ENERGY AUDIT OF THREE PHASE INDUCTION MOTOR WITH CAPACITOR BANK PLACEMENT

Dissertation submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ENGINEERING
in
POWER SYSTEMS & ELECTRIC DRIVES

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CERTIFICATE

I hereby certify that the work which is being presented in dissertation entitled, **"ENERGY AUDIT OF THREE PHASE INDUCTION MOTOR WITH CAPACITOR BANK PLACEMENT"**, in partial fulfillment of the requirement for the award of the degree of Master of Engineering in Power Systems and Electric Drives at Thapar University, Patiala is an authentic record of my own work carried out under the supervision of **Ms. Manvir Kaur, Lecturer (EIED).** The matter embodies in this dissertation has not been submitted for the award of any other degree to any other university.

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ABSTRACT

Rice Industry being one of most energy intensive processes holds a good promise of saving electrical energy. This dissertation through one of its preliminary study of a major rice manufacturing plant Dunar Rice industry in Karnal identifies the key areas where electrical energy can possibly be saved. Induction motor being the major energy consumer in the plant offer opportunities of energy saving. In the plant many induction motors are in-house rewound. This work reports the analysis done on rewound induction motor for its efficiency. Practical comparisons between rewound motors and new motors are shown. It is found that rewound motors, if replaced by new ones, have a payback period in the range of 2 years to as less as 6 months.

In second part capacitor placement is done and results are analyzed on energy auditing after power factor improvement by installing capacitor bank to the different motors. Data analysis has shown that the total capital cost and benefits increased but the payback period is decreased as compared to first analysis.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Rice is the staple food of majority of Indians and specifically in South Indian. Rice comes out after milling of paddy. Rice mills are the lifeline for the economic development of rural India. The rice mills are generally located in the rural areas and near to paddy growing area [18]. There are about 108 rice mills in Haryana.

The cost of energy as a percentage of processing cost of paddy cost varies anywhere between 4% to 5%. The rice milling units in the cluster use wood, GN Husk and Rice Husk as fuels for Boilers, hot air dryers etc. [20].The major activity of the cluster units is processing of paddy for production of rice to cater for the domestic market [17]. The rice produced in these mills are of medium and high quality and is marketed through dealer network in different places of the state [18]. The most common variety of rice produced in the cluster rice mills is Ponni rice for domestic market requirement. The most typical feature of the Ponni rice is the final moisture content is maintained at 8.5% to 9.0%, where as in the normal practice in other types the final moisture content is maintained at 12% to 13%.

1.2 Classification of Rice Mills:

The rice mills can be broadly classified as:

1.2.1 Classification based on production:

There are about 108 units of rice mills, the rice mills can be categorized into two types based on production capacity, and they are:

- Less than 15 TPD
- Above 15 TPD

There are 40 rice mills having production capacity less than 15 TPD and balance 68 rice Mills falls under second category having production capacity more than 15 TPD. The Classification based on production capacity is furnished graphically in Fig. 1.1.

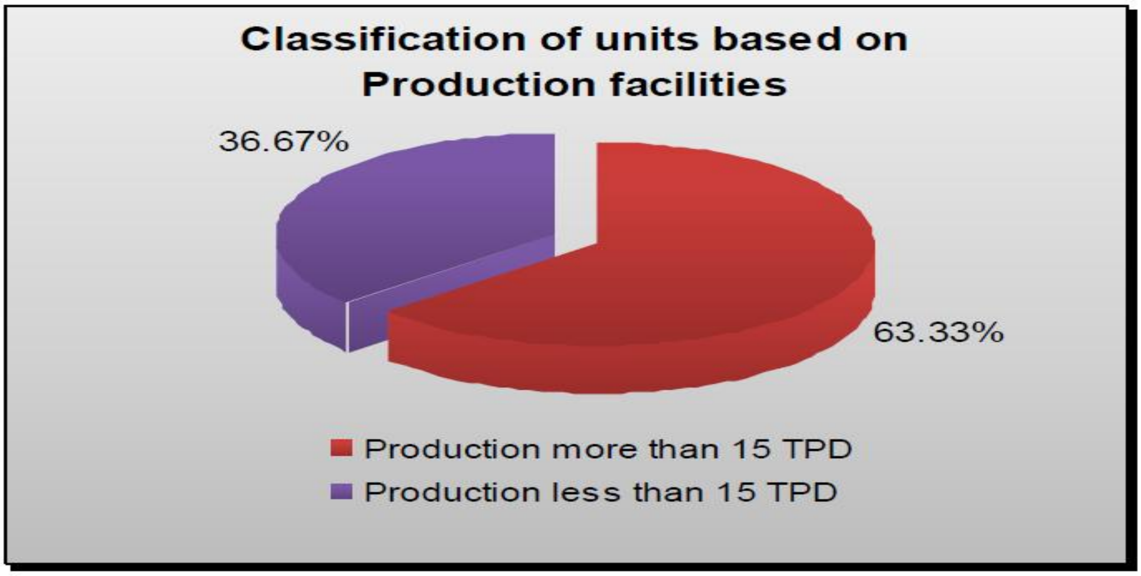


Fig. 1.1: Classification of units based on production facilities

1.2.2 Classification based on annual energy bill:

Out of 108 units, 32 units have energy bill below Rs.30 lakhs per annum, 50 units have Energy bill between Rs.30 lakhs to Rs. 40 lakhs per annum and the balance 26 units have Energy bill above Rs. 40 lakhs. The classification based on annual energy bill is furnished Graphically in Figure 1.2.

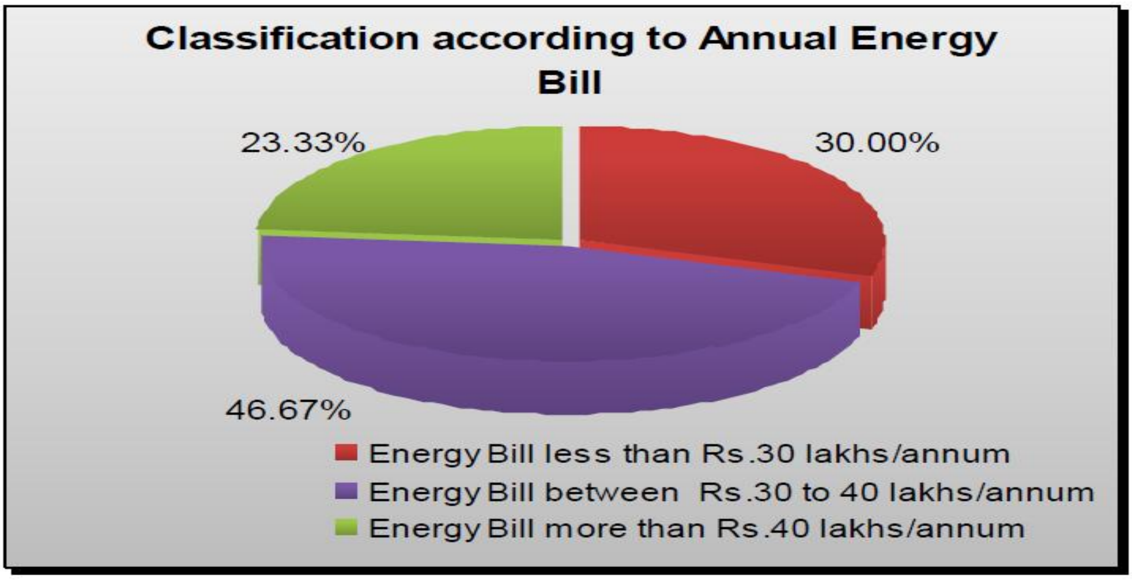


Fig. 1.2: Classification of units based on annual energy bill

1.3 Rice Manufacturing Process

In Rice industry, two types of rice are prepared:

1) Raw Rice
2) Boiled Rice

1.3.1 Raw Rice manufacturing process

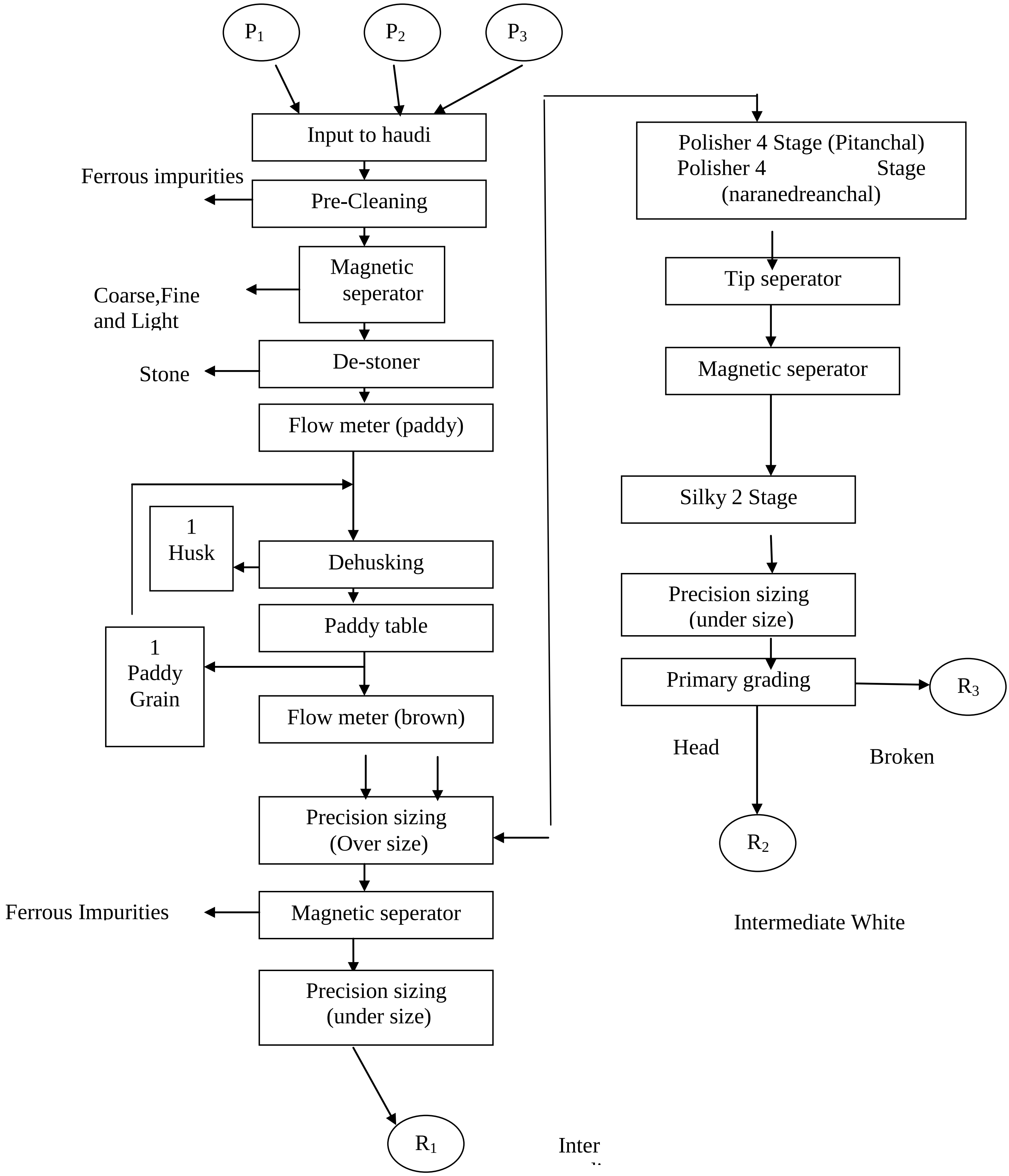
- Paddy is put in the elevator
- Cleaner
- De Husker /Rubber Sheller/Huller
- Separator
- Polisher
- Grader
- De Stoner (separate small stones)

1.3.2 Boiled Rice manufacturing process

- Paddy is placed in hot water for 12 hrs
- Cleaning
- Boiler /Husk feeder
- Dryer
- Rubber Sheller
- Separator
- Polisher
- Grader
- De Stoner.

1.3.3 DUNAR RICE MILL MANUFECTURING PROCESS:

1.3.1 Detailed description of DUNAR manufacturing process



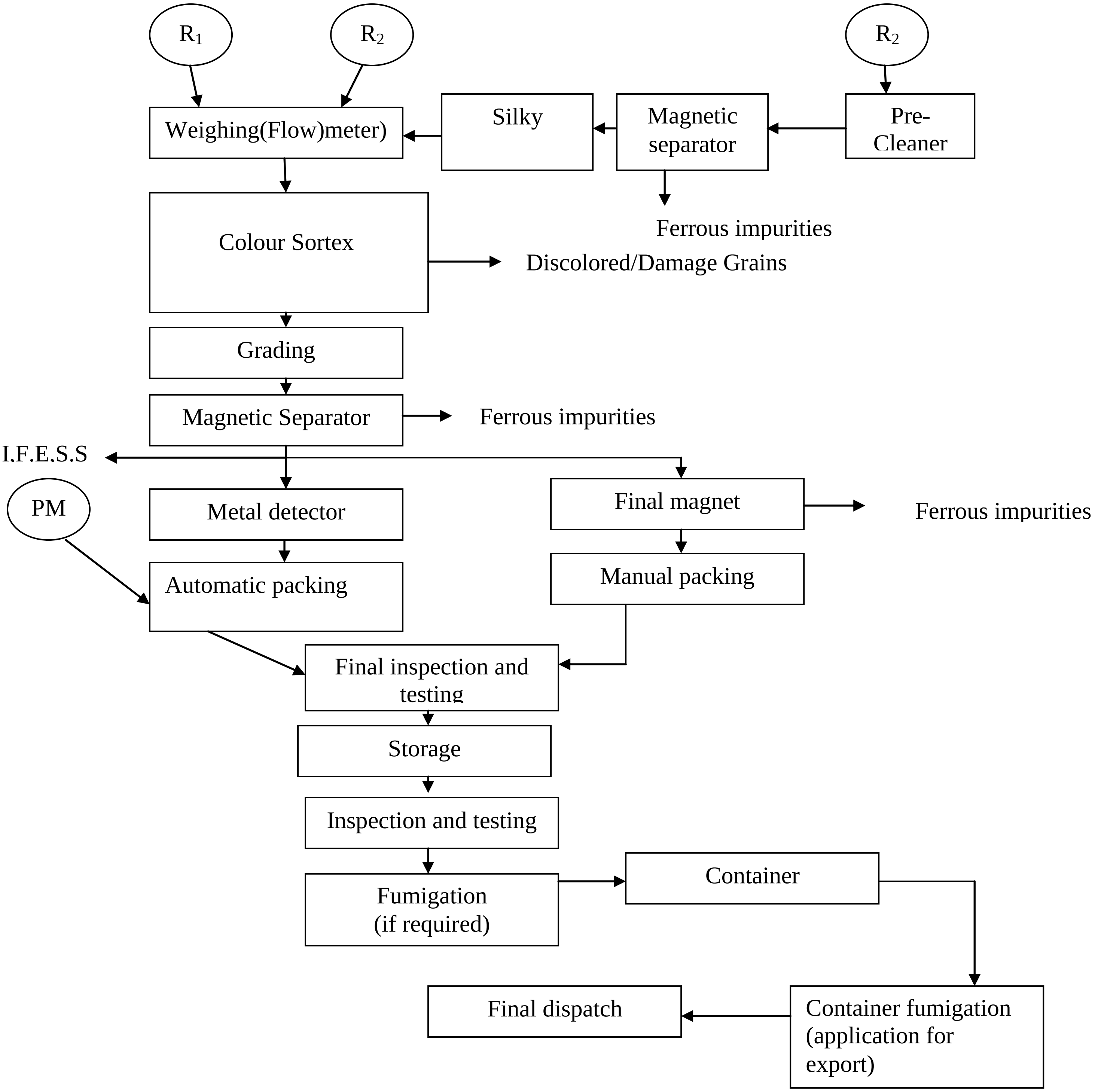


Fig. 1.4 Detailed description of DUNAR manufacturing process

1.3.2 Steps followed by DUNAR Rice Industry are explained below

a) Paddy Processing

b) Pre-cleaning

c) Dehusking

d) Grading

e) Silky

These steps can be explained as

a) Paddy Processing

Fig. 1.5 Paddy Processing

With the help of elevator**,** the paddy enters to machine from haudi for pre-cleaning process. The capacity of paddy in DUNAR rice industry is 15 TPD. The 20 HP motor is used for same process.

b) Pre-Cleaning

Before dehusking process, pre-cleaning process is to be followed. In this process, stones, dust particles and other type of impurities are removed. With the help of magnetic separator, different ferrous impurities or metallic impurities are removed. Stones are removed by de-stoner.

