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.

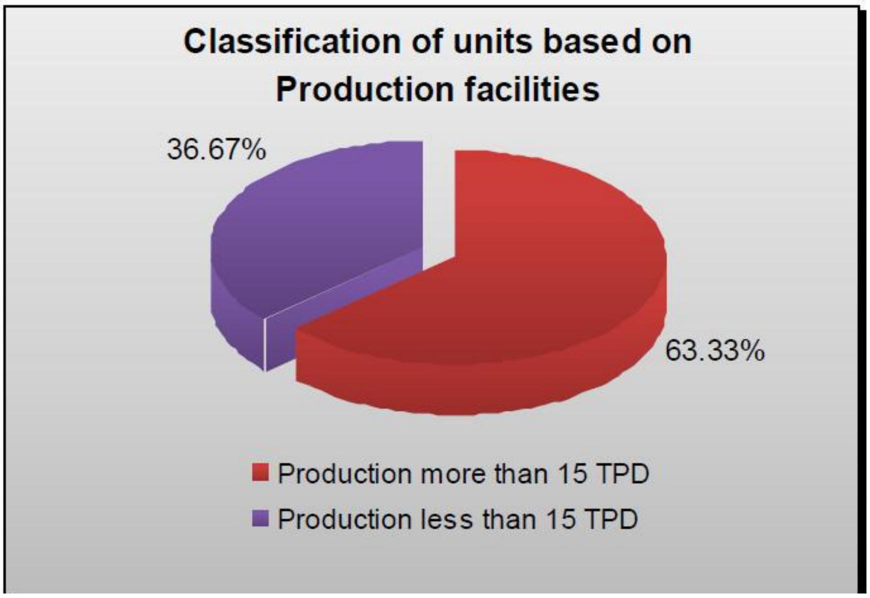


Fig. 1.1: Classification of units based on production facilities

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.

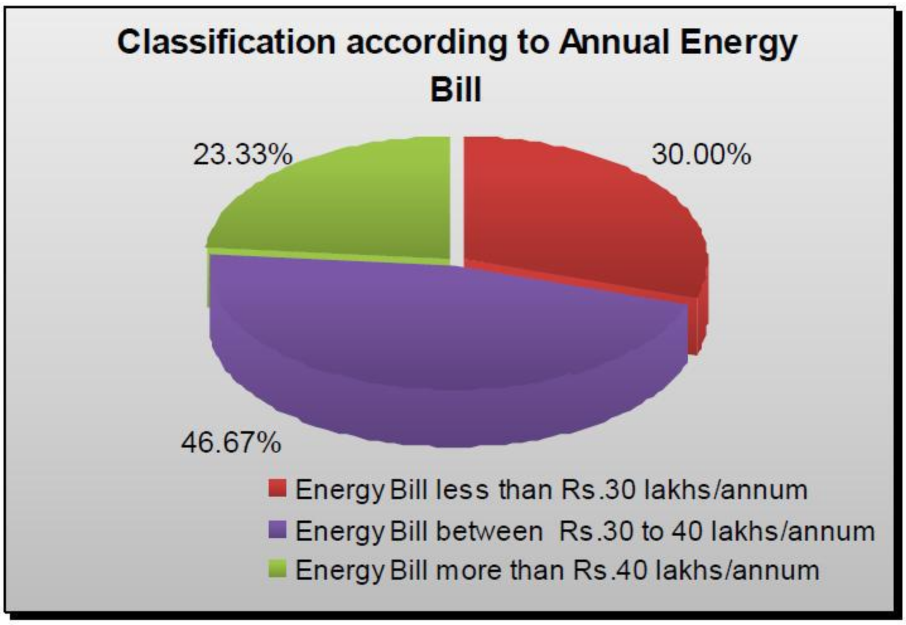


Fig. 1.2: Classification of units based on annual energy bill

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

1.4 Energy Auditing

Energy audit is an important commercial tool to save energy and to improve financialstate of an organisation. Almost all the large scaled and many small scaled organisationsi.e. industries as well as non-industrial sectors are conducting energy audit to save energyand to minimize the electricity cost. We will discuss about energy audit briefly in theproceeding sections.

1.4.1 Definition of energy audit

An energy audit is an inspection, survey and analysis of energy flow for energyconservation in buildings, processor systems to reduce the amount of energy input(s) intothe 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 primaryconcern. Beyond simply identifying the source of energy use, an energy audit seeks toprioritize the energy uses according to the greatest to least cost effective opportunity forenergy savings. An energy audit serves the purpose of identifying where a plant facilityuses 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 studiesranging from a quick walk-through a facility to identify major areas of comprehensiveanalysis of the implications of alternative energy efficiency measures sufficient to satisfythe financial criteria of sophisticated investors. Numerous audit procedures have beendeveloped for non-residential (tertiary) buildings (ASHRAE [5]; IEA-ECBCS Annex11 [6]; Krarti, 2000). Audit is to identify the most efficient and cost-effective EnergyConservation Opportunities (ECOs) or Measures (ECMs). Energy ConservationOpportunities (or Measures) can consist in more efficient use or of partial or globalreplacement of the existing installation.

When looking to the existing audit methodologies developed 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 behaviour 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 concerns and needs.

Common types/levels of energy audits are distinguished below:

- **Level 0 – Benchmarking**: This first analysis consists of a preliminary Whole Building Energy Use (WBEU) analysis based on the analysis of the historic utility use and cost and the comparison of the performances of the building to those of similar building. This 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, 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 sophisticated computer based simulation tools to evaluate precisely the selected energy retrofits;
- **Level 3 – Investment-Grade audit**: Detailed analysis of Capital-Intensive Modifications focuses on potential costly ECOs, requiring rigorous engineering study.

Level 0 - Benchmarking

The impossibility of describing all possible situations that might be encountered duringan audit means that it is necessary to find a way of describing what constitutes good,average and bad energy performance across a range of situations. The aim ofbenchmarking is to answer this question. Benchmarking mainly compares the measuredconsumption with reference consumption of other similar buildings or generated bysimulation tools to identify excessive or unacceptable running costs.As mentioned before, benchmarking is also necessary to identify building presentingenergy saving potential. An important issue in benchmarking is the use of performanceindexes to characterize the building.

These indexes can be:

- Comfort indexes, comparing the actual comfort conditions to the comfort requirements;
- Energy indexes, consisting in energy demand divided by heated/conditioned area, allowing comparison with reference values of the indexes coming from regulation or similar buildings;
- Energy demands, directly compared to ―reference' energy demands generated by means of simulation tools.

Level 1 - Walk-through or Preliminary Audit

The preliminary audit (alternatively called a simple audit or walk-through audit) is thesimplest and quickest type of audit. It involves minimal interviews with site-operationpersonnel, a brief review of facility utility bills and other operating data, and a walkthroughof the facility to become familiar with the building operation and to identify anyglaring areas of energy waste or inefficiency.

