weigh hopper which is critical to bulk handling, the Proportional Integral Derivative (PID) control to above listed machines is necessary. The control must establish lean pneumatic conveying which is considered to be high energy efficient [4]. Consider the below given example for calculating SPC of material charging process: 6 raw materials are ingredients in a recipe for a given paint product. Table6.1 briefs the information of ingredients

For charging of material X1[1] in M1 quantity, from FIBC to silo, energy calculation

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[1] The original names of products and materials are replaced due to company‘s confidentiality policy

Raw material	**Density (kg/m3)**	**Ingredient weight (kg)**	**% *w/w***
X1	580	M1=1061	7.04
X2	290	M2= 566	3.76
X3	463	M3= 1415	9.38
X4	482	M4= 2830	18.78
X5	836	M5= 4670	30.99
X6	970	M6= 4529	30.05

Table 6.1: paint product data sheet

is done as follows

$$P_{11} = t_1 \sum_{i=1}^{8} a_{1i} \quad \text{kWh} \tag{6.1}$$

where, a_{11} = measured power of FIBC filter fan

a_{12} = measured power of aeration blower

a_{13} = measured power of pneumatic conveyor

a_{14} = measured power of vibrator screen

a_{15} = measured power of rotary air lock

a_{16} = measured power of tundish fan

a_{17} = measured power of transfer blower

a_{18} = measured power of silo air filter fan

t_1 = time taken for transferring

It is to be observed that time taken by each machine will be same as each of it is operating simultaneously.Similarly for process stage Silo to Weigh Hopper, energy calculation is done as follows:

$$P_{12} = t_2 \sum_{i=1}^{4} a_{2i} \quad \text{kWh} \tag{6.2}$$

where, a_{21} = measured power of pneumatic conveyor

a_{22} = measured power of vent fan

a_{23} = measured power of rotoflo

a_{24} = measured power of silo air filter fan

t_2 is the standard transfer time calculated through field trials for process stage

For process stage Weigh hopper to charge hopper, energy calculation is done as follows:

$$P_{13} = t_3 \sum_{i=1}^{6} a_{3i} \qquad \text{kWh} \tag{6.3}$$

where, a_{31} = measured power of rotary air lock
a_{32} = measured power of pneumatic conveyor
a_{33} = measured power of aeration blower
a_{34} = measured power of silo aeration blower
a_{35} = measured power of transfer blower
a_{36} = measured power of vent fan
t_3 is the standard transfer time calculated through field trials for the process stage
Summing up the process stage energy, the total energy consumed in material charging of X1 is,

$$P_1 = P_{11} + P_{12} + P_{13} \qquad \text{kWh} \tag{6.4}$$

Thus, the specific energy consumption of material X1 is,

$$E_1 = \frac{P_1}{M1} \qquad \frac{kWh}{kg} \tag{6.5}$$

If these calculations are considered per hour per ton of material then, the specific power consumption is said to be kW/ton. Now if the calculations are repeated for each material charging then,

$$S = \frac{\sum_{i=1}^{6} E_i}{\sum_{i=1}^{6} M_i} = \frac{E_{total}}{M_{total}} \qquad \frac{kW}{batch} \tag{6.6}$$

Hence, S is the the Specific Power Consumption for a given paint product. Table6.2 describes SPC for material charging proces of different paint products which are calculated using the above technique.

Product Name	SPC	Tolerance		Unit
		+5%	-5%	
TE1	3.223	3.384	3.062	kW/batch
AC7	3.357	3.525	3.189	kW/batch
Classic White	3.910	4.105	3.714	kW/batch
AC2	3.085	3.240	2.931	kW/batch
BR White	3.529	3.705	3.352	kW/batch
AB2	3.820	4.012	3.629	kW/batch
AC9	2.893	3.038	2.749	kW/batch
AB6	3.433	3.605	3.262	kW/batch
HQ6	3.321	3.487	3.155	kW/batch
PRIMER WHITE	3.951	4.148	3.753	kW/batch
AB15	2.856	2.999	2.713	kW/batch
AB17	3.963	4.161	3.765	kW/batch