Fig. 1.6 Pre-Cleaner

With the help of 1st pass dust are removed. After removing of dust paddy is entering to 2nd pass to remove ferrous impurities. Stones are removed with 3rd pass machine. Basically these passes are as a sortex. Following pass machine are shown in figure 1.9. Final cleaned paddy is going to the Flow-meter machine to check the pressure of paddy before entering to the De-husking machine.

c) Dehusking

De-husking is a process to remove the husk from paddy to obtain the first stage of rice. It is a closed loop system to increase the reliability of de-husking.

Fig. 1.7 De-Husker

It consists of a paddy grain from paddy table, after de-husking process and again fed to de-husking machine. The 50 HP motor is used for this purpose.

d) Grading

Grading is the process of providing the different qualities of product. According to the requirement of customers, rices are graded on two basis:

- **Based on precision size**

  On the basis of precision size, grading can be of oversize, undersize, and tip separator from rice. In this process, machines are specified for the size of rice and above this specified size, rice can be considered as oversize and below this specified value, it can be considered as undersize. According to their size, quality can be obtained. To separate broken rice or tips, 10 HP motor is used.

- **Based on colour**

  After polishing, rice can be separate on the basis of colour, like brown, white or green colour etc. this is done by sortex. The 15 HP motor is used for sortex and 40 HP motor is used for polisher.

e) Silky

The main purpose of silky is to increase the shining of rice after polishing. It consists of a small quantity of water for providing the shining to rice. The 10 HP motor is used for this purpose.

The prepared rice is packed into different size of bags according to requirements such and 50 kg etc . The 5 HP motor is used for packing purpose.

1.4 ENERGY AUDIT

Energy audit is an important commercial tool to save energy and to improve financial state of an organization. Almost all the large scaled and many small scaled organizations i.e. industries as well as non-industrial sectors are conducting energy audit to save energy and to minimize the electricity cost. The energy conservation is cost effective with a short payback period and modest investment. There is a good scope of energy conservation in various sectors, via domestic, industry and agriculture [4]. In the proceeding sections energy audit is briefly discussed.

1.4.1 Definition of energy audit

An energy audit is an inspection, survey and analysis of energy flow for energy conservation in buildings, processor systems to reduce the amount of energy input(s) into the system without affecting negatively to the output(s).

1.4.2 Principle

When the object of study is an occupied building then reducing energy consumption, while maintaining or improving human comfort, health and safety, are of primary concern, beyond simply identifying the source of energy use, an energy audit seeks to prioritize the energy uses according to the greatest to least cost effective opportunity for energy savings. An energy audit serves the purpose of identifying where a plant facility uses energy and identifies energy conservation opportunities.

1.4.3 Types of energy audit

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through a facility to identify major areas of comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of sophisticated investors. Numerous audit procedures have been developed for nonresidential (tertiary) buildings (ASHRAE) [9] IEA-ECBCS Annex 11 [16] Krarti 2000 Audit is to identify the most efficient and cost-effective Energy Conservation Opportunities (ECOs) or Measures (ECMs). Energy Conservation Opportunities (or Measures) can consist in more efficient use or of partial or global replacement of the existing installation.

1.4.3.1 Common types/levels of energy audits are:

- **Level-0 Benchmarking:** The first analysis consists of preliminary whole Building Energy Use (WBEU) analysis based on the analysis of the historic utility. It uses the cost and the comparison of the performances of the building to those of similar building. The benchmarking of the studied installation allows determining. If further analysis is required or not.

- **Level-1 Walk-through audit:** Preliminary analysis is made to assess building energy efficiency to identify simple and low-cost improvements, but makes a list of energy conservation measures (ECMs), or energy conservation opportunities (ECOs) to orient the future detailed audit. This inspection is based on visual verifications, study of installed equipment, operating data and detailed analysis of recorded energy consumption collected during the benchmarking phase.

- **Level-2 Detailed/General energy audit:** Based on the result of the pre-audit, this type of energy audit consists of survey of energy usage in order to provide a comprehensive analysis of the studied installation. It gives a more detailed analysis of the facility, a breakdown of the energy use and a first quantitative evaluation of the ECOs/ECMs selected to correct the defects or improve the existing installation. This level of analysis can involve advanced on-site measurements and computer based simulation tools to evaluate precisely the selected energy retrofits [12].

- **Level-3 Investment-Grade audit:** Detailed analysis of Capital–Intensive Modifications focuses on potential costly ECOs, requiring rigorous engineering study.

When looking to the existing audit methodologies development in IEA-ECBCS Annex 11, by ASHRAE and by Krarti (2000), it appears that the main issues of an audit process are :-

- ➢ The analysis of building and utility data including study of the installed equipment and analysis of energy bills.

- The survey of the real operating conditions.
- The understanding of the building behavior and of the interaction with the weather, occupancy and operating schedules.
- The selection and the evaluation of energy conservation measures.
- The estimation of energy saving potential.
- The identification of costumer concern and needs.

1.5 Organization of Dissertation

The work carried out in the dissertation has been summarized in six chapters.

Chapter 1 covers the overview of energy audit and explained the energy audit in detail.

Chapter 2 presents the literature review.

Chapter 3 discusses the energy audit technique opportunities in rice industry.

Chapter 4 covers the energy audit by payback period technique

Chapter 5 discusses energy auditing after power factor improvement by installing capacitor bank

Chapter 6 contains the conclusion and future scope.

CHAPTER - 2
LITERATURE REVIEW

Phumiphak,T. *et al.* (2004)[14] suggested that energy is one of the main factor for continuous development and economic growth for any country. The industrial sector consumes a large amount of energy. It was found that consumption of energy in industrial machines such as boilers, motors, compressors, lightening systems etc. save energy by using energy auditing. According to energy auditing data, energy saving using variable speed drive was 68,923MWh, 132,922MWh, 78,768MWh and 49,230MWh. Electrical energy can be saved up to 40% of motor loading. It is found that by VSI control method large energy can be saved.

Bureau of energy efficiency (BEE) (2005) [13] suggested that for process of energy management at any stage, investment is required for modification purpose.

Bureau of energy efficiency (BEE) (2005) [10] suggested that the energy auditor advises the senior management of organization for capital investment for modernization such as industry or other electrical set up. The financial issues associated with capital investment in energy saving projects were investigated. The discounted cash flow techniques of net present value and internal rate of return were discussed.

Kamalapur. G.D. *et al*. (2009) [5] suggested that we can reduce the gap between demand and supply, which is continuously increasing day by day, with the help of energy auditing. The energy auditing is a cost effective method with a short payback period in various sectors such as domestic, industry and agriculture etc.

Pabamalie, H.L. *et al*. (2010)[2]suggested that It is an economical method that leads to plant to make right decision in replacing the inefficient Induction motor with more efficient motor.

Ahiduzzaman,MD.*et al.* (2011) [25] observed the various industrial process in the areas of production of rice, elimination process of husk, use of husk to harness energy in order to produce electrical power. It also surveyed that use of biomass with the husk can be improved source of biomass energy for producing electricity. Before going to install such power plant a details study is needed to make an assessment of biomass resource for electricity generation, rice mills were surveyed.

Bureau of energy efficiency (2011) [20] the government of India has set up the 'Bureau of Energy Efficiency' (BEE) under the provision of energy conservation act 2001. The objective of the energy efficiency program is to accelerate energy efficiency technology.

Bureau energy efficiency (2011) [19] suggested that rice mills are the important aspect of economic development for rural sector and accordingly mills are located in the paddy agricultural area. The cost of power production depends on distance of fuel source (husk) as well as power consumption areas.

Wang, J. *et al.* (2011) [17] it was observed that rice husk is one of the most abundant renewable biomass energy sources, which is wastage in rice milling company. Paddy drying unit of biomass energy, use rice husk as a heat source. Some techniques were studied that contain the delivery of rice husk and combustion. Production spot stated that the unit using rice husk as a heat source can reduce energy costs about 85%.

Bureau energy efficiency (BEE), (2012) [18] suggested that the increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. Energy balances are used in the examination of the various stages , over the whole process and even extending over the total production system from the raw material to the finished product

CHAPTER – 3
ELECTRICAL ENERGY AUDITING TECHNIQUES IN RICE INDUSTRY

3.1 INTRODUCTION

It has been observed that practically in today's world rice manufacturing plant's electricity consumption is increasing every year, due to prolonged use of the equipments in inefficient operating parameters and also due to increase in production. Rice manufacturing process comes with a large design safety factor, which has to be optimized after process stabilization for optimum power consumption. The energy cost to production cost is around 15 to 20% and this comes second to raw material. So, in rice industry focus area is energy consumption at load end and optimizing the energy usage of rice manufacturing machines.

3.2 AREAS OF ENERGY AUDIT

In the study of energy audit of the running equipment, we first see the visible abnormal symptoms in the inefficient transfer of energy in the system using the II law of thermodynamics. There are some areas where energy audit is required such as:-

- Lighting – sparks, in case of contractor switching, loose joints etc, which lead to reduction in efficiency.
- Heating- in motors, other load equipment coupled to motor due to friction, metal-to-metal touch and poor lubrication misalignment are reason for inefficiency.
- Sound – from the equipment in the form of vibration, mounting on bed, noise from belts, bearing, metal to metal contact etc, reduce efficiency.

If in the running equipment the transfer of energy takes place perfectly and here exist losses occur that are acceptable, then the quality and quantity of the output is good and there is less wastage of energy and output. If the transfer is not rightly done i.e. done with more losses, then productive output reduces, waste output increases and dissipated in the form of heat, light, sound which is a sign of visible loss in the equipment operating parameters.

3.3 ENERGY AUDIT PROCESS

Fig. 3.1shows the flow diagram depicting the energy audit process.

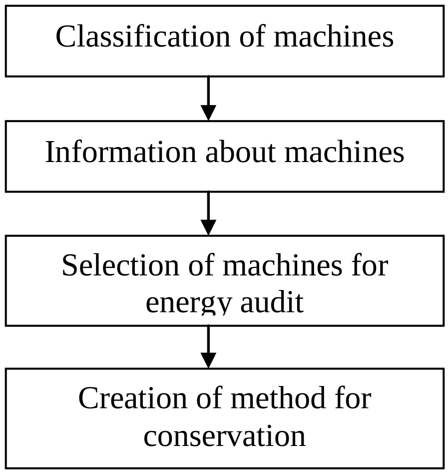


Fig. 3.1 Energy audit process

The details of the energy audit process are:

- Classification of machines is carried out from the power rating of the load and type of load for which they are used.

- Information about the machines is collected which includes method of power transmission, loading sequence, sources of energy wastage and method of control.

- Energy against power rated data is used for the selection of machines for detailed energy audit.

To identify the methods for energy conservation, following points are considered.

- alternate to reduce/avoid energy losses

- alternate to reduce down time

- alternate to optimum selection

3.4 DATA ANALYSIS AND RECOMMENDATIONS

There can be three types of parameters for the analysis done on Rewound Induction Motor to conserve energy these are explained as:

- Rated parameters
- Measured parameters
- Calculated parameters

3.4.1 Rated parameters: - These are printed on the name plate and given in the manual by manufacturer.

3.4.2 Measured Parameters:-These are measured using different instruments under different conditions, like no-load, partial-load and full-load.

One or more of the following measurements may be involved:

- Speed measured by tachometer.
- Currents measured by clamp-on transducer.
- Voltages measurement.
- Input power measurement.
- Stator winding resistance reading.
- Winding temperature data.

3.4.3 Calculated parameters: That are determined (or computed) from rated and measured parameters using standard formulae's.

Rated parameters i.e. no. of phases, poles, rated power, rated voltage, rated current, F.L. rated speed, supply frequency, rated o/p power etc.

Measured parameters i.e. N.L voltage, N.L current N.L power, N.L speed, temp. of still motor, temp. of N.L motor, temp. of F.L motor, resistance of R.M, rotor resistance, F.L voltage, F.L current, F.L power, F.L speed etc.

Calculated parameters i.e. sync. speed, stator resistance of N.L &F.L motor, stator Cu. At N.L & F.L, iron and F&W losses, N.L&F.L slip F.L rotor losses, stray losses, F.L o/p power, % age loading, power factor at F.L, efficiency at F.L, net saving, benefits, payback period, rated efficiency etc.

3.4.4 Standard Formule's for calculated parameters

Synchronous speed:

It can be calculated as:

Sync. Speed = 120f/p

Here f=supply frequency

P=no. of poles

Stator resistance:

It can be calculated as:

Stator resistance of N.L and F.L motor=R_2/R_1= $(235+T_2)/(235+T_1)$

Here R_2 = unknown resistance at temp. T_2

R_1= resistance at temp. T_1

F.L = Full Load

N.L = No Load

Stator Cu. loss:

It can be calculated as:

Stator Cu. loss at N.L and F.L = I^2R

Here I= N.L/F.L current

R= N.L/F.L resistance

Iron and friction and windage losses:

It can be calculated as:

Iron and friction and windage losses= P_{in}- stator Cu. loss at N.L

Here P_{in} = input power

F.L rotor losses:

It can be calculated as:

F.L rotor losses = I^2R

HereI= current at full load

R = rotor resistance

Stray losses:

It can be calculated as:

Stray losses = 1.5% of F.L input power for 1-125 HP motor

1.3% of F.L input power for 126-500 HP motor

1.2% of F.L input power for 501-2499 HP motor

0.9% of F.L input power for 2500 and above HPM

F.L output power:

It can be calculated as:

F.L output power= $P_{in\ (F.L)}$-stator Cu. loss at F.L-F&W losses- rotor

Cu. loss- stray losses

Percentage loading:

It can be calculated as:

Percentage loading= (F.L. output power/rated power) ×100

Efficiency:

It can be calculated as:

Actual efficiency= (actual output power/actual input power) ×100

Rated efficiency= (rated output power/rated input power) ×100

Net saving:

It can be calculated as:

Net saving= benefits - (running cost + electrical expenses)

3.4.5 Simple Payback Period

The simple payback period can be defined as 'the length of time required for running total of net savings before depreciation to equal the capital cost of the project'. In theory, once the payback period has ended, all the project capital cost will have been couped and any additional cost savings achieved can be seen as clear 'profit'. Obviously, shorter the payback period more attractive the project becomes. The length of the maximum permissible payback period generally varies with the business culture concerned [10]

Generally, Simple Payback Period is, the time (number of years) required to recover the initial investment (First Cost), considering only the Net Annual Saving [13]. In some companies, payback periods in excess of 3 years are considered acceptable. The Simple Payback is usually calculated as follows:

$$\text{Simple payback period (years)} = \frac{\text{Capital cost of the project (in Rs.)}}{\text{Net Annual savings (in Rs.)}}$$

Here, Net Annual savings = benefits – costs

$$PB = \frac{CC}{AS}$$

Where, PB = payback period (years), CC = Capital cost of project (Rs.)