Typically, only major problem areas will be covered during this type of audit. Correctivemeasures are briefly described, and quick estimates of implementation cost, potentialoperating cost savings, and simple payback periods are provided. A list of energyconservation measures (ECMs) or energy conservation opportunities (ECOs) that requirefurther consideration is also provided. This level of detail is not sufficient for reaching afinal decision on implementation proposed measure, but is adequate to prioritize energyefficiencyprojects and to determine the need for a more detailed audit.

Level 2 - General Audit

The general audit (alternatively called detailed energy audit or complete site energyaudit) expands on the preliminary audit described above by collecting more detailedinformation about facility operation and by performing a more detailed evaluation ofenergy conservation measures.

Utility bills are collected for a 12 to 36 months period to allow the auditor to evaluate thefacility‘s energy/demand rate structures and energy usage profiles. If interval meter datais available, the detailed energy profiles made by this data will be typically analyzed forsigns of energy waste. Additional metering of specific energy-consuming systems areoften performed to supplement utility data. In-depth interviews with facility operatingpersonnel are conducted to provide a better understanding of major energy consumingsystem and to gain insight into short and longer term energy consumption patterns. Thistype of audit will be able to identify all energy-conservation measures appropriate for thefacility, given its operating parameters. A detailed financial analysis is performed foreach and every measures based on detailed implementation cost estimates; site-specificoperating cost savings, and the customer‘s investment criteria. Sufficient detail isprovided to justify project implementation.

Level 3 - Investment-grade audit

In most corporate settings, upgrades to a facility‘s energy infrastructure must completefor capital funding with non-energy-related investments. Both energy and non-energyinvestments are rated on a single set of financial criteria that generally stress the expectedReturn On Investment (ROI). The projected operating savings from the implementationof energy projects must be developed such that they provide a high level of confidence.In fact, investors often demand guaranteed savings. The investment-grade audit expandson the detailed audit described above and relies on a complete engineering study in orderto detail technical and economical issues necessary to justify the investment related to thetransformations.

Chapter 2

Literature Survey

Kumar, M. *et. al* (2013)suggested some of the major areas of energy conservation practices so that there may be a chance to see the state of Andhra Pradesh as "NO POWERCUT" state in India. A viable and immediate solution in this juncture is the energy conservation as cited by the slogan "Energy conserved is Energy Generated". Optimum use of electrical energy, not only results in cash savings, but also improves the economy of the country substantially. Hence there is an urgent need for energy management and control, which ultimately concludes with the practice of energy conservation. Energy as we all know is a crucial input in the process of economic, social and industrial development. Energy consumption is increasing at a very fast rate. With growing demand for energy it has become essential to minimize energy leakages. This article shows the present status of energy crisis in "Andhra Pradesh" state. This article also shows about the gap between power generation and demand and it suggest some of the methods to make the gap between power generation and demand is equal to Zero.

Khanchi, Sapna et. Al (2013) described the improvement of power factor of an induction motor by using capacitor bank. When power factor is improved, automatically energy will be saved A power factor is the goal of any electrical utility company since if the power factor is less than one, they have to supply more current to the user for a given amount of power use. In so doing they occur more line losses. Induction motors are the most widely used electrical motors due to their reliability, low cost and robustness. For industrial and mining applications, 3- phase AC induction motors are the prime movers for the vast majority of machines. It has been estimated that 70% to 80% of all electricity in the world is consumed by these motors. At no load induction motor has very low power factor. It improves at increasing load from no load to full load. Power factor correction is achieved by the addition of capacitors in parallel with the connected motor circuits and can be applied at the starter, or applied at the switchboard or distribution panel.

Bureau energy efficiency (BEE), (2012) 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.

Wang, J. *et al.* (2011)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%.

Ahiduzzaman,MD.*et al.* (2012) 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) 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) 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.

Pabamalie, H.L. *et al.* (2010) 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.

Kamalapur. G.D. *et al.* (2009) 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.

Bureau of energy efficiency (BEE) (2005) 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.

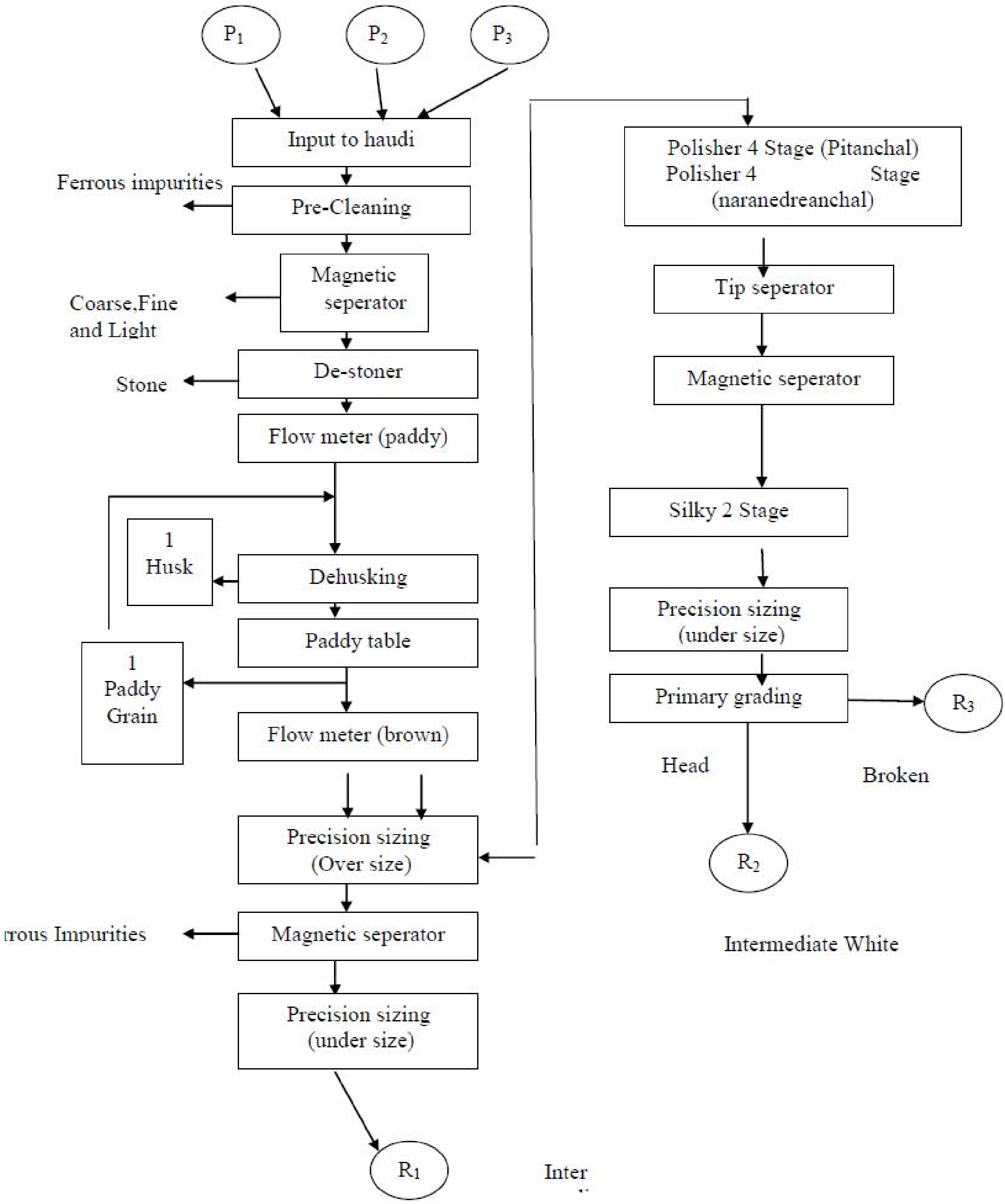
Phumiphak,T. *et al.* (2004) suggested that energy is one of the main factor for continuous development and economic growth for any country. The industrial sector consumes a large amount of energy. It was found that consumption of energy in industrial machines such as boilers, motors, compressors, lightening 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) suggested that for process of energy management at any stage, investment is required for modification purpose.