Table 6.2: Benchmarked SPC for different paint products

6.2 Power Comparison of Material Charging Process

Energy from transfer transfer time, instant power measurement of each power utilizing machine for individual process stage and their batch quantities was calculated. Also a power report of Silo block energy meters was taken for reference of comparison. The results are found as mentioned below:

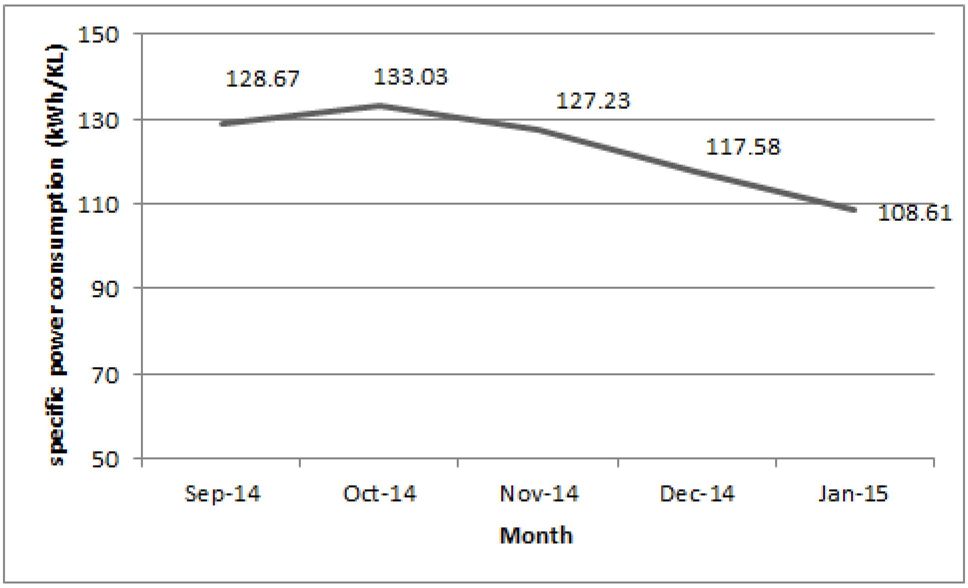
Sr. No	**Particulars**	**Month**		**Unit**
1	Month	Sep-14	Jan-15	
2	production	16287.57	15702.6	kL
3	Actual Consumption	167404.7	130260.6	kWh
4	As per benchmark Consumption	107740	111294	kWh
5	Potential Saving	59664.7	18966.6	kWh/month
6	Potential Saving	417652.9	132766.2	Rs./month

Table 6.3: power comparison of material charging process

Chapter 7

Conclusion

- The implementation of several suggestions enlisted in detail energy audit study resulted in observable reduction in SPC of the plant since November 2014.



- By monitoring the benchmark standards for material charging and taking necessary actions, the % variation between actual power consumption and benchmarks is reduced to 14.56 from 35.64 in the span of 5 months (Sept-14 to Jan-15) in paint manufacturing facility.

- Improvement in overall SPC is possible if the study on other processes is carried out in future.

Chapter 8

Future Work

The present work contains the scope of standardizing one of the processes in the paint manufacturing facility, however it projects many opportunities for future work that are enlisted below:

a) A separate study on improving the operation and maintenance utilities of the plant can be conducted to further reduce specific power consumption.

b) Deriving the SPC (specific Power consumption) of other processes and hence SPC for total plant comprehensively.

c) Improving other processes to make them energy efficient by further research and technical on-field implementation to verify results.

d) The benchmark standards discussed in this document are relative to specific paint manufacturing facility. These standards can be compared by conducting a field survey and comparison with other paint manufacturing companies across the world having same production process. After comparing with world standards if there lies any scope of improvement then necessary corrective actions may to be taken to achieve the same.

References

[1] `http://www.equitymaster.com/research-it/sector-info/paint/Paints-Sector-Analysis-Report.asp`.

[2] *Books on Energy Management.* Bureau of Energy Efficiency, Ministry of Power, Government of India, 2005.

[3] Portasilo Pvt Ltd. *Bulk handling system.*

[4] CM Shukla et al. Energy conservation for a paint company using lean manufacturing technique. *Universal Journal of Industrial and Business Management*, 1(3):83–89, 2013.

[5] Rodger Talbert. *Paint technology handbook.* CRC Press, 2007.