AS = Annual net cost saving achieved (Rs.)

3.4.6 Formulae description using flow chart

Sync. Speed = 120f/p

↓

Stator resistance of N.L & F.L motor

$$\frac{R_2}{R_1} = \frac{235 + T_2}{235 + T_1}$$

↓

Stator CU. Losses at N.L & F.L = I^2R

↓

Iron, F&W losses = P_{in} – stator Cu. Losses at N.L

↓

N.L & F.L slip = $\frac{N_S - N_r}{N_S} \times 100$

↓

F.L rotor losses = I^2R

↓

Stray losses = 1.5% of F.L input power

↓

F.L output power= P_{in} – stator Cu. loss at F.L – F&W loss – rotor Cu. loss at F.L – stray loss

↓

%age loading = $\frac{Full\ load\ output\ power}{rated\ power} X\ 100$

↓

Actual efficiency = $\frac{output\ power}{input\ power} X\ 100$

↓

Rated efficiency = $\frac{rated\ output\ power}{rated\ input\ power} X\ 100$

CHAPTER 4

ENERGY AUDITING BY PAYBACK PERIOD CALCULATIONS

4.1 INTRODUCTION

This chapter aims to analyze the efficiencies of the in-house rewound induction motors in the rice manufacturing plant under study and to minimize (or conserve) energy usage by improving the efficiencies of these motors. The electrical energy audit process in rewound induction motors is evaluated in process stages. The choice of stages is due to the nature of the process and as well, the details of rewound induction motors in the rice manufacturing plant. As far as possible the same structure will be used for all the different rated motors to facilitate comparison between the rewound induction motor and new motor.

4.2 METHODOLOGY

The methodology adopted for conducting the detailed energy audit are:

- List of electrical motors of different horse power and operating parameters.
- Measurement of operating parameters of various equipments under different conditions, to estimate their operating efficiency.
- Analysis of data collected to develop specific energy saving proposals.

4.3 PROBLEM FORMULATION:

In this study the subject of investigation (or say under study) is a major rice manufacturing plant Dunar Rice industry This plant includes a 22KV substation and 1 MW diesel plant. The installed capacity is 16,425 Tons Per Annum (TPA).

- In the method, energy auditing is done by calculating the rated and actual efficiency, total capital cost and net savings of different rewound motors. With the help of these parameters, the payback period can be calculated and on the basis of payback period calculations, energy auditing can be done.

- In the second method, energy auditing is done by calculating the improvement in power factor after installing a capacitor bank (combination of capacitor). After installing a capacitor bank, the efficiency, total capital cost and benefits changes. Thus, the net saving changes and its affect on payback period.

4.4 Analysis on rewound motor

With the help of tables different parameter of rewound motor are explained, it is compared with new motor.following result are found.

Table 4.1 Rated Parameters of 15 HP Rewound Motors

TOR IDENTIFY	MOTOR MODEL	MOTOR TYPE	NO. OF POLES	RATED POWER (W)	RATED VOLTAGE (V)	RATED CURREN T (A)	F.L. RATED SPEED (RPM)	SUPPL Y FREQ. (Hz)	RATED O/P POWER (W)
New	New	15 HP	4	12000	415	19	1460	50	11016
R.M 1	Old		4	12000	415	19	1460	50	11016
R.M 2			4	12000	415	19	1460	50	10920
R.M 3			4	12000	415	19	1460	50	11016
R.M 4			4	12000	415	19	1460	50	11016
R.M 5			4	12000	415	19	1460	50	11016

Table 4.2 (a) Measured Parameters of 15 HP Rewound Motors

MOTOR IDENTIFY	N.L. VOLT (V)	N.L. CURR (A)	N.L. I/P POWER (W)	N.L. SPEED (RPM)	TEMP. OF STILL MOTOR (°C)	RESIS. OF R.M (Ω)
New	415	8	523.87	1480	12	0.35
R.M 1	410	7.5	589	1480	13	0.8
R.M 2	410	9	550	1480	15	1.2
R.M 3	410	8	579.89	1480	16	0.78
R.M 4	410	10	580	1485	20	1.2
R.M 5	410	8.5	591	1480	14	0.91

Table 4.2 (b) Measured Parameters of 15 HP Rewound Motors

MOTOR IDENTIFY	TEMP. OF N.L. MOTOR (°C)	TEMP. OF LOADED MOTOR (°C)	F.L. VOLT (V)	F.L. CUR. (A)	F.L. I/P POWER (W)	F.L. SPEED (RPM)	ROTOR RESIS. (Ω)
New	34	140	415	20	13500	1475	0.53283
R.M 1	43	142	410	25	13500	1470	0.39044
R.M 2	49	151	410	23	14000	1475	0.39635
R.M 3	43	143	410	22	13400	1475	0.42376
R.M 4	50	150	415	30	14100	1480	0.17811
R.M 5	44	145	410	25	14000	1475	0.3364

Table 4.3 (a) Calculated Parameters of 15 HP Rewound Motors

MOTOR IDENTIFY	SYNC. SPEED (RPM)	STATOR RESIS. OF N.L. MOTOR (Ω)	STATOR RESIS OF LOADED MOTOR (Ω)	STATOR CU. LOSS AT N.L (W)	STATOR CU. LOSS AT F.L (W)	IRON & F&W LOSSES (W)	N.L. SLIP (%)	F.L. SLIP (%)
New	1500	0.381174089	0.531376518	24.3951417	212.5506073	499.4748583	1.33333333	1.666666667
R.M 1	1500	0.896774194	1.216129032	50.44354839	760.0806452	538.5564516	1.33333333	2
R.M 2	1500	1.3632	1.8528	110.4192	980.1312	439.5808	1.33333333	1.666666667
R.M 3	1500	0.863904382	1.174661355	55.28988048	568.5360956	524.6001195	1.33333333	1.666666667
R.M 4	1500	1.341176471	1.811764706	134.1176471	1630.588235	445.8823529	1	1.333333333
R.M 5	1500	1.019638554	1.38875502	73.66888554	867.9718876	517.3311145	1.33333333	1.666666667

Table 4.3 (b) Calculated Parameters of 15 HP Rewound Motors

MOTOR IDENTFY	F.L. ROTOR LOSSES (W)	STRAY LOSSES (1.5%)	F.L.O/P POWER (W)	%AGE LOADING (%)	POWER FACTOR AT F/L	EFFICIENCY AT F/L (%)	CAPITAL COST (Rs.)	INSTALLATION COST (Rs.)
New	213.13	202.5	12372.34453	103.1028711	0.94	91.64699655	40190	5000
R.M 1	244.027	202.5	11754.8359	97.95696586	0.76	87.07285854	9500	5500
R.M 2	209.67	210	12160.618	101.3384833	0.86	86.86155714	9000	6000
R.M 3	205.1	201	11900.76378	99.17303154	0.86	88.81167004	9200	5500
R.M 4	160.3	211.5	11651.72941	97.0977451	0.66	82.63637881	9300	5000
R.M 5	0.25	210	12194.447	101.6203916	0.79	87.10319284	9600	6000

Table 4.3 (C) Calculated Parameters of 15 HP Rewound Motors

MOTOR IDENTFY	TOTAL CAPITAL COST (Rs.)	RUNNING COST (Rs.)	POWER I/P (W)	RUNNING TIME (Hr.)	ELECTRICAL EXPENSES (Rs.)	NET SAVING (Rs.)	BENIFITS (Rs.)	PAYBACK PERIOD (Yr.)	RATED EFFICIENCY (%)
New	45190	200	13500	20	1333.8	28243.75	29777.55	1.6	92
R.M 1	15000	250	13500	20	1333.8	15000	16583.8	1	92
R.M 2	15000	260	14000	20	1383.2	10714.28571	12357.48571	1.4	91
R.M 3	14700	270	13400	20	1323.92	8166.666667	9760.586667	1.8	92
R.M 4	14300	250	14100	20	1393.08	23833.33333	25476.41333	0.6	92
R.M 5	15600	280	14000	20	1383.2	13000	14663.2	1.2	92

Table 4.4 Rated Parameters of 20 HP Rewound Motors

MOTOR IDENTFY	MOTOR MODEL	MOTOR TYPE	NO. OF PHASES	NO. OF POLES	RATED POWER (W)	RATED POWER (HP)	RATED VOLTAGE (V)	RATED CURRENT (A)	F.L. RATED SPEED (RPM)	SUPPLY FREQ. (Hz)	RATED O/P POWER (W)
New	New	20 HP	3	4	15000	20	415	27	1460	50	13800
R.M 1	Old		3	4	15000	20	415	27	1460	50	13800
R.M 2			3	4	15000	20	415	27	1460	50	13800
R.M 3			3	4	15000	20	415	27	1460	50	13800

Table 4.5 Measured Parameters of 20 HP Rewound Motors

MOTOR IDENTFY	N.L. VOLT (V)	N.L. CURR (A)	N.L. I/P POWER (W)	N.L. SPEED (RPM)	TEMP. OF STILL MOTOR (°C)	RESIS. OF R.M (Ω)	TEMP. OF N.L. MOTOR (°C)	TEMP. OF LOADED MOTOR (°C)	F.L. VOLT (V)	F.L. CUR. (A)	F.L. I/P POWER (W)	F.L. SPEED (RPM)	ROTOR RESIS. (Ω)
New	415	11	615	1490	20	0.25	39	137	410	30	17000	1475	0.298
R.M 1	410	10	660	1490	24	1.2	41	141	410	31	17300	1475	0.262
R.M 2	410	10	660	1490	23.5	0.91	40	131	410	34.5	17200	1475	0.211
R.M 3	410	10.5	680	1490	30	0.77	47	150	415	33	18000	1475	0.248

Table 4.6 (a) Calculated Parameters of 20 HP Rewound Motors

MOTOR IDENTIFY	SYNC. SPEED (RPM)	STATOR RESIS. OF N.L. MOTOR (Ω)	STATOR RESIS OF LOADED MOTOR (Ω)	STATOR CU. LOSS AT N.L (W)	STATOR CU. LOSS AT F.L (W)	IRON & F&W LOSSES (W)	N.L. SLIP (%)	F.L. SLIP (%)
New	1500	0.268627451	0.364705882	32.50392157	328.2352941	582.4960784	0.66666667	1.666666667
R.M 1	1500	1.278764479	1.742084942	127.8764479	1674.143629	532.1235521	0.66666667	1.666666667
R.M 2	1500	0.968085106	1.288433269	96.80851064	1533.557698	563.1914894	0.66666667	1.666666667
R.M 3	1500	0.819396226	1.118679245	90.33843396	1218.241698	589.661566	0.66666667	1.666666667

Table 4.6 (b) Calculated Parameters of 20 HP Rewound Motors

MOTOR IDENTIFY	F.L. SLIP (%)	F.L. ROTOR LOSSES (W)	STRAY LOSSES (1.5%)	F.L.O/P POWER (W)	%AGE LOADING (%)	POWER FACTOR AT F/L	EFFICIENCY AT F/L (%)	CAPITAL COST (Rs.)	INSTALLATION COST (Rs.)
New	1.666667	268.15	255	15566.11863	103.7741242	0.8	91.56540369	50040	5000
R.M 1	1.666667	251.56	259.5	14582.67282	97.21781879	0.79	84.29290647	10600	5000
R.M 2	1.666667	251.72	258	14593.53081	97.29020542	0.7	84.84610937	10100	5000
R.M 3	1.666667	269.87	270	15652.22674	104.3481782	0.76	86.9568152	9700	5000

Table 4.6 (c) Calculated Parameters of 20 HP Rewound Motors

MOTOR IDENTIFY	RUNNING COST (Rs.)	TOTAL CAPITAL COST (Rs.)	POWER I/P (W)	RUNNING TIME (Hr.)	ELECTRICAL EXPENSES (Rs.)	NET SAVING (Rs.)	BENIFITS (Rs.)	PAYBACK PERIOD (Yr.)	RATED EFFICIENCY (%)
New	180	55220	17000	20	1679.6	34512.5	36372.1	1.6	92
R.M 1	185	15785	17300	20	1709.24	26308.33333	28202.57333	0.6	92
R.M 2	180	15280	17200	20	1699.36	25466.66667	27346.02667	0.6	92
R.M 3	190	14890	18000	20	1778.4	12408.33333	14376.73333	1.2	92

Table 4.7 Rated Parameters of 50 HP Rewound Motors

MOTOR IDENTIFY	MOTOR MODEL	MOTOR TYPE	NO. OF PHASES	NO. OF POLES	RATED POWER (W)	RATED POWER (HP)	RATED VOLTAGE (V)	RATED CURRENT (A)	F.L. RATED SPEED (RPM)	SUPPLY FREQ. (Hz)	RATED O/P POWER (W)
New	New	50 HP	3	4	37000	50	415	62	1480	50	34780
R.M 1	Old		3	4	37000	50	415	62	1480	50	34780
R.M 2			3	4	37000	50	415	62	1480	50	34780
R.M 3			3	4	37000	50	415	62	1480	50	34780
R.M 4			3	4	37000	50	415	62	1480	50	34410
R.M 5			3	4	37000	50	415	62	1480	50	34780
R.M 6			3	4	37000	50	415	62	1480	50	34040

Table 4.8 Measured Parameters of 50 HP Rewound Motors

MOTOR IDENTFY	N.L. VOLT (V)	N.L. CURR (A)	N.L. I/P POWER (W)	N.L. SPEED (RPM)	TEMP. OF STILL MOTOR (°C)	RESIS. OF R.M (Ω)	TEMP. OF N.L. MOTOR (°C)	TEMP. OF LOADED MOTOR (°C)	F.L. VOLT (V)	F.L. CUR. (A)	F.L. I/P POWER (W)	F.L. SPEED (RPM)	ROTOR RESIS. (Ω)
New	415	21	1290	1495	25	0.11	39	110	415	51	41000	1485	0.082
R.M 1	415	10.202	660.15	1495	28	0.79	43	120	415	62	41900	1485	0.063
R.M 2	415	10.22	660.169	1495	23.05	0.99	47	132	415	62.5	42000	1485	0.054
R.M 3	410	10.519	680.175	1495	29	0.83	45.5	127	415	61.5	41275	1485	0.054
R.M 4	420	21.5	2003.5	1495	23	0.67	45	119	410	58	41050	1485	0.048
R.M 5	415	23	1800	1490	37	0.87	43	141	415	63	43000	1480	0.053
R.M 6	410	21.5	1700	1495	38	0.91	40	130	410	63.5	44300	1485	0.052

Table 4.9 (a) Calculated Parameters of 50 HP Rewound Motors

MOTOR IDENTIFY	SYNC. SPEED (RPM)	STATOR RESIS. OF N.L. MOTOR (Ω)	STATOR RESIS OF LOADED MOTOR (Ω)	STATOR CU. LOSS AT N.L (W)	STATOR CU. LOSS AT F.L (W)	IRON & F&W LOSSES (W)	N.L. SLIP (%)	F.L. SLIP (%)
New	1500	0.115923077	0.145961538	51.12207692	379.6459615	1238.877923	0.3333333	1
R.M 1	1500	0.835057034	1.06634981	86.90488846	4099.048669	573.2451115	0.3333333	1
R.M 2	1500	1.081883356	1.407982949	113.0009855	5499.933395	547.1680145	0.3333333	1
R.M 3	1500	0.881875	1.138106061	97.57890523	4304.601648	582.5960948	0.3333333	1
R.M 4	1500	0.727131783	0.919302326	336.1166667	3092.533023	1667.383333	0.3333333	1
R.M 5	1500	0.889191176	1.202647059	470.3821324	4773.306176	1329.617868	0.6666667	1.3333333
R.M 6	1500	0.916666667	1.216666667	423.7291667	4905.904167	1276.270833	0.3333333	1