Chapter 3

DUNAR RICE MILL MANUFECTURING PROCESS

3.1 Detailed description of DUNAR manufacturing process



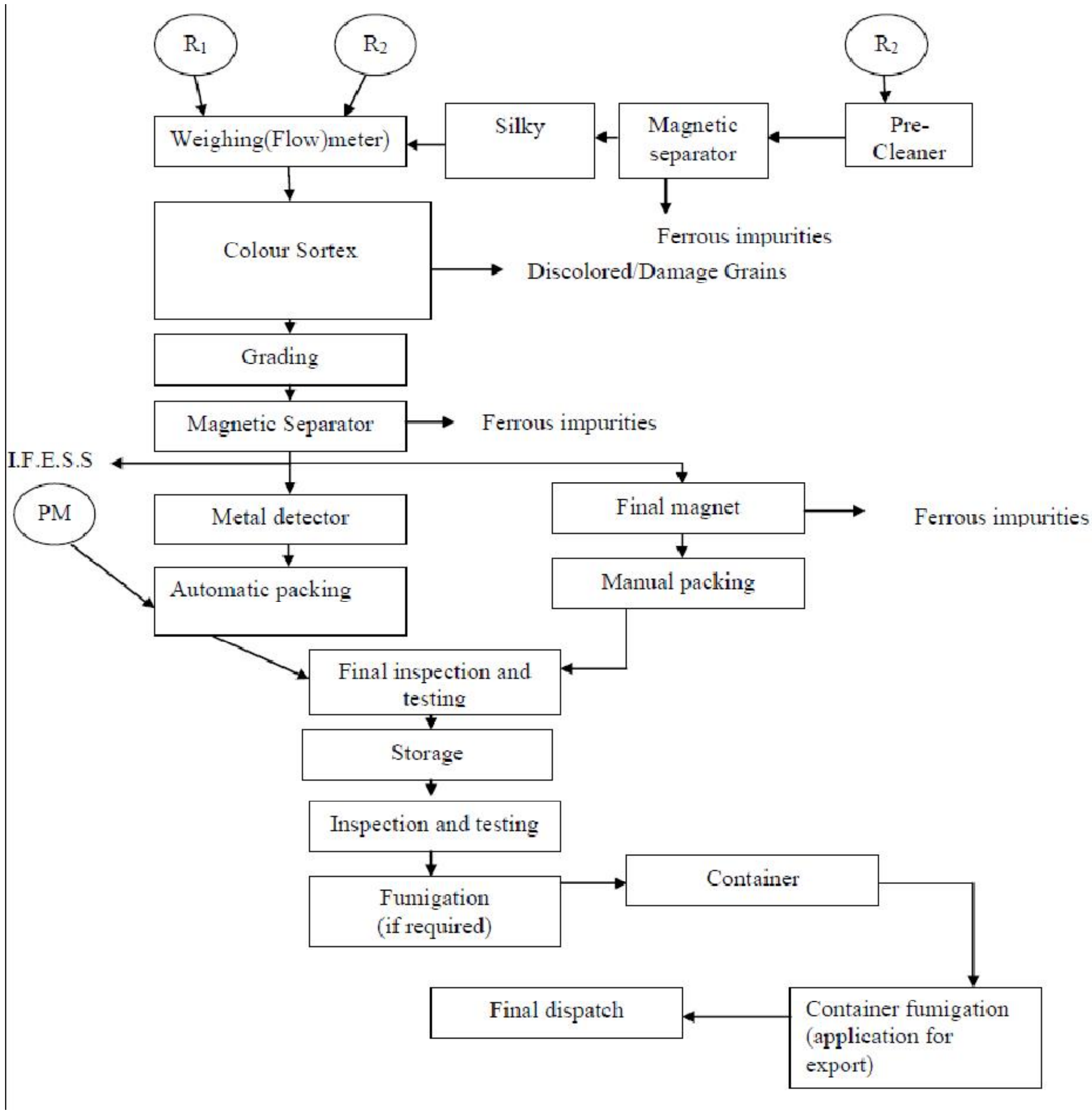


Fig. 3.1 Detailed description of DUNAR manufacturing process

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. 3.2 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 destoner.

Fig. 3.3 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 Dehusking 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. 3.4 De-Husker

It consists of a paddy grain from paddy table, after de-husking process and again fed to dehusking 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.

Chapter 4

Proposed Work

4.1 Problem Formulation

Dunar rice mill is using induction motors and if the load applied to induction motor is purely resistive then current flowing will be totally in phase but this is not the case as load can't be pure resistive in practical. The motor has magnet and magnetic current can't be in phase with voltage as magnetic current produces flux which is out of phase to provide rotation to shaft. Because of this phase difference in induction motor, rice mill suffers from distribution losses. This phase difference is also called the power factor.