Table 4.9 (b) Calculated Parameters of 50 HP Rewound Motors

INSTALLATION COST (Rs.)	TOTAL CAPITAL COST (Rs.)	RUNNING COST (Rs.)	POWER I/P (W)	RUNNING TIME (Hr.)	ELECTRICAL EXPENSES (Rs.)	NET SAVING (Rs.)	BENIFITS (Rs.)	PAYBACK PERIOD (Yr.)	RATED EFFICIENCY (%)
5000	164570	200	41000	20	4050.8	91427.77778	95678.578	1.8	94
5500	20500	250	41900	20	4139.72	34166.66667	38556.387	0.6	94
6000	20500	260	42000	20	4149.6	51250	55659.6	0.4	94
5500	20300	270	41275	20	4077.97	40600	44947.97	0.5	94
5000	18500	250	41050	20	4055.74	23125	27430.74	0.8	93
6000	19800	280	43000	20	4248.4	49500	54028.4	0.4	94
5000	19100	300	44300	20	4376.84	38200	42876.84	0.5	92

Table 4.9 (C) Calculated Parameters of 50 HP Rewound Motors

MOTOR IDENTIFY	F.L. ROTOR LOSSES (W)	STRAY LOSSES (1.5%)	F.L.O/P POWER (W)	%AGE LOADING (%)	POWER FACTOR AT F/L	EFFICIENCY AT F/L (%)	CAPITAL COST (Rs.)	INSTALLATION COST (Rs.)
New	213.13	615	38553.34612	104.1982327	0.94	94.0325515	159570	5000
R.M 1	244.027	628.5	36355.17922	98.25724113	0.76	86.76653752	15000	5500
R.M 2	209.67	630	35113.22859	94.90061781	0.86	83.60292522	14500	6000
R.M 3	205.1	619.125	35563.57726	96.11777637	0.86	86.16251304	14800	5500
R.M 4	160.3	615.75	35514.03364	95.98387471	0.66	86.51408927	13500	5000
R.M 5	210.25	645	36041.82596	97.41034042	0.79	83.8181999	13800	6000

Tables 4.1 to 4.9 contain parameters of all the three parameter types of the analyzed rewound motors of different powers.

Practically collected parameters of the in-house rewound induction motor needed to determine the efficiency. Here we are also determining the actual efficiency of the new motor because actual efficiency of new motor differs from its manufacturer's rated efficiency. Difference may be of very low value. These parameters are used to make comparisons of rewound motors with new induction motor of same rating.

After comparing the efficiencies of the rewound induction motors with that of new motors, payback period of the rewound induction motors is estimated to make the decision easy regarding the replacement of the rewound induction motors with the new ones.

After analyzing the rewound motors, a recommendation is made to save electrical energy. The comparisons between rewound motor and new motor of different ratings (or result) are shown below in the form of figures. These figures also include the payback period of individual analyzed rewound induction motor.

4.6 Analysis with bar chart:-

a) For stator resistance

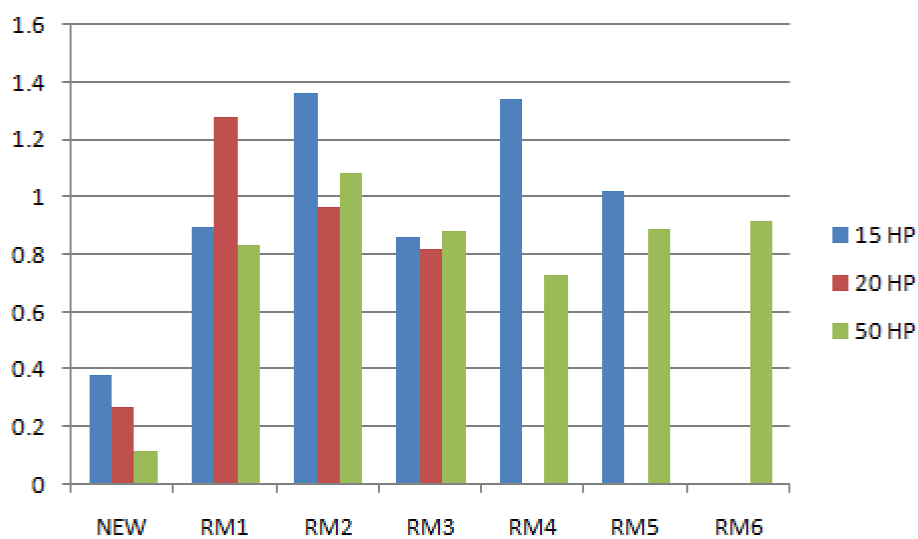


Fig. 4.1 Stator resistance at N.L motor analysis

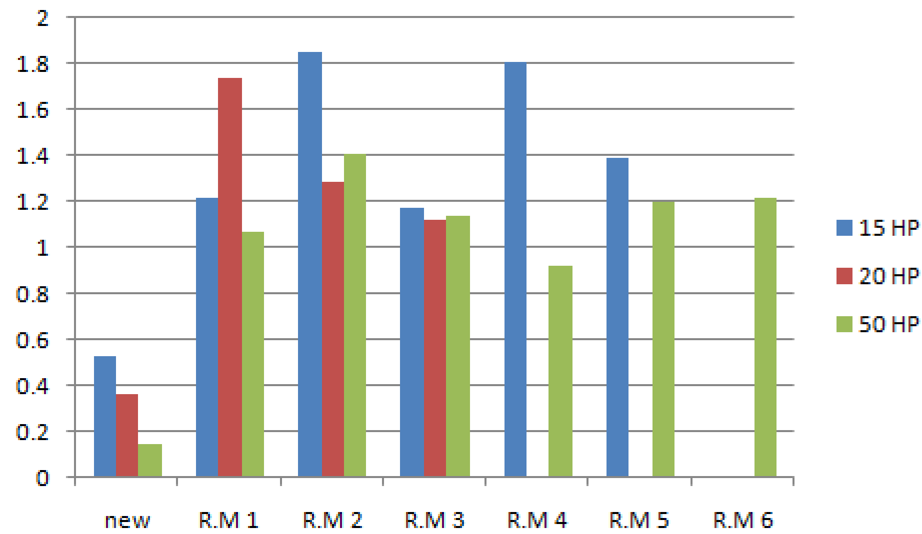


Fig. 4.2 Stator resistance of F.L motor analysis

From fig 4.1 and fig. 4.2, we notice that the value of stator resistance at no load and full load is minimum for new motor as compared to rewound motors. It also shows that as the motor rating increases like from 15 HP to 20 HP or 20 HP to 50 HP, the value of stator resistance decreases.

b) For stator copper loss

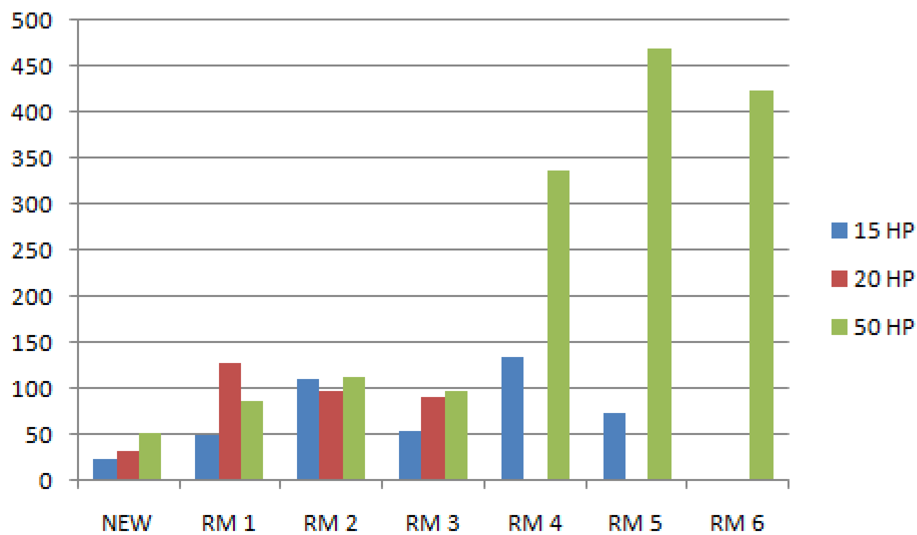


Fig. 4.3 No load stator Cu. losses analysis

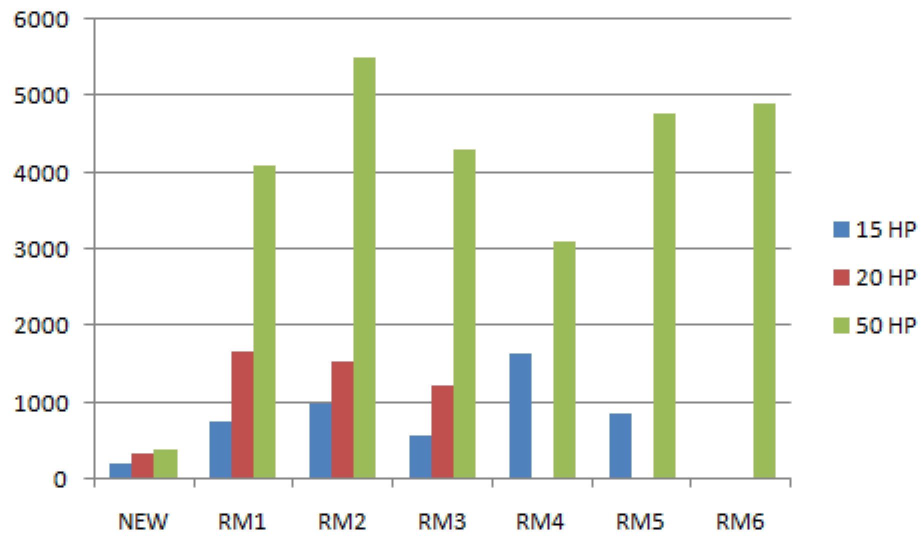


Fig. 4.4 Full load stator Cu. losses analysis

From fig. 4.3 and fig. 4.4, we noticed that stator copper losses at no load and full load increases as the motor rating increases and the losses are minimum for new motors as compared to rewound motors.

C) Iron and friction windage losses

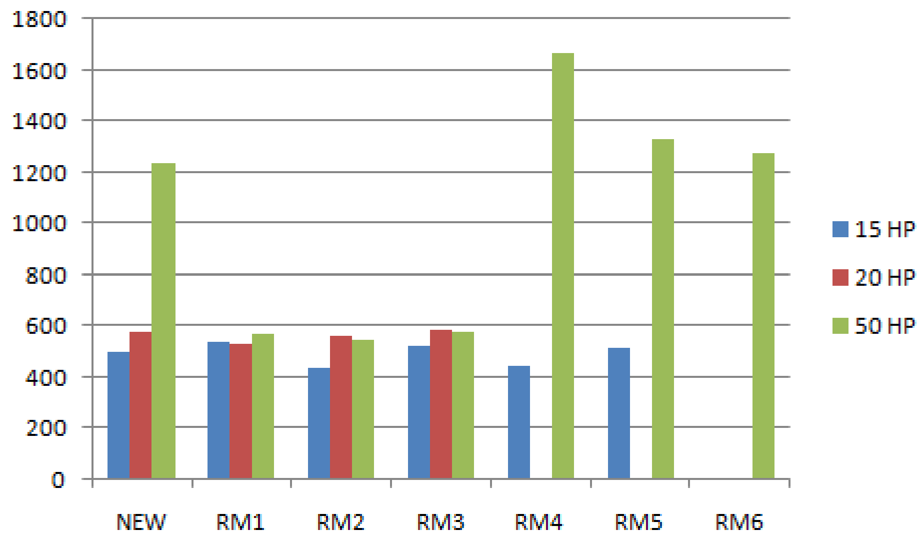


Fig. 4.5 Iron and friction windage losses analysis

From fig. 4.5, it shows that iron and friction windage losses increases as the motor rating increases. in new motor these loss small as compared to rewound motor.

d) Full load rotor losses

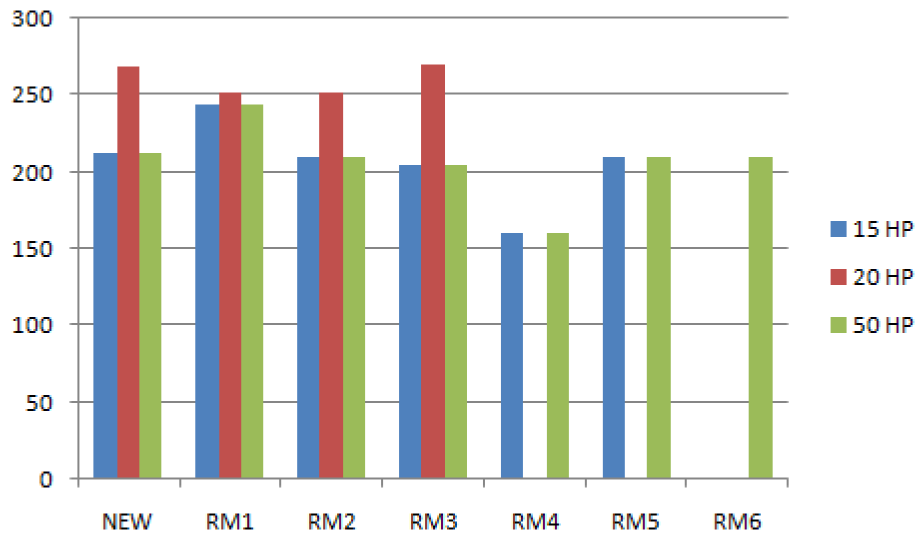


Fig. 4.6 Full load rotor losses analysis

From fig. 4.6, it shows that full load rotor losses increases as the motor rating increases.

e) Stray Losses

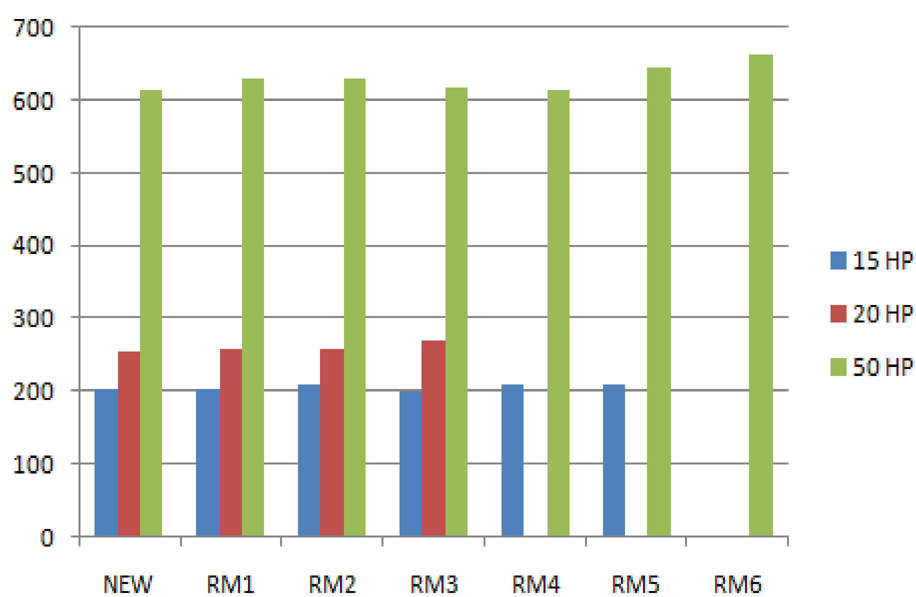


Fig. 4.7 Stray losses analysis

From the fig. 4.7, we notice that the value of stator losses is minimum for new motor as compared to rewound motors. It also show that as the motor rating increases like from 15 HP to 20 HP or 20 HP to 50 HP, the value of stator losses increases.

f) Full load output power

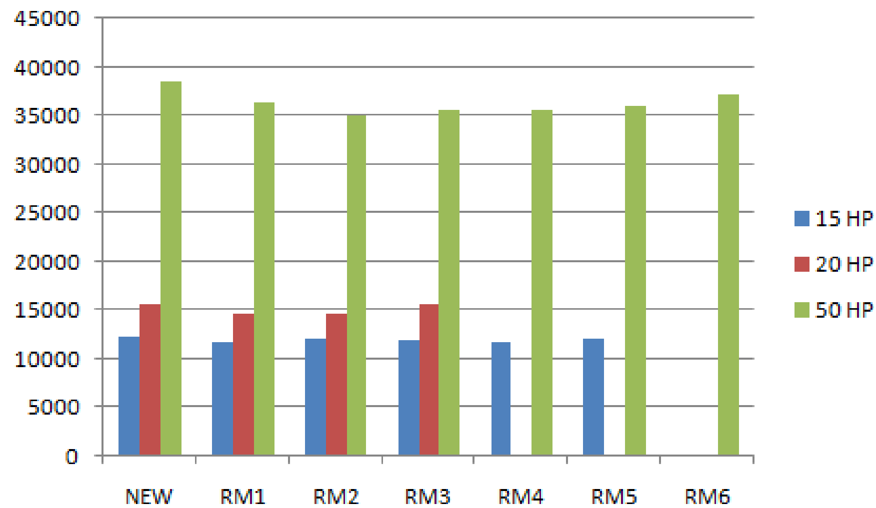


Fig. 4.8 Full load output power analysis

From the fig. 4.8, we notice that the value of full load output power is high for new motor as compared to rewound motors. It also show that as the motor rating increases like from 15 HP to 20 HP or 20 HP to 50 HP, the value of full load output power increases.

g) Actual efficiency

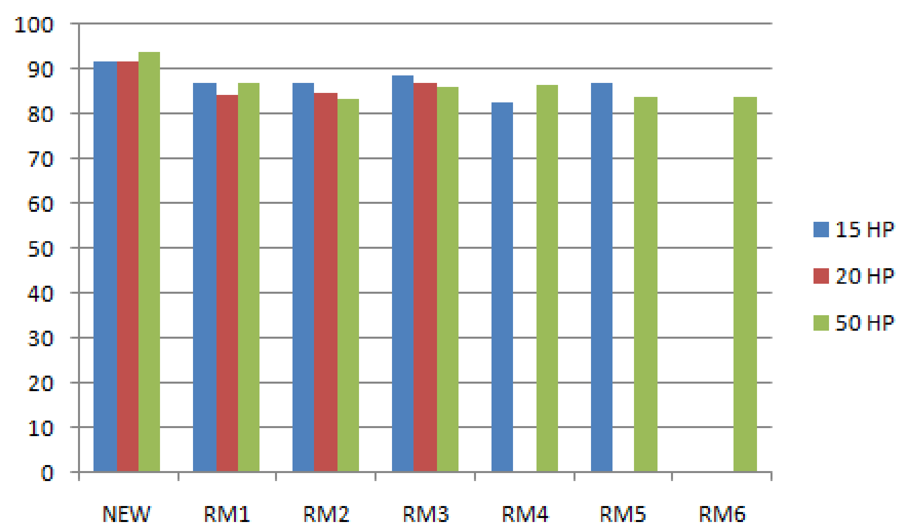


Fig. 4.9 Actual efficiency analysis

From the fig.4.9, we noticed that efficiency of new motor is high as compared to rewound motor for 15HP, 20HP and 50HP motors.

h) Rated efficiency

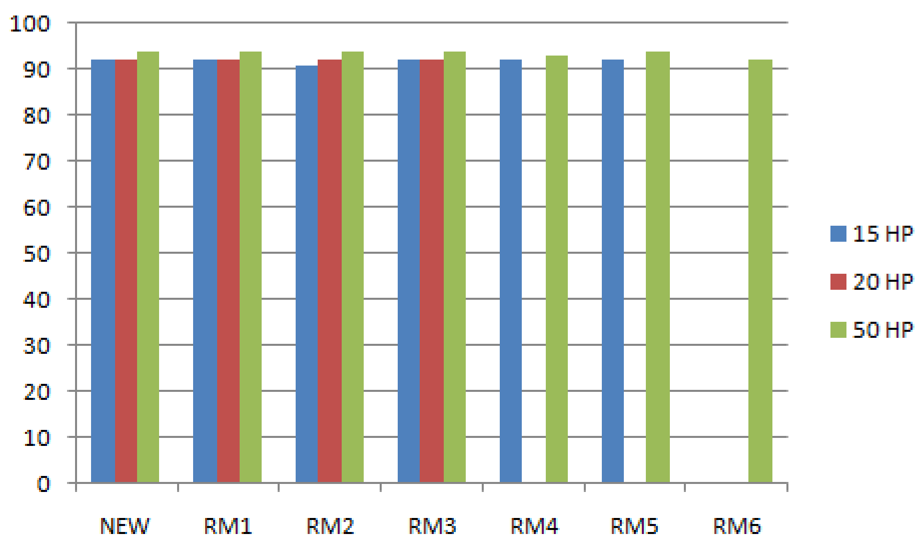


Fig. 4.10 Rated efficiency analysis

From the fig.4.10, we noticed that rated efficiency of motors of several ratings remains almost same.

i) Benefit analysis

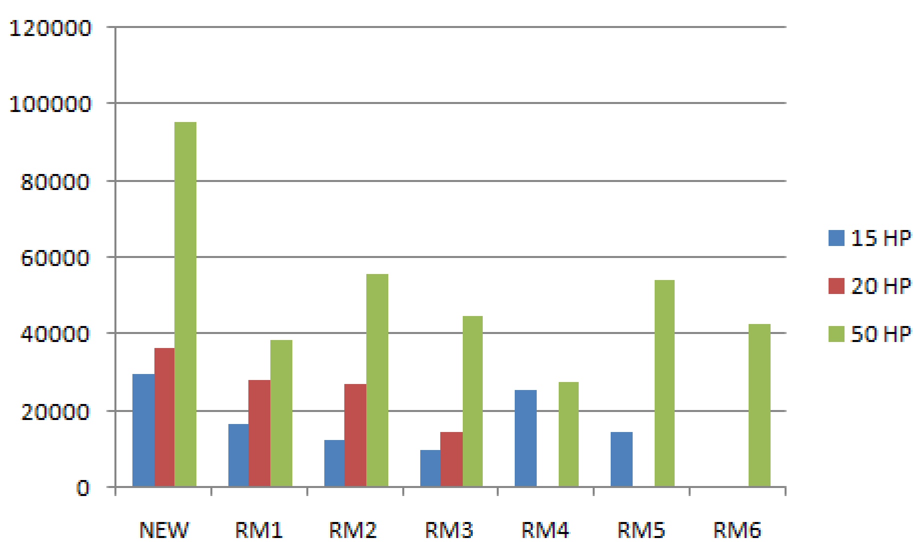


Fig. 4.11 Benefits analysis

From the above figure, we notice that the benefits are high for new motor as compared to rewound motors. It also show that as the motor rating increases like from 15 HP to 20 HP or 20 HP to 50 HP, benefits also increases.

j) Power factor at full load

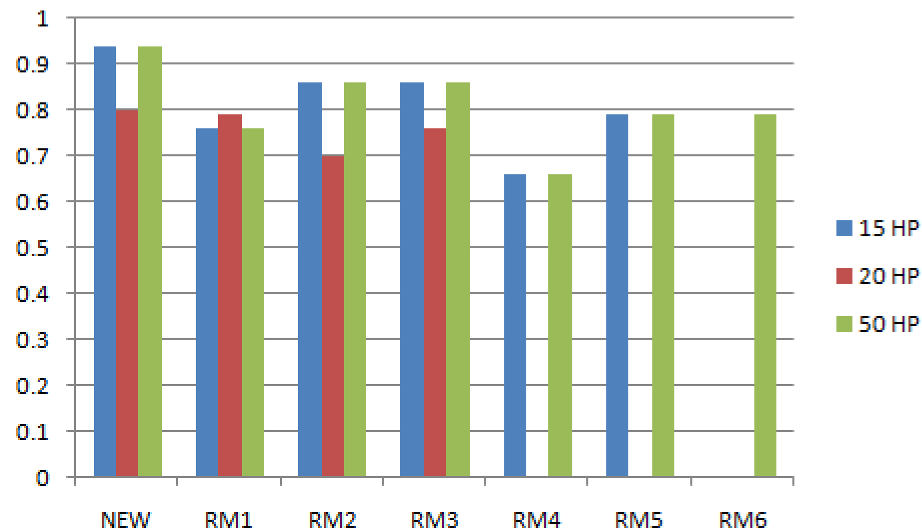


Fig 4.12 Power factor at full load analysis

From the fig.4.12, we noticed that the power factor for new motor is high as compared to rewound motors for several ratings of motor.

k) Total capital losses

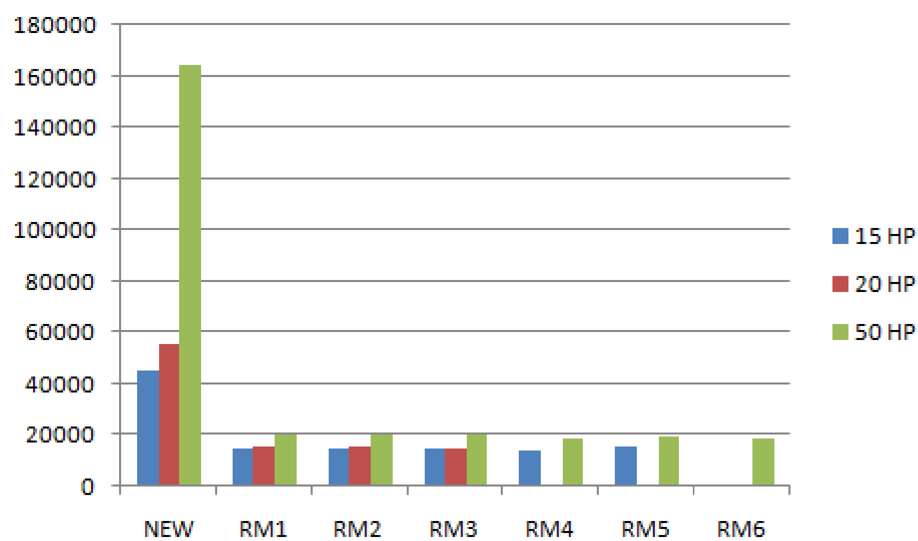


Fig. 4.13 Total capital loss analysis

From the fig4.13, we notice that the total capital cost is high for new motor as compared to rewound motors. I

l) Payback period

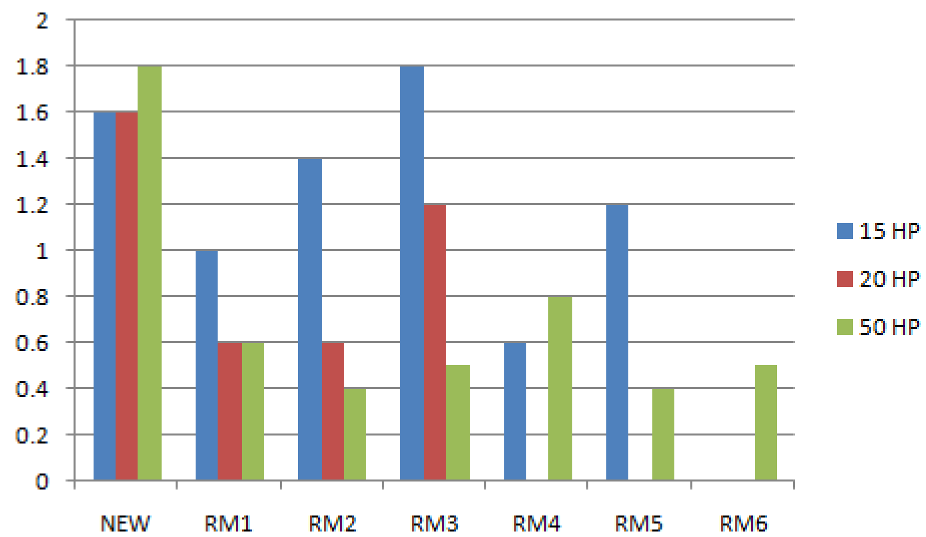


Fig. 4.14 Payback period analysis

From the fig.4.14, we noticed that the payback period decreases as the motor rating increases.

m) 15HP Motor analysis

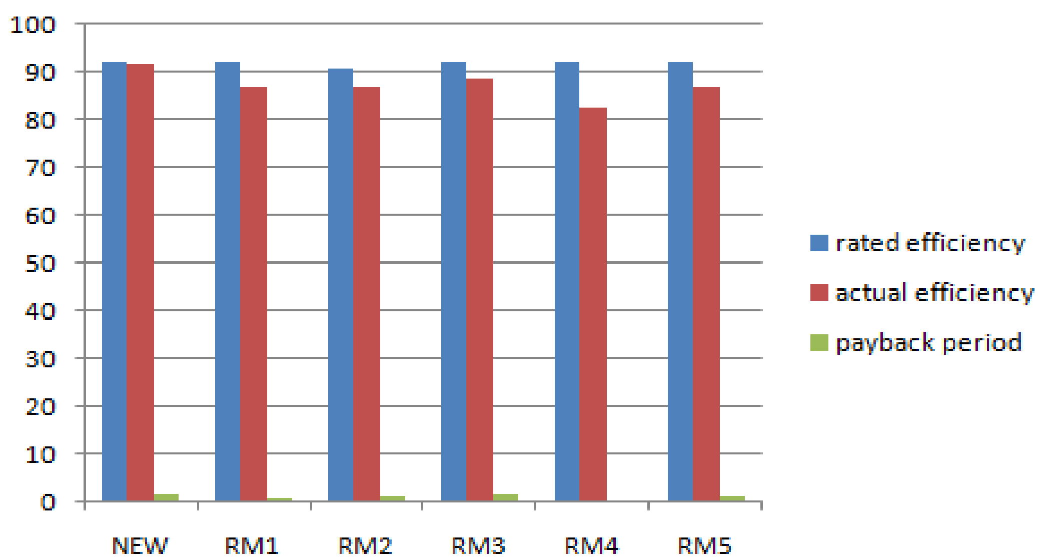


Fig: 4.15 15HP Motor Analysis

Figure 4.15 shows the result of analysis done on 15HP motors. Efficiencies of five 15HP rewound motors are determined and compared with efficiency of new induction motor. Then payback periods are calculated which is resulting in very less payback period i.e. near about 2 years to 6 months. In the analysis of 15HP motors shown in the above figure, first comparison is between rated efficiency and actual efficiency of the new motor. Then the comparisons between efficiency of the new motor and actual efficiencies of the in-house rewound induction motors. Each comparison of the rewound motor also includes its payback period in the Figure 4.17.