So

$$power\ factor = cos\emptyset = cosine\ of\ angle\ betwen\ useful\ power\ and\ total\ power \quad ....(1)$$

Power factor correction is the term given to atechnology that has been widely used restore the power factor to as close tounity as is economically viable. This is normallyachieved by the addition of capacitors to the electricalnetwork which compensate for the reactive powerdemand of the inductive load and thus reduce theburden on the supply. There should be no effect on theoperation of the equipment.To reduce losses in the distribution system, and toreduce the electricity bill, power factor correction,usually in the form of capacitors, is added to neutralizeas much of the magnetizing current as possible.Capacitors contained in most power factor correctionequipment draw current that leads the voltage, thusproducing a leading power factor. If capacitors areconnected to a circuit that operates at a nominallylagging power factor, the extent that the circuit lags isreduced proportionately. Typically the corrected powerfactor will be 0.92 to 0.95. Some power distributors offerincentives for operating with a power factor of betterthan 0.9, for example, and some penalize consumerswith a poor power factor. There are many ways thatthis is metered but the net result is that in order toreduce wasted energy in the distribution system, theconsumer is encouraged to apply power factorcorrection. Most Network Operating companies nowpenalize for power factors below 0.95 or 0.9.

Improvement in power factor reduces the electricity bills, reduces the I^2R losses and makes available extra KVA for the supply. Energy auditing of rice mill is a process to increase the saving of mill and if electricity bills of induction motors used in mill is reduced then savings per annum will increase automatically. Dunar rice mill is using five 15 hp induction motors, three 20 hp motors and six 50hp induction motors. If I^2R losses in these are lowered then efficiency of motors are increased and electricity savings too. In our work the work done by M.kumar in 2013 is extended. In that rewounding of motors is done to improve its efficiency and later output is validated by neural network. But in our work following problem points will be discussed:

- 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.
- Although of Rewounding of motors is cheap and payback period is very less but if there in motors which are in action continually, also face problems of any part defect or load problem. That load imbalance decrease the efficiency of motor. If motor is newly installed then this problem is not amongst considered ones but in old motors load imbalance is a problem which has to be considered to improve the efficiency.

4.2 Proposed Method

The proposed method for energy auditing is divided into two action plans. In the very first plan information and data about the mill is gathered. It is necessary to analyze the potential options which require energy auditing first. In second plan of action efficient action over potential mill's part which requires energy auditing is being taken. These are described as:

***Action Plan 1**:* In the study of energy audit of the running equipment, we first see the visible abnormalsymptoms in the inefficient transfer of energy in the system using the II^{nd}law ofthermodynamics. Smooth energy transfer from one form to other like electricity to theoutput shaft speed, belt transmission etc. does not produce abnormal heating, heavy noise,spark etc. If in the running equipment the transfer of energy takes place perfectly and unavoidablelosses occur that are acceptable, then the quality and quantity of the output is good andthere is less wastage of energy and output. If the transfer is not rightly done i.e. done withmore avoidable losses, then productive output reduces, and waste output increases &dissipated in the form of heat, light, sound which is a sign of visible loss in the equipmentoperating parameters. For this process following steps are taken sequentially shown in figure 4.1.

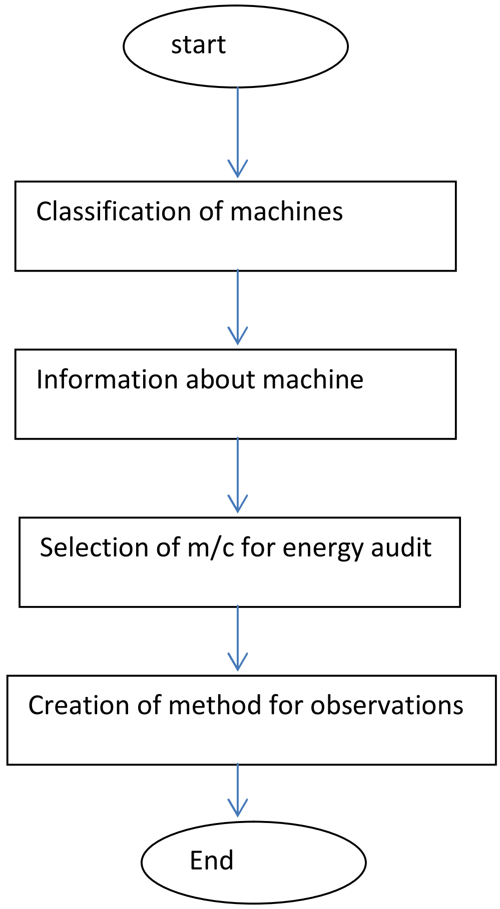


Figure 4.1: process flow diagram for action plan1

By adopting above steps and after analyzing it has been found that major electricity consumption source in rice mill is induction motors. All other electrical fitting and supply are in good conditions, so only motors are left which have to be analyzed in detail so that exact power consumption can be found out. Dunar rice mill is using three different ratings of induction motor i.e. 15hp,20 hp, 50 hp. These three types are analyzed separately. Them way of checking energy consumption is to calculate the efficiency of motors. For this some motor parameters like speed of motor, current in rotor, voltage, input power, stator winding resistance, winding temperature and payback period have to be observed. These parameters can tell exactly about motor's efficiency. The efficiency of motor can be expressed as:

$$\% \, efficicency = \frac{output\ power}{input\ power} \times 100$$

To measure above listed parameters, following methods were adopted which used some external devices for measurements.

- Rated parameters: every motor comes with a sticker pasted on motor form its manufacturing company which has the description of motors rating parameters like its serial number, power, voltage, current etc. These parameters are noted for each motor.
- Speed measured by tachometer: The most conventional unit of measuring the speed of a motor is in RPM. This stands for revolutions per minute, or the number of times the motor‘s shaft will rotate in one minute. The typical RPM range of most motors, running in industries, is from 1500 to 8000. To get a rough estimation of a motor's RPM speed, one method is to attach a piece of tape of coloured disc to the motor shaft, and count the number of rotations a minute. This depends much on your ability to focus on the moving object, and so accuracy declines as RPM increases.A more accurate and conventional method of measuring RPM is using a device called tachometer, which can precisely measure the speed of up to thousands of RPM. There are namely two types of tachometers, the contact and non-contact tachometers.In our work we have used contact type tachometer.
- Currents measured by clamp-on transducer: The clamp-on current transducer is a non-contact current transducer for use in 50/60 Hz AC current measuring applications. Installation is easy; the transducer is clamped over the wire carrying the current to be measured and the two transducer secondary wires are connected to the monitoring instrument.

  Procedure applying to measure current:

  1. Turn on the clamp meter and set the function for measuring current. There is also a selection knob or button to select whether you are measuring alternating current (AC) or direct current (DC) flow. As we are measuring current in induction motors, so we set the knob on AC.

2. Clamp the meter onto the power cord. The ends of the clamp meter arms, which resemble pincers, will have a recessed area through which the power cord should be placed. Ensures that the clamp meter arms are stable with the cord between them.
3. Now we read the current flow on the clamp meter display. Most clamp meters have automatic range finders, but our meter is not automatic one, so we increase the range of the meter until we get a reading. Write down the reading, which will be numbers that represent the amount of amperes, or amps, flowing through the cable.
4. Now we measure the amount of current flow through a motor by turning the motor on and loading it once with partial load and then full load. The current flow keeps on rising when the motor is being loaded from no-load to full-load.
5. We adjust the position of the clamp meter to ensure that we are getting accurate current flow readings. Note down all the readings. 6. Remove the clamp meter from the power cord.