n) **20HP Motor analysis**

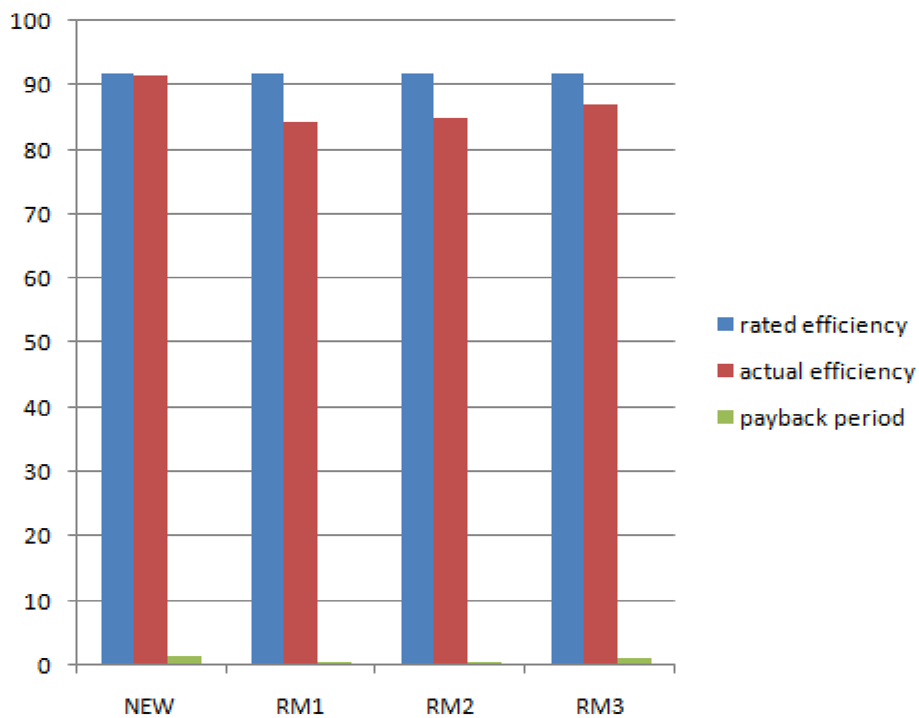


Fig: 4.16 20HP Motor Analysis

Figure 4.16 shows the result of analysis done on 20HP motors. This figure includes first comparison of rated and actual efficiency of the new motor, then between efficiency of the new motor and rewound motors of 20HP rating. Then payback periods are also calculated for 20HP rewound motors, which is resulting in an average of very less payback period i.e. near about 6months to 1.5 year. Similarly next figures include the comparisons in the same fashion.

o) 50HP Motor Analysis

Fig. 4.17 shows the result of analysis done on 50hp motors. Efficiencies of six 50hp rewound motors have been calculated and after comparing them with efficiency of

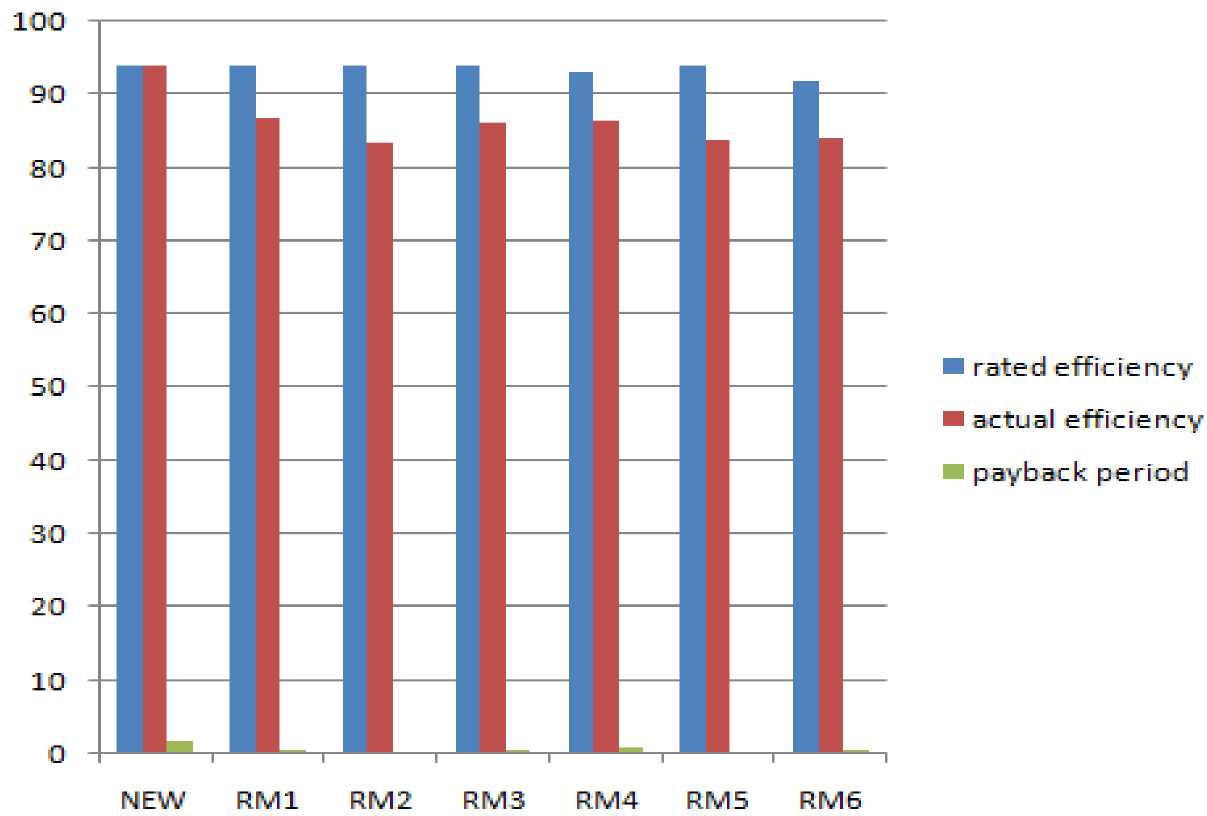


Fig. 4.17 50HP Motor Analysis

industrial wound induction motor, we are getting an average payback of very less period, which ranges from 6months to 9months.

According to analysis done on the in-house rewound induction motors, it is recommended to replace these rewound induction motors with new motors. From analysis it was found that there is relationship between motor power and its payback p eriod . The relationship is stating that as large as the motor is, the lower is its payback period.

p) Average payback period

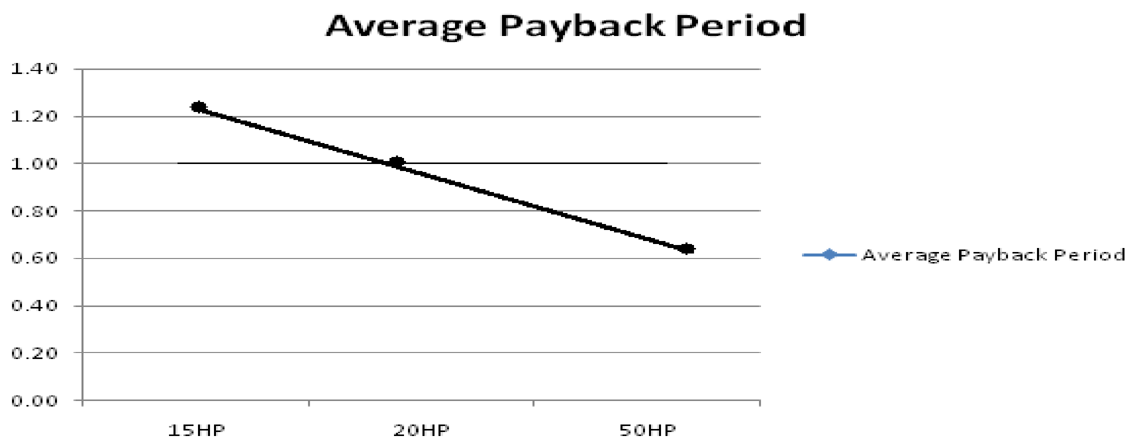


Fig. 4.18 Motor Powers vs. Payback Period

Fig. 4.18 show the relationship between motor power and its payback period. payback period decreases with the increase in the motor power. So it is highly recommended to replace the high power motor with new motors instead of repairing them.

Table 4.11 Relationship between motor power and its payback period

MOTOR HORSE POWER	AVERAGE PAYBACK PERIOD
15 HP	1.27
20 HP	1
50 HP	0.71

Different induction motor powers and their corresponding payback periods are shown in table 4.11. From this table, we also understand the relationship between motor power and its payback period that is payback period decrease with increase in motor power

CHAPTER 5

ENERGY AUDITING AFTER POWER FACTOR IMPROVEMENT BY INSTALLING CAPACITOR BANK

5.1 INTRODUCTION

This chapter aims to analyze the Energy Auditing by power factor improvement after installing capacitor bank to Rewound Induction Motor. Capacitor bank is a combination of capacitors. The size of capacitor bank depends upon reactive power. It may be connected into two configurations i.e.

- Star connection
- Delta connection

The power factor can be expressed as

Power factor = **cos ∅ = kW / kVA = R / Z**

The complex power in electrical system is supplied by utility.

Mathematically, S = P + j Q

Where, S = Input complex power

P = Active power

Q = Reactive power

Q = SQRT [$(kVA)^2 - (kW)^2$]

Capacitance (μF) = (kVAR * 10^9) / 2πf $(V_L)^2$

5.2 Standard formule's for capacitor calculations:

Actual kW:

It can be calculated as:

Actual kW= VI (cos∅)

Actual kVA:

It can be calculated as:

Actual kVA = (V*I) / 1000

Actual kVAR:

It can be calculated as:

$Q = SQRT [(kVA)^2 - (kW)^2]$

Desired kW:

It can be calculated as:

Desired kW= VI ($\cos\emptyset_{desired}$)

Here $\cos\emptyset_{desired}$ is the desired power factor.

Desired kVA:

Desired kVA = Actual kVA

Desired kVAR:

It can be calculated as:

Desired Q= SQRT [(desired kVA)^2 - (Desired kW)^2]

Required kVAR:

It can be calculated as:

Required kVAR= actual kVAR – desired kVAR

Capacitance:

It can be calculated as:

C (µF) = (kVAR* 10^9) / $2\pi f V_L^2$ (star connection)

C (µF) = (kVAR* 10^9) / $6\pi f V_L^2$ (delta connection)

Net savings:

It can be calculated as:

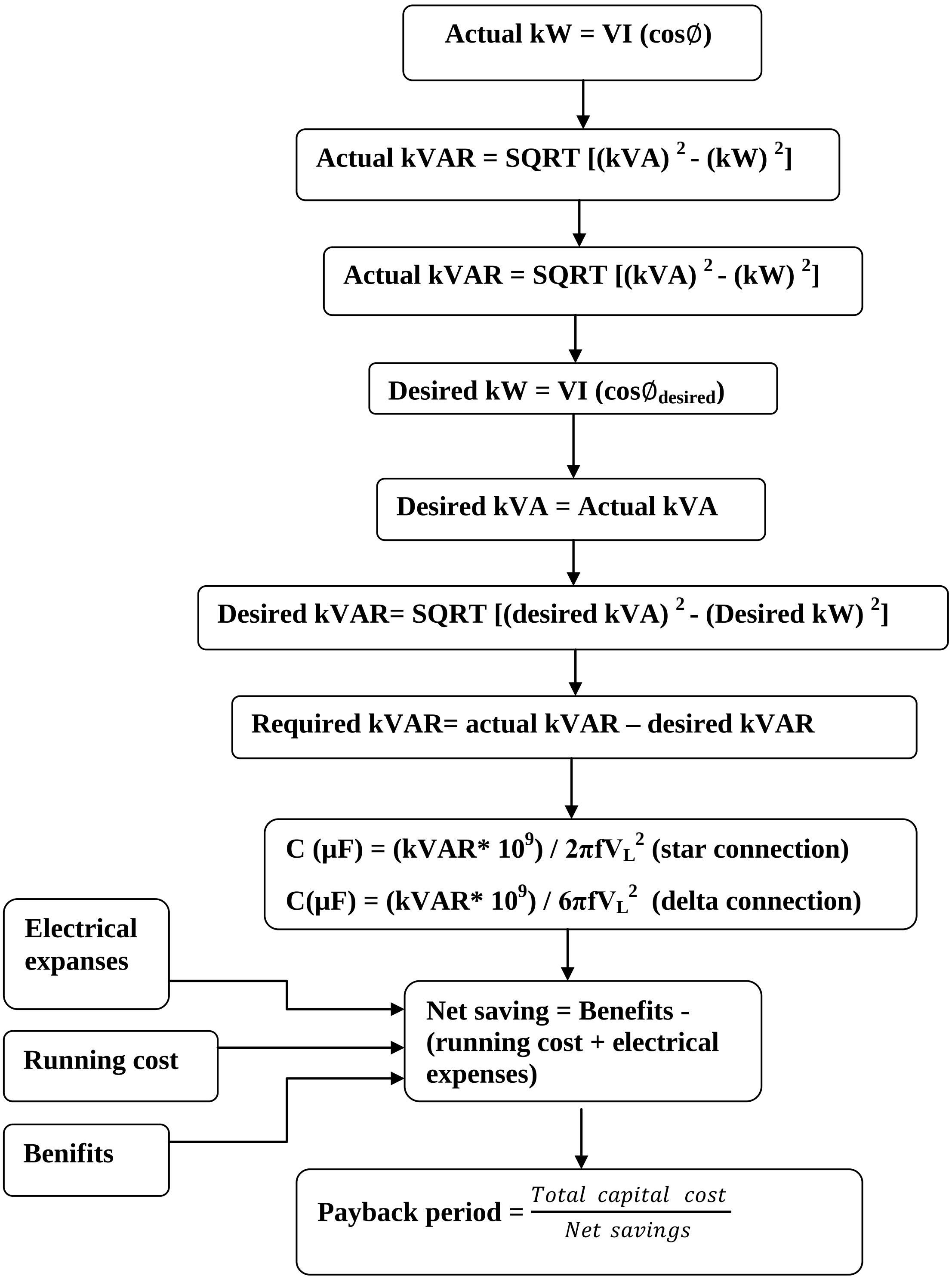
Net savings = benefits – (running cost + electrical expenses)

Payback period:

It can be calculated as:

Payback period = (total capital cost) / (net savings)

5.3 Formule description using flowchart:



5.4 DATA ANALYSIS AND RECOMMENDATION:

Table 5.1 (a) Capacitor Calculations for 15 HP Rewound Motor

MOTOR IDENTIFIER	F.L. VOLT (V)	F.L. CUR. (A)	VOLT- AMPERES	KILOVOLT-AMPERES	POWER FACTOR AT F/L	KILO –WATTS
New	415	20	8300	8.3	0.94	7.802
R.M 1	410	25	10250	10.25	0.76	7.79
R.M 2	410	23	9430	9.43	0.86	8.1098
R.M 3	410	22	9020	9.02	0.86	7.7572
R.M 4	415	30	12450	12.45	0.66	8.217
R.M 5	410	25	10250	10.25	0.79	8.0975

Table 5.1 (b) Capacitor Calculations for 15 HP Rewound Motor

(kW's*kW's)	(KILOVOLTAMPERES* KILOVOLTAMPERES)	(kV's*kV's-kW's*kW's)	ACTUAL kVAR's	DESIRED POWER FACTOR	DESIRED kW's	DESIRED kW's* DESIRED kW's
60.871204	68.89	8.018796	2.83174787	0.96	7.968	63.489024
60.6841	105.0625	44.3784	6.661711492	0.96	9.84	96.8256
65.76885604	88.9249	23.15604396	4.81207273	0.96	9.0528	81.95318784
60.17415184	81.3604	21.18624816	4.602852177	0.96	8.6592	74.98174464
67.519089	155.0025	87.483411	9.353256706	0.96	11.952	142.850304
65.56950625	105.0625	39.49299375	6.284345133	0.96	9.84	96.8256

Table 5.1 (c) Capacitor Calculations for 15 HP Rewound Motor

ACTUAL kVA's*ACTUAL kVA's	DESIRED kVAR's* DESIRED kVAR's	DESIRED kVAR's	REQUIRED kVAR's	C(STAR COMBINATION OF CAPACITORS C's)	PER UNIT RATE	TOTAL RATE
68.89	5.400976	2.324	0.50774787	9.389063339	550	1650
105.0625	8.2369	2.87	3.791711492	71.83530223	1700	5100
88.9249	6.97171216	2.6404	2.17167273	41.14310048	1100	3300
81.3604	6.37865536	2.5256	2.077252177	39.35427003	950	2850
155.0025	12.152196	3.486	5.867256706	108.4948812	2770	8310
105.0625	8.2369	2.87	3.414345133	64.68596439	1800	5400

Table 5.2 Calculated Parameters of 15 HP Rewound Motors with Capacitor Bank

CAPACITOR BANK COST	TOTAL CAPITAL COST (Rs.)	POWER I/P (W)	RUNNING TIME (Hr.)	ELECTRICAL EXPENSES (Rs.)	NET SAVING (Rs.)	BENIFITS (Rs.)	PAYBACK PERIOD (Yr.)
1650	46840	13500	20	1333.8	32527.77778	34061.57778	1.44
5100	20100	13500	20	1333.8	22333.33333	23917.13333	0.9
3300	18300	14000	20	1383.2	14523.80952	16167.00952	1.26
2850	17550	13400	20	1323.92	10833.33333	12427.25333	1.62
8310	22610	14100	20	1393.08	41870.37037	43513.45037	0.54
5400	21000	14000	20	1383.2	19444.44444	21107.64444	1.08

Table5.3 (a) Capacitor Calculations for 20 HP Rewound Motor

MOTOR IDENTIFIER	F.L. VOLT (V)	F.L. CUR. (A)	VOLT- AMPERES	KILOVOLT-AMPERES	POWER FACTOR AT F/L	KILO –WATTS
New	410	30	12300	12.3	0.8	9.84
R.M 1	410	31	12710	12.71	0.79	10.0409
R.M 2	410	34.5	14145	14.145	0.7	9.9015
R.M 3	415	33	13695	13.695	0.76	10.4082

Table 5.3 (b) Capacitor Calculations for 20 HP Rewound Motor

(kW's*kW's)	(KILOVOLTAMPERES* KILOVOLTAMPERES)	(kV's*kV's-kW's*kW's)	ACTUAL kVAR's	DESIRED POWER FACTOR	DESIRED kW's	DESIRED kW's* DESIRED kW's
96.8256	151.29	54.4644	7.38	0.96	11.808	139.428864
100.8196728	161.5441	60.72442719	7.792587965	0.96	12.2016	148.8790426
98.03970225	200.081025	102.0413228	10.10155051	0.96	13.5792	184.3946726
108.3306272	187.553025	79.22239776	8.900696476	0.96	13.1472	172.8488678

Table5.3 (c) Capacitor Calculations for 20 HP Rewound Motor

ACTUAL kVA's*ACTUAL kVA's	DESIRED kVAR's* DESIRED kVAR's	DESIRED kVAR's	REQUIRED kVAR's	C(STAR COMBINATION OF CAPACITORS C's)	PER UNIT RATE	TOTAL RATE
151.29	11.861136	3.444	3.936	74.56889856	1750	5250
161.5441	12.66505744	3.5588	4.233787965	80.21059585	2100	6300
200.081025	15.68635236	3.9606	6.140950512	116.3424583	3120	9360
187.553025	14.70415716	3.8346	5.066096476	93.68015799	2500	7500

Table 5.4 Calculated Parameters of 20 HP Rewound Motors with Capacitor Bank

CAPACITOR BANK COST	TOTAL CAPITAL COST (Rs.)	POWER I/P (W)	RUNNING TIME (Hr.)	ELECTRICAL EXPENSES (Rs.)	BENIFITS (Rs.)	NET SAVING (Rs.)	PAYBACK PERIOD (Yr.)
5250	60290	17000	20	1679.6	43547.65556	41868.05556	1.44
6300	21900	17300	20	1709.24	42264.79556	40555.55556	0.54
9360	24460	17200	20	1699.36	46995.6563	45296.2963	0.54
7500	22200	18000	20	1778.4	22333.95556	20555.55556	1.08

Table 5.5 (a) Capacitor Calculations for 50 HP Rewound Motor

MOTOR IDENTIFIER	F.L. VOLT (V)	F.L. CUR. (A)	VOLT- AMPERES	KILOVOLT- AMPERES	POWER FACTOR AT F/L	KILO –WATTS
New	415	51	21165	21.165	0.94	19.8951
R.M 1	415	62	25730	25.73	0.76	19.5548
R.M 2	415	62.5	25937.5	25.9375	0.86	22.30625
R.M 3	415	61.5	25522.5	25.5225	0.86	21.94935
R.M 4	410	58	23780	23.78	0.66	15.6948
R.M 5	415	63	26145	26.145	0.79	20.65455
R.M 6	410	63.5	26035	26.035	0.79	20.56765

Table 5.5 (b) Capacitor Calculations for 50 HP Rewound Motor

(kW's*kW's)	(KILOVOLTAMPERES* KILOVOLTAMPERES)	(kV's*kV's- kW's*kW's)	ACTUAL kVAR's	DESIRED POWER FACTOR	DESIRED kW's	DESIRED kW's* DESIRED kW's
447.957225	395.815004	52.14222099	7.220957069	0.96	20.3184	412.8373786
662.0329	382.390203	279.642697	16.72252065	0.96	24.7008	610.1295206
672.7539063	497.5687891	175.1851172	13.23575148	0.96	24.9	620.01
651.3980063	481.7739654	169.6240408	13.02397945	0.96	24.5016	600.3284026
565.4884	246.326747	319.161653	17.86509594	0.96	22.8288	521.1541094
683.561025	426.6104357	256.9505893	16.02967839	0.96	25.0992	629.9698406
677.821225	423.0282265	254.7929985	15.96223664	0.96	24.9936	624.680041

Table 5.5 (c) Capacitor Calculations for 50 HP Rewound Motor

ACTUAL kVA's*ACTUAL kVA's	DESIRED kVAR's* DESIRED kVAR's	DESIRED kVAR's	REQUIRED kVAR's	C(STAR COMBINATION OF CAPACITORS C's)	PER UNIT RATE	TOTAL RATE
447.957225	35.11984644	5.9262	1.294757069	23.94211151	850	2550
662.0329	51.90337936	7.2044	9.518120652	176.0051453	4480	13440
672.7539063	52.74390625	7.2625	5.973251478	110.4548926	2865	8595
651.3980063	51.06960369	7.1463	5.877679454	108.6876143	2800	8400
565.4884	44.33429056	6.6584	11.20669594	212.3147797	5234	15702
683.561025	53.59118436	7.3206	8.70907839	161.0446709	4110	12330
677.821225	53.14118404	7.2898	8.672436638	164.3023496	4180	12540

Table 5.6 Calculated Parameters of 50 HP Rewound Motors with Capacitor Bank

CAPACITOR BANK COST	TOTAL CAPITAL COST (Rs.)	POWER I/P (W)	RUNNING TIME (Hr.)	ELECTRICAL EXPENSES (Rs.)	BENIFITS (Rs.)	NET SAVING (Rs.)	PAYBACK PERIOD (Yr.)
2550	167120	41000	20	4050.8	104193.8272	103993.8272	1.62
13440	33940	41900	20	4139.72	338712.963	338462.963	0.54
8595	29095	42000	20	4149.6	501010	500750	0.36
8400	28700	41275	20	4077.97	399092.2222	398822.2222	0.45
15702	34202	41050	20	4055.74	255902.7778	255652.7778	0.72
12330	32130	43000	20	4248.4	506030	505750	0.36
12540	31640	44300	20	4376.84	403344.4444	403044.4444	0.45

5.5 Analysis with bar chart:

a) 15 HP motor analysis:

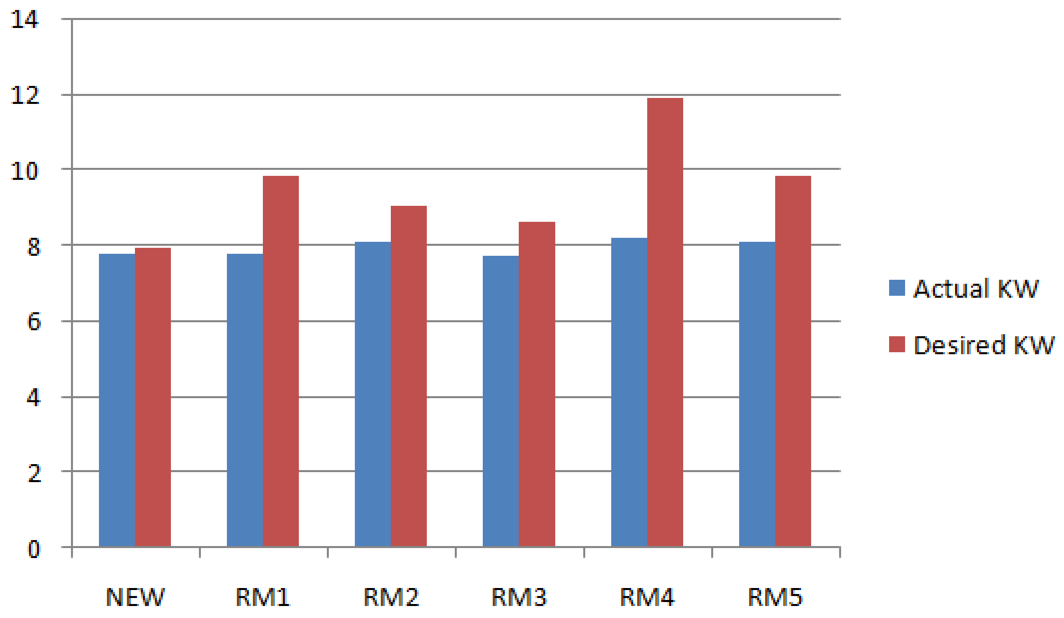


Fig.5.1 Diff. b/w actual and desired kW 15 HP

The fig.5.1 shows the difference of actual KW/active power and desired KW / active power.

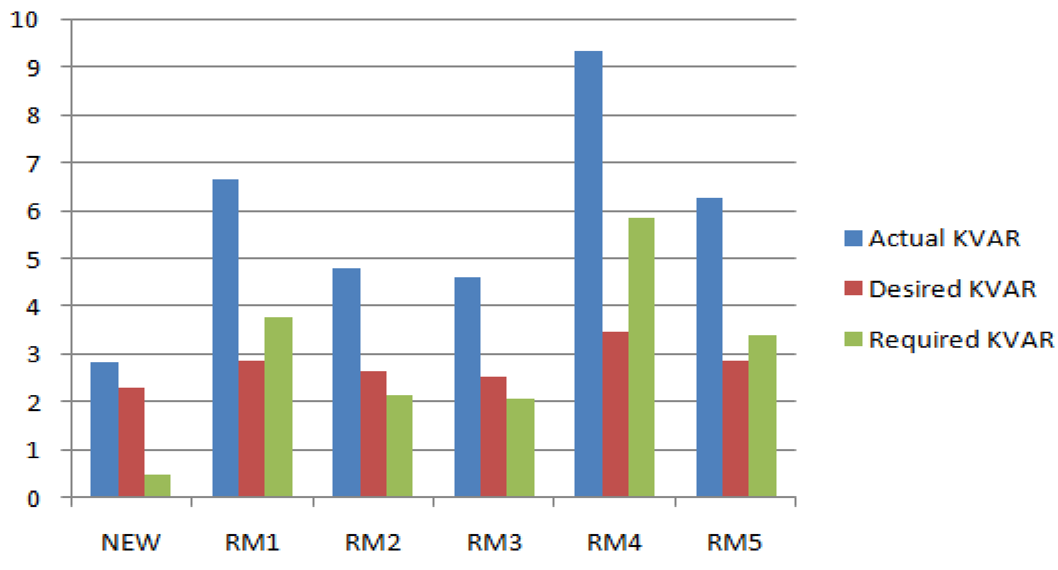


Fig.5.2 Diff. b/w actual and desired kVAR 15 HP

Fig. 5.2 shows the difference of actual KVAR/complex power and desired KVAR / complex power.

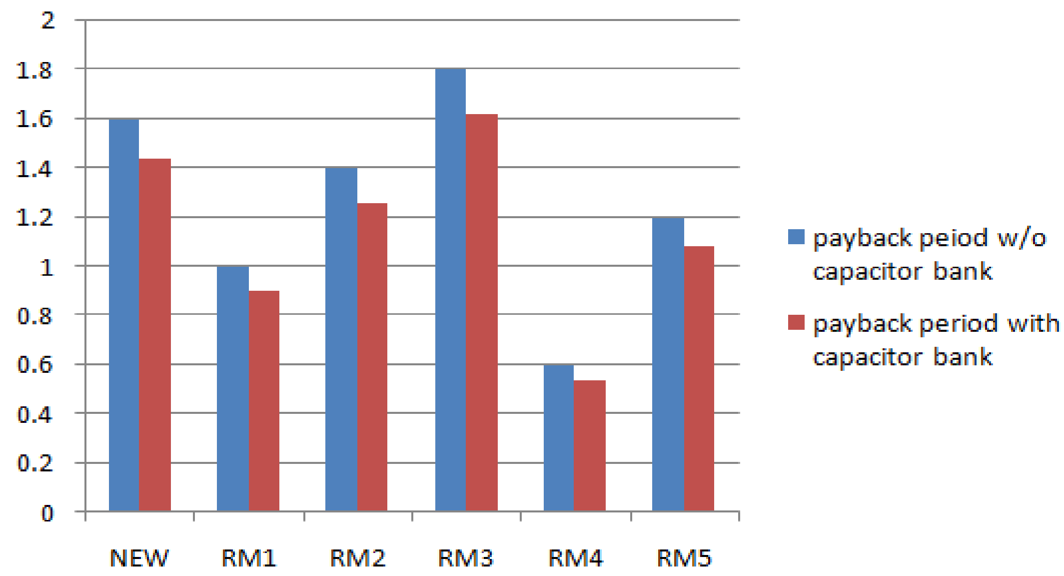


Fig: 5.3 15HP Motor Analysis

Fig. 5.3 shows the result of analysis done on 15HP motors, payback period without capacitor bank and with capacitor bank. So, we notice that payback period is reduced as the capacitor bank is installed i.e payback period with capacitor bank is less as compared to payback period without capacitor bank.

b) 20 HP motor analysis:

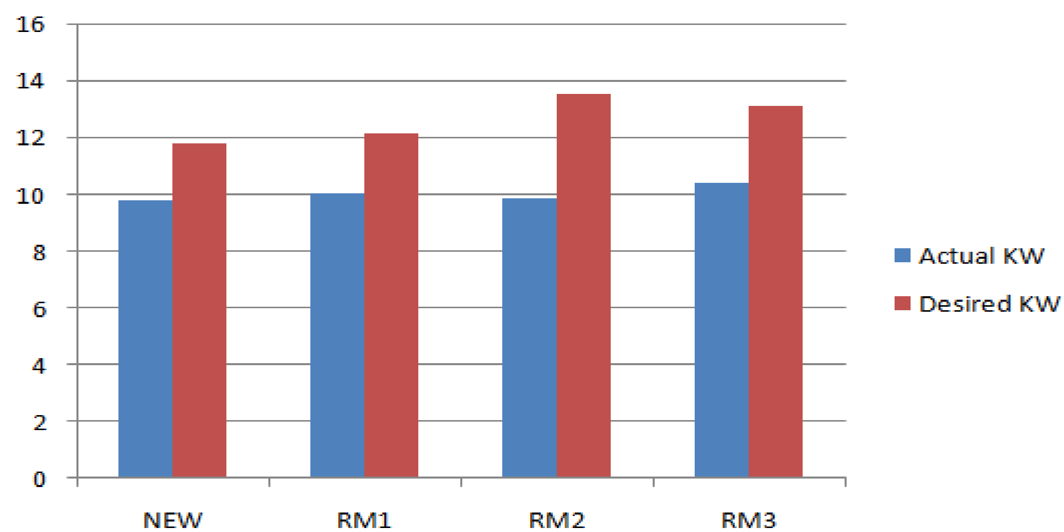


Fig.5.4 Diff. b/w actual and desired kW 20 HP

The fig.5.4 shows the difference of actual KW/active power & desired KW/active power.