- Voltage Measurement: Voltage is a differential parameter; it is always measured between two points. There are two ways to measure three-phase voltage—between two of the three lines or between a line and neutral or ground. Service and motor voltages are quoted as line to line, unless otherwise noted. Because of the phase difference, line-to-line readings are 1.73 times line-to-neutral readings. Instruments for measuring voltages include the voltmeter, the potentiometer, and the oscilloscope. The voltmeter works by measuring the current through a fixed resistor, which, according to Ohm's Law, is proportional to the voltage across the resistor. Figure 4.2 shows the multimeter that is used to measure voltage across motor.

  If the motor connection are as delta connection then phase voltage will be equal to line voltage and if these connection are star connections then phase voltage will be calculated after dividing the line voltage by square root of 3.

$$\text{Phase voltage} = \text{line voltage}/\sqrt{3}$$

Figure 4.2: Multimeter used for measuring voltage

- Stator resistance measurement: Measurement of winding resistance is done across line to line i.e. R & Y, Y & B and R & B phases. The average value of line-to-line resistance obtained is designated as R_{ll}.

  To convert the measured value of line-to-line resistance to phase resistance, the following relationships are used.

  In Star‘ connection, phase resistance, phasor resistance= 0.5*R11

  In Delta‘ connection, phase resistance, phasor resistance= 1.5*R11

  The resistance must be corrected to the operating/full load temperature by usingfollowing relationship:

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

Where, R2 = unknown resistance at temperature T2

R1 = resistance measured at temperature T1

- Input power measurement: For no-load power measurement, a low power factor corrected power analyzer having full-scale error of not more than 0.5% is used. It is noted that energy meters, which are used usually in measurements where p.f. might be above 0.7, indicate errors of 5 to 10% when used in low p.f. (0.1 to 0.3) load conditions. Hence it is important to have power analyzers with CT's calibrated for various load currents and p.f. ranging from 0.1 to 1.0. Measurement of energy consumed during a known period is done using a power analyzer and power is estimated from energy measurement and time duration.

After observing theses parameters for each motor some parameters need to be calculated which are required to calculate the annual savings as net cost can be provided by mill's accounts department. Following formulas are used for calculation purpose:

$$sync. speed = 120f/p$$

$$sstator\ resistnace\ N.L\ \&\ F.L\ motor = \frac{R_2}{R_1} = \frac{235 + T_2}{235 + T_1}$$

$$\text{Stator CU. Losses at N. L} \ \&\ F.L = I^2 R$$

$$\text{Iron, F\&}W\ losses = P_{\text{in}} - \text{ stator Cu. Losses at N. L}$$

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

$$\text{Full load rotor Losses} = I^2 R$$

$$\text{Stray losses} = \text{1.5\% of F. L input power}$$

B

B

$$\mathrm{F.L\ output\ power} = \mathrm{Pin} - \mathrm{stator\ Cu.loss\ at\ F.L} - \mathrm{F\&}W\ loss - rotor\ Cu.loss\ at\ F.L - stray\ loss$$

$$\%\ efficicency = \frac{output\ power}{input\ power} \times 100$$

$$Rated\ efficicency = \frac{rated\ output\ power}{rated\ input\ power} \times 100$$

The rated parameters and calculated parameters by above said methods are tabulated in appendix. In tables shown in appendix a new parameter payback period is also added. This parameter is the defining parameter of proposed method as our main objective will be to improve the payback period. The payback period is the length of time required for running total ofnet savings before depreciation to equal the capital cost of the project. Once the payback period has ended then project's capital cost will be converted into total profit. So payback period should be minimum. Payback period can be expressed mathematically as:

$$payback\ period = \frac{capital\ cost\ of\ the\ project}{net\ annual\ savings}$$

Action plane 2: after observing the parameters it is required that losses in motor should be decreased. In our reference paper it is done my rewounding the induction motor. But another way can also be adopted for this. In literature survey it has been found that if power factor of motor is decrease then reactive losses are also decreased and installation of capacitors in parallel with motor is the solution for this. But there is an issue with capacitor size and rating as we are dealing to minimize the payback period so capacitor installation cost should be minimum. For this purpose a bio optimized algorithm named 'bacterial foraging optimization (BFO)' is used to minimize the cost as its objective function.

For the objective function of BFO energy loss cost and capacitor cost collectively minimized. For this following parameters have been considered:

- Power loss cost which has been calculated by considering full load stator current and resistance. Full load stator current is considered because power factor correction is added to neutralize a portion of the magnetizing current of the motor and in case of full load power factor increases because of constant magnetizing field.
- Installation cost of capacitor
- Cost of capacitor per unit rating

The formula used to minimize the cost is given as:

$$Cost=min(Ce*sum(EL)+sum(CC))$$

Where CC= cost of capacitors = installation cost + cost of capacitor per unit

Ce= energy rate

EL= energy Loss

A brief description about algorithm of bacterial foraging optimization is described under.

Bacteria Foraging Optimization Algorithm (BFOA), is a new comer to the family of nature-inspired optimization algorithms. For over the last five decades, optimization algorithms like Genetic Algorithms (GAs), Evolutionary Programming (EP), Evolutionary Strategies (ES), which draw their inspiration from evolution and natural genetics, have been dominating the realm of optimization algorithms. Recently natural swarm inspired algorithms like Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) have found their way into this domain and proved their effectiveness. Application of group foraging strategy of a swarm of *E.coli* bacteria in multi-optimal function optimization is the key idea of the new algorithm. Bacteria search for nutrients in a manner to maximize energy obtained per unit time. Individual bacterium also communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemotaxis and key idea of BFOA is mimicking chemotactic movement of virtual bacteria in the problem search space.

During foraging of the real bacteria, locomotion is achieved by a set of tensile flagella. Flagella help an *E.coli* bacterium to tumble or swim, which are two basic operations performed by a bacterium at the time of foraging. When they rotate the flagella in the clockwise direction, each flagellum pulls on the cell. That results in the moving of flagella independently and finally the bacterium tumbles with lesser number of tumbling whereas in a harmful place it tumbles frequently to find a nutrient gradient. Moving the flagella in the counter clockwise direction helps the bacterium to swim at a very fast rate. In the above-mentioned algorithm the bacteria undergoes chemotaxis, where they like to move towards a nutrient gradient and avoid noxious environment. Generally the bacteria move for a longer distance in a friendly environment. Figure 3.1 depicts how clockwise and counter clockwise movement of a bacterium take place in a nutrient solution.