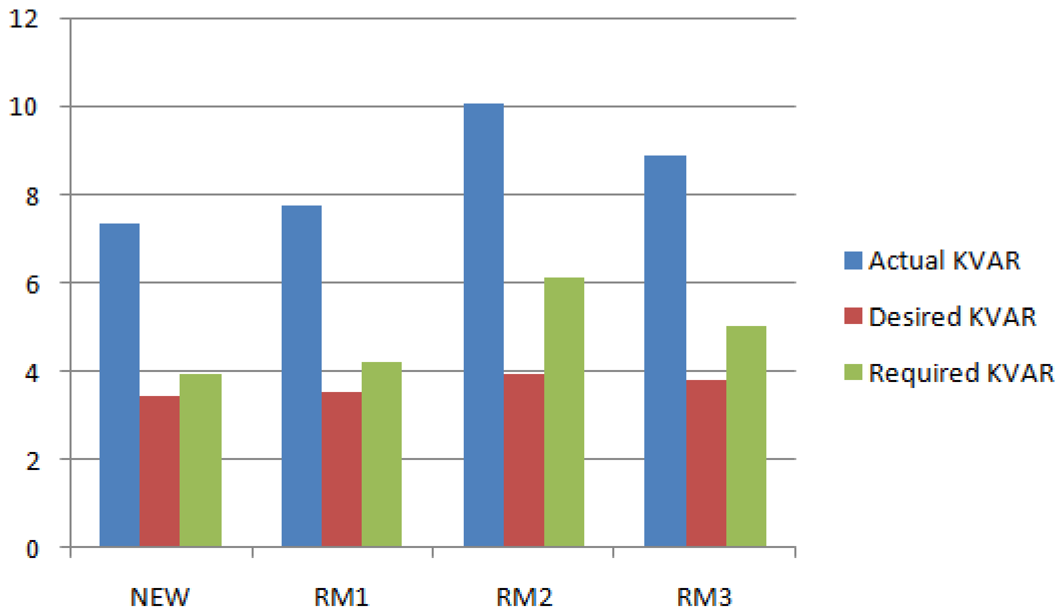


Fig.5.5 Diff. b/w actual and desired kVAR 20 HP

The fig.5.5 shows the difference of actual kVAR/complex power and desired kVAR/complex power.

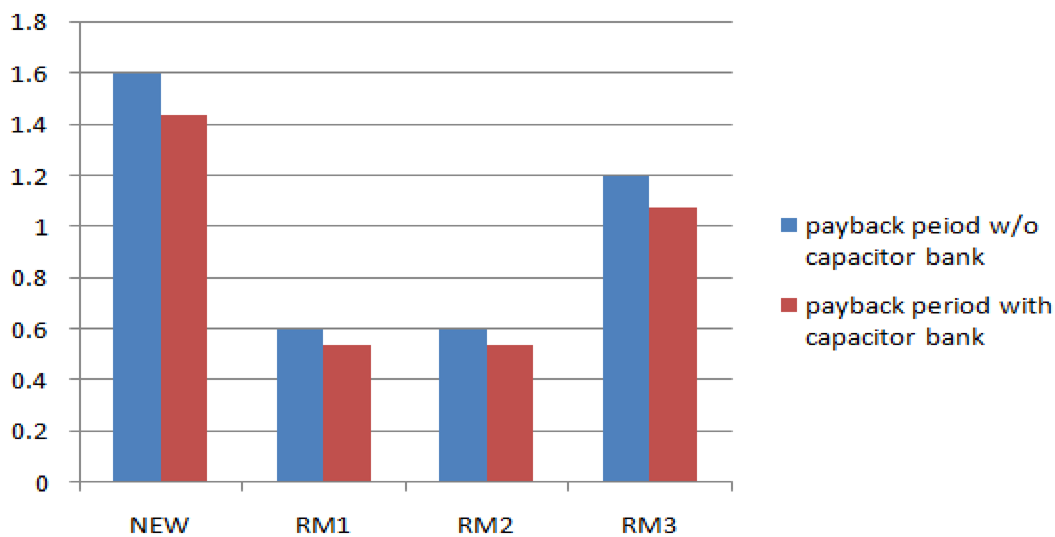


Fig: 5.6 20 HP Motor Analysis

Figure 5.6 shows the result of analysis done on 20HP motors. This fig. shows the payback period without capacitor bank and with capacitor bank. So, we notice that payback period is reduced as the capacitor bank is installed i.e payback period with capacitor bank is less as Compared to without capacitor bank.

c) 50 HP motor analysis:

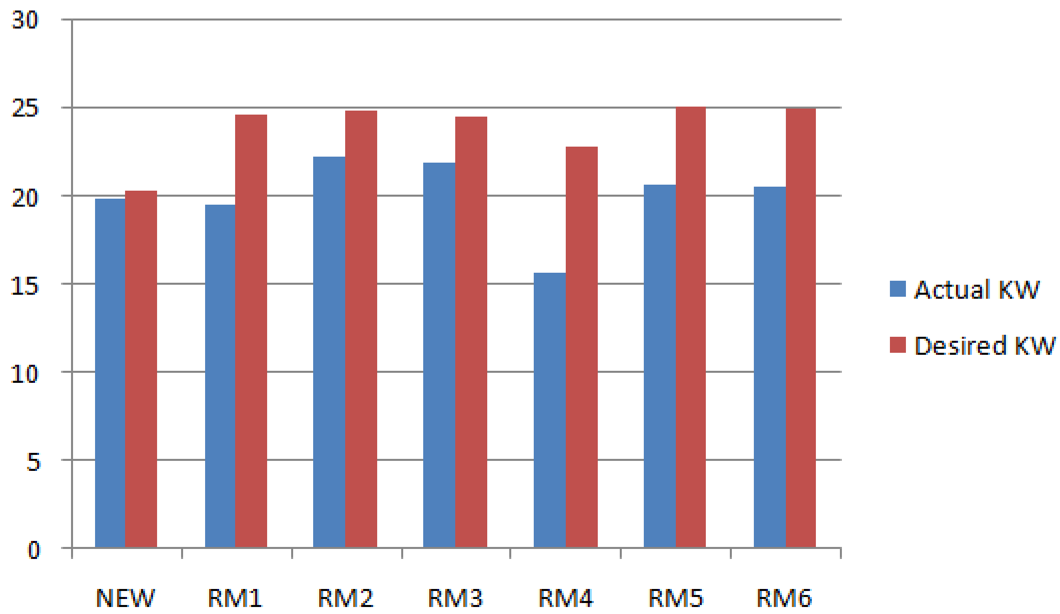


Fig. 5.7 Diff. b/w actual and desired kW 50 HP

The fig. 5.7 shows the difference of actual KW/active power and desired KW/active power.

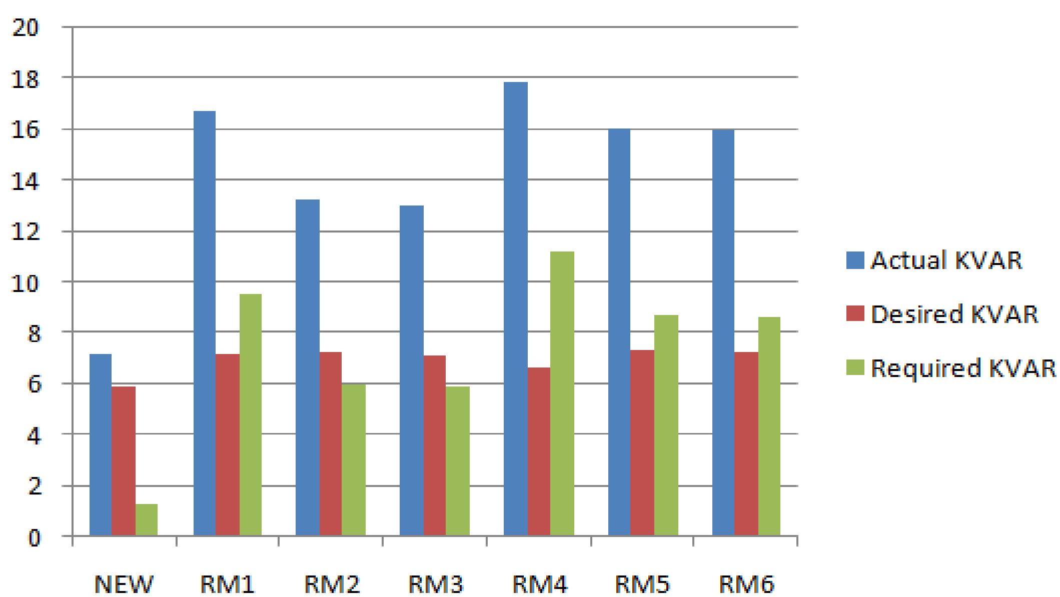


Fig. 5.8 Diff. b/w actual and desired kVAR 50 HP

The fig.5.8 shows the difference of actual KVAR/complex power and desired KVAR/complex power.

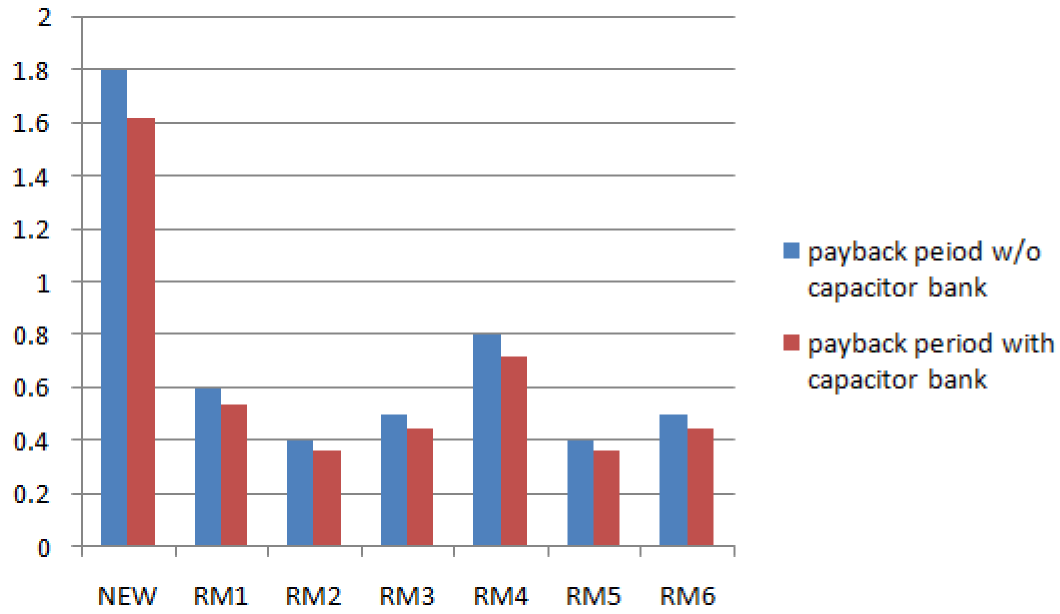


Fig: 5.9 50HP Motor Analysis

Fig. 5.9 shows the result of analysis done on 50 HP motors. This shows the payback period without capacitor bank and with capacitor bank. So, we notice that payback period is reduced as the capacitor bank is installed i.e payback period with capacitor bank is less as compared to payback period without capacitor bank.

d) Payback period analysis:

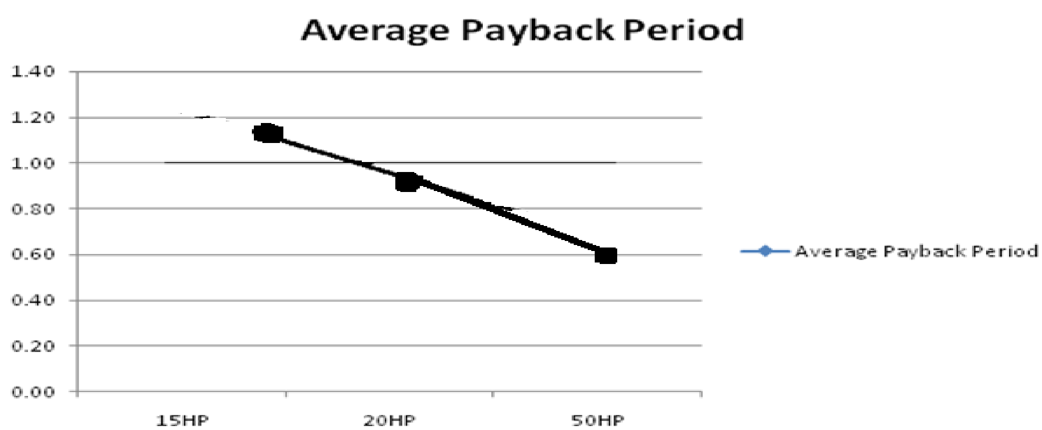


Fig. 5.10 Motor power v/s payback period

Fig. 5.10 shows the relationship between motor power and its payback period. It can be analyzed that payback period decreases with the increase in the motor power. So it is highly recommended to replace the high power motor with new motors instead of repairing them. The payback period can be decreased very less by installing capacitor bank to motors. With the help of capacitor bank installation, the power factor can be improved so benefits increased but total capital cost also increases. Thus payback period reduces.

Table 5.7 Relationship between motor power and its payback period

MOTOR HORSE POWER	AVERAGE PAYBACK PERIOD
15 HP	1.1
20 HP	0.9
50 HP	0.6

Different induction motor powers and their corresponding payback periods are shown in table 5.7. From this table, we also understand the relationship between motor power and its payback period as understood by Figure 5.10. As increase the motor Horse power with decrease its average payback period.

CHAPTER - 6
CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

Electrical energy is the most flexible type of energy since it can be converted to any form and can be transferred with equal ease. With every passing year the demand of electrical energy rises much higher than its supply and therefore the only way to plug this gap is to identify the place where it can be conserved.

The preliminary study of rice plant has explored the possible energy saving areas such as induction motor, power factor improvement and optimized parallel loading of transformer. Analysis of some has been done to save energy. It has been seen in this study that a huge chunk of energy can be saved by replacing in- house rewound induction motor by new motor.

After doing a thorough analysis on the rewound induction motor for its efficiency, it is found that rewound motor, if replaced by new ones, have a payback period in the range of 2 years to as less as 6 months. It is therefore recommended that the rewound motor should be analyzed for its efficiency and if the efficiency has found inadequate, these could be replaced by the new motors.

In second method, energy auditing also has been done after power factor improvement by installing capacitor bank to the different motors for energy saving purpose. After doing this analysis, it is found that the total capital cost and benefits increased but the payback period is decreased as compared to first analysis. It is also noticed that the efficiency improves.

6.2 FUTURE SCOPE

Present work reflects upon the preliminary study done on a typical rice plant with regard to a conservation of electrical energy only. The scope for further study exists in doing a detailed energy audit covering energy efficient motors.

From the second analysis, the scope for further study can be to implement the power factor improvement of capacitor bank for the delta connection of motor.

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