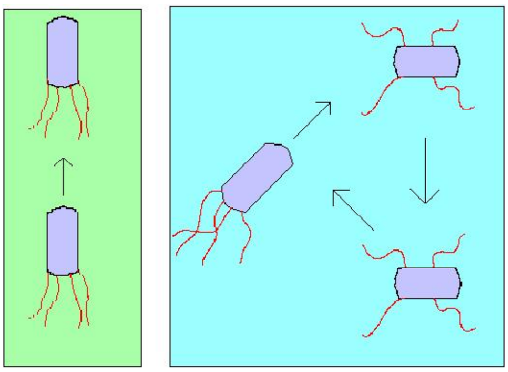


Fig.4.3. Swim and tumble of a bacterium

When they get food in sufficient, they are increased in length and in presence of suitable temperature they break in the middle to from an exact replica of itself. This phenomenon inspired Passino to introduce an event of reproduction in BFOA. Due to the occurrence of sudden environmental changes or attack, the chemotactic progress may be destroyed and a group of bacteria may move to some other places or some other may be introduced in the swarm of concern. This constitutes the event of elimination-dispersal in the real bacterial population, where all the bacteria in a region are killed or a group is dispersed into a new part of the environment.

Thus search for food of E.Coli can be categorised into four steps: Chemotactic, Swarming, Reproduction and Killing/ Dispersion. Mathematically these can be represented step by step as:

Chemotactic:

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + c(i)\frac{\Delta(i)}{\sqrt{\Delta^t(i)\Delta(i)}}$$

Where $\theta^i(j,k,l)$represents *i*-th bacterium at *j*th chemotactic, *k*-th reproductive and *l*-th elimination-dispersal step. *C*(*i*) is the size of the step taken in the random direction specified by the tumble (run length unit).

Swarming

$J(i, j, k, l) = J(i, j, k, l) + J_{cc}(\theta(j, k, l), P(j, k, l)$

where *J (i, j, k, l)* is the fitness function.

BFO Algorithm: steps for BFO algorithm are discussed as

Parameters:

[Step 1] Initialize parameters p, S, Nc, Ns, Nre, Ned, Ped, C(i)(i=1,2…S),

Algorithm:

[Step 2] Elimination-dispersal loop: l=l+1

[Step 3] Reproduction loop: k=k+1

[Step 4] Chemotaxis loop: j=j+1

[a] For i =1,2…S take a chemotactic step for bacterium i as follows.

[b] Compute fitness function, J (i, j, k, l).

Let, J (i, j, k, l) = J (i, j, k, l)+ J_{cc} (θ(j, k, l),P(j, k, l)) (i.e. add on the cell-to cell attractant–repellant profile to simulate the swarming behaviour)

[c] Let Jlast=J (i, j, k, l) to save this value since we may find a better cost via a run.

[d] Tumble: generate a random vector D(i)ÎÂp with each element (i),m 1,2,..., p, m D = a random number on [-1, 1].

[e] Move: Let

$$\theta^{i}(j+1,k,l) = \theta^{i}(j,k,l) + c(i)\frac{\Delta(i)}{\sqrt{\Delta^{t}(i)\Delta(i)}}$$

This results in a step of size C(i) in the direction of the tumble for bacterium i.

[f] Compute J (i, j +1, k, l) and let

J (i, j 1, k, l) = J (i, j, k, l) +J_{cc} (θ(j 1, k, l), P(j 1, k, l))

[g] Swim

i) Let m=0 (counter for swim length).

ii) While m< s N (if have not climbed down too long).

- Let m=m+1.
- If J (i, j +1, k, l) < Jlast (if doing better), let Jlast = J (i, j +1, k, l) and let

$$\theta^{i}(j+1,k,l) = \theta^{i}(j,k,l) + c(i)\frac{\Delta(i)}{\sqrt{\Delta^{t}(i)\Delta(i)}}$$

And use this θ(j +1, k, l) to compute the new J (i, j +1, k, l) as we did in [f]

- Else, let m= s N . This is the end of the while statement.

[h] Go to next bacterium (i+1) if i ≠ S (i.e., go to [b] to process the next bacterium).

[Step 5]If c j < N , go to step 4. In this case continue chemotaxis since the life of the bacteria is not over.

[**Step 6**] Reproduction:

[a] For the given k and l, and for each i = 1,2,..., S , let

$$J_{health} = \sum_{j=1}^{N+1} J(i,j,k,l)$$

be the health of the bacterium i (a measure of how many nutrients it got over its lifetime and how successful it was at avoiding noxious substances). Sort bacteria and chemotactic parameters C(i) in order of ascending cost health J (higher cost means lower health).

[b] The r S bacteria with the highest J_{health} values die and the remaining r S bacteria with the best values split (this process is performed by the copies that are made are placed at the same location as their parent).

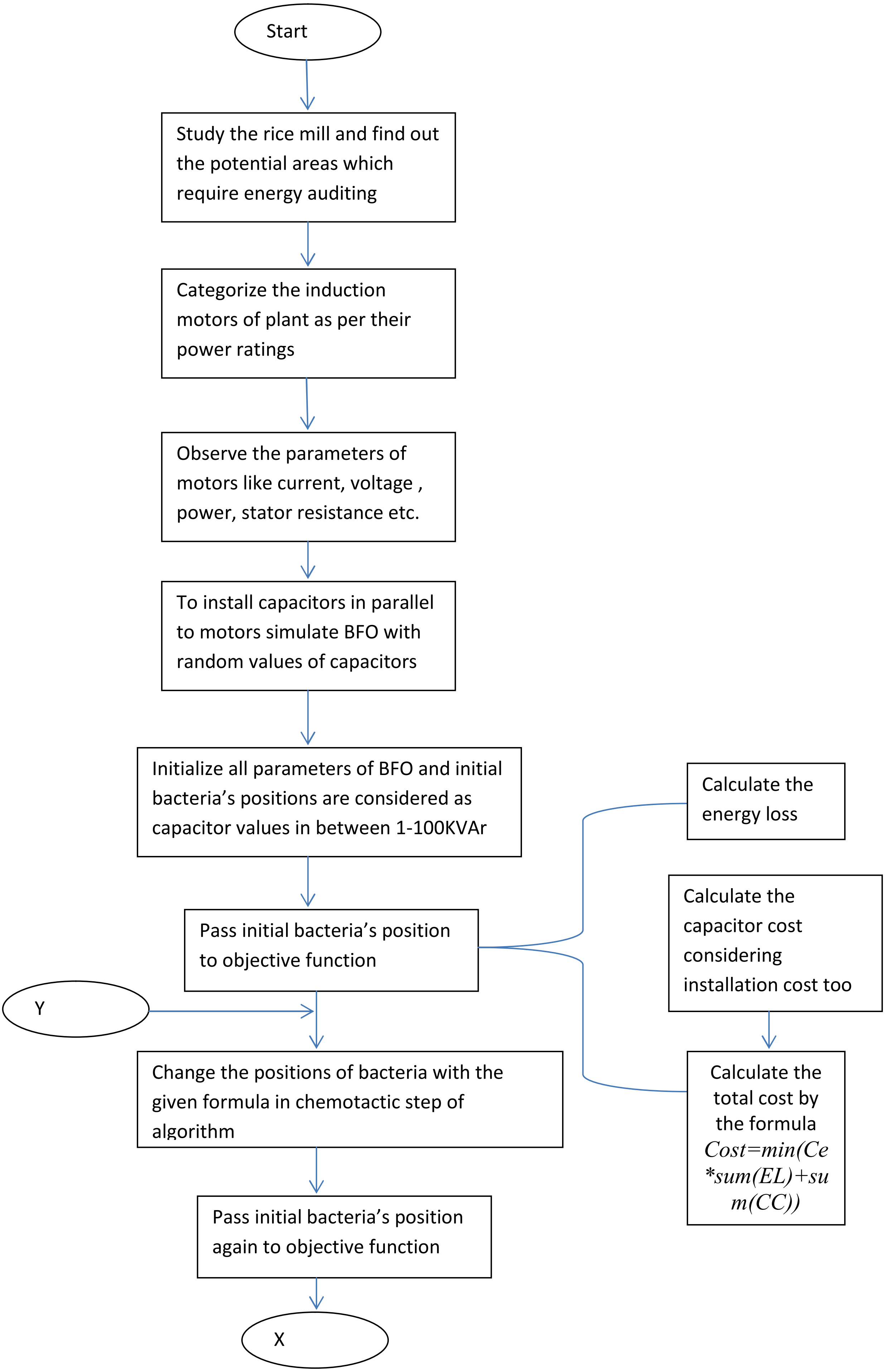
[**Step 7**] If $k < N_{re}$, go to step 3. In this case, we have not reached the number of specified reproduction steps, so we start the next generation of the chemotactic loop.

[**Step 8**] Elimination-dispersal: For i = 1,2..., S with probability ed P , eliminate and disperse each bacterium (this keeps the number of bacteria in the population constant). To do this, if a bacterium is eliminated, simply disperse another one to a random location on the optimization domain. If $l < N_{ed}$, then go to step 2; otherwise end.

In above BFO algorithm the initial positions of bacteria are considered as the capacitor's capacitance values which are transferred to objective function. These are random values between 1-100 KVAr.

4.3 Flow chart

The description of complete proposed work is represented in the form of flow chart in figure 4.4


Start
Study the rice mill and find out the potential areas which require energy auditing
Categorize the induction motors of plant as per their power ratings
Observe the parameters of motors like current, voltage , power, stator resistance etc.
To install capacitors in parallel to motors simulate BFO with random values of capacitors
Initialize all parameters of BFO and initial bacteria's positions are considered as capacitor values in between 1-100KVAr
Calculate the energy loss
Calculate the capacitor cost considering installation cost too
Pass initial bacteria's position to objective function
Y
Change the positions of bacteria with the given formula in chemotactic step of algorithm
Calculate the total cost by the formula $Cost=min(Ce*sum(EL)+sum(CC))$
Pass initial bacteria's position again to objective function
X

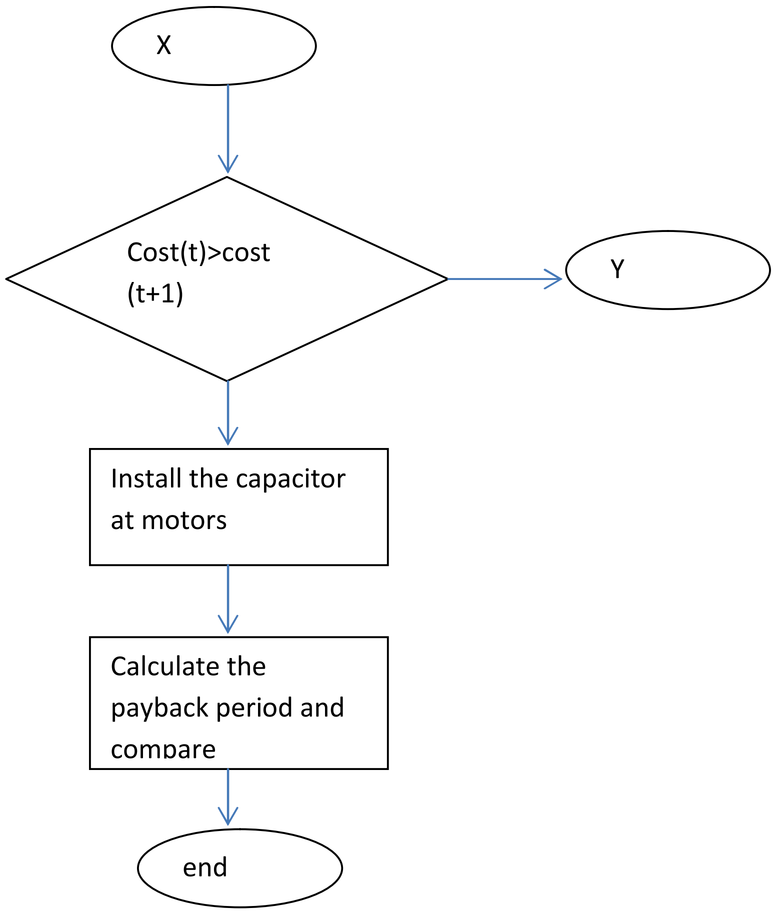


Figure 4.4: flow chart of complete algorithm

Chapter 5

Results & Discussion

Energy auditing of Dunar rice mill is done in our proposed workincludes a 22KV substation and 1MWdiesel plant. The installed capacity is 16,425Tons Per Annum (TPA). As discussed in previous chapter capacitors of different ratings are installed at each motor to improve their power factors. The capacitor rating installed is dynamically optimized by bio inspired bacterial foraging optimization (BFO) which calculates the rating keeping the constraint of cost in installation of capacitor so that maximum saving and minimum payback period can be achieved. Initial parameters which are considered for BFO algorithm are shown in table 1.

Table 1: initialization parameters for BFO

Number of bacteria	26
Searching space dimension	Equal to number of motors
Chemotactic steps	50
Elimination/dispersal steps	4
Reproduction steps	2
Length of swim	4

To make our work user friendly a graphical user interface (GUI) is developed using MATLAB which is shown in figure 5.1. As discussed Dunar rice mill have three different ratings of induction motor i.e. 15hp,20hp and 50 hp. For comparison purpose, results after installation of capacitors are compared with a new motor of respective rating so that it can be concluded that whether new motor installation will cost less or capacitor installations. GUIclearly shows the required comparison in form of bar graphs and tabulated values.

Case 1: 15 hp motor

After selecting the 15 hp motor from the pop up menu 15 hp parameters are loaded into GUI after calculation and rated too. On pressing the button named capacitor calculation, BFO algorithm starts executing and look for optimum value of capacitor for which total loss cost and installation cost of capacitor is minimum as discussed in proposed work.

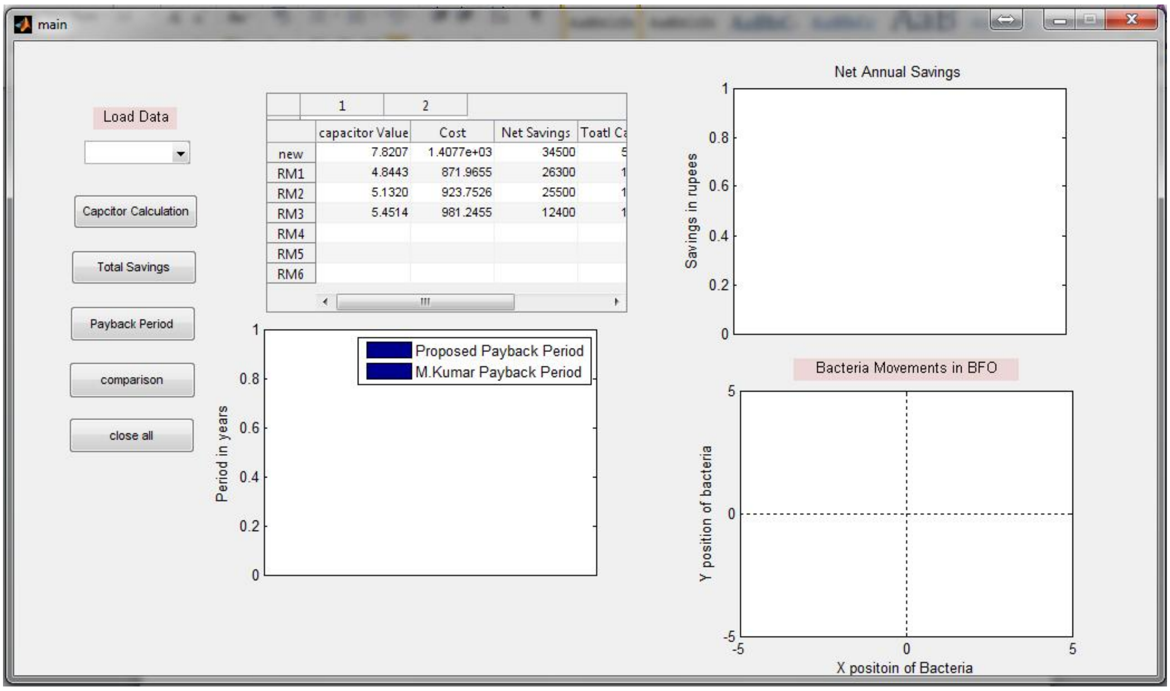


Figure 5.1: GUI of proposed work

The table in the GUI shows the optimum capacitor value and total cost. The total savings and payback period are calculated and tabulated in GUI by pressing the respective buttons. The results of 15 hp motor are shown in table 5.1.

Table 5.1: Calculated payback period for 15 hp motor

	Capacitor Value	Capacitor cost in rupees	Net savings (in rupees)	Total capital cost (in rupees)	Payback period(in years)
New	2.5885	465.9312	2.8244e+04	2.8710e+04	1.0165
RM1	3.4893	628.0684	15000	1.5628e+04	1.0419
RM2	3.9453	710.1540	1.0714e+04	1.1424e+04	1.0663
RM3	5.5988	1.0078e+03	8.1667e+03	9.1744e+03	1.1234
RM4	3.7745	679.4109	2.3833e+04	2.4513e+04	1.0285
RM5	2.4493	440.8805	13000	1.3441e+04	1.0339

A comparison with M.Kumar work's payback period is shown in figure 5.2.

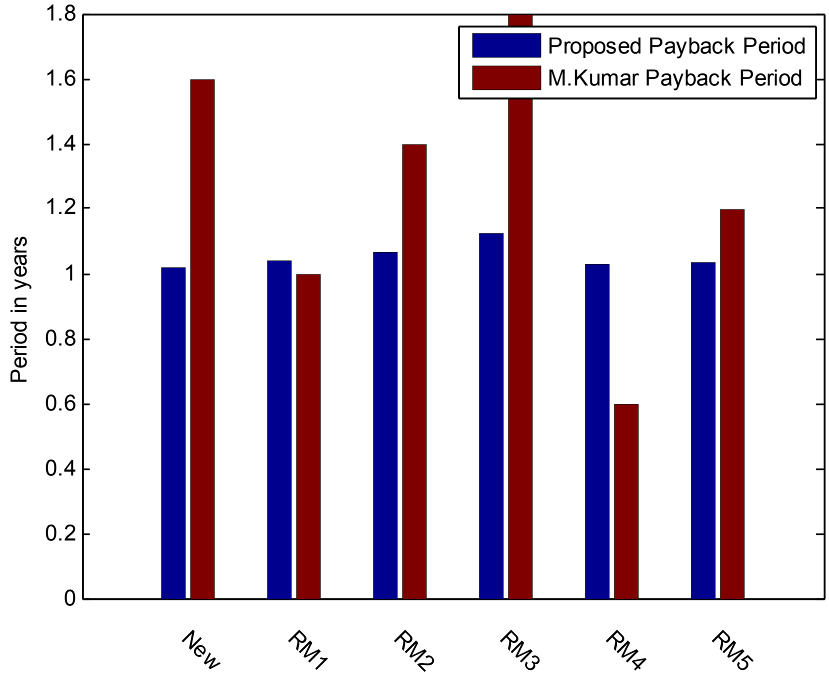


Figure 5.2: comparison of Payback period of 15 hp motor

The bar graph above shows that for every motor of 15 hp, installation of capacitors costs less and payback period is also decreased than reference paper, which considered only the rewounding of motors. The new motor installation also doesn't affect much in payback period. So for 15 hp motor any option can be considered whether new motor is installed or capacitors are installed in parallel with old motor in terms of payback period. But net annual saving graph of figure 5.3 shows maximum annual saving in case of new motor, so new motor installation can be better option in this case.

Case 2: 20 hp motor

In case of 20 hp motor following are observations which are calculated by BFO.

Table 5.2: Calculated payback period for 20 hp motor

	Capacitor Value	Capacitor cost in rupees	Net savings (in rupees)	Total capital cost (in rupees)	Payback period(in years)
New	5.2394	943.0920	26300	1.6543e+04	0.6290

RM1	5.0621	911.1745	25500	1.6011e+04	0.6279
RM2	4.7210	849.7824	12400	1.5550e+04	1.2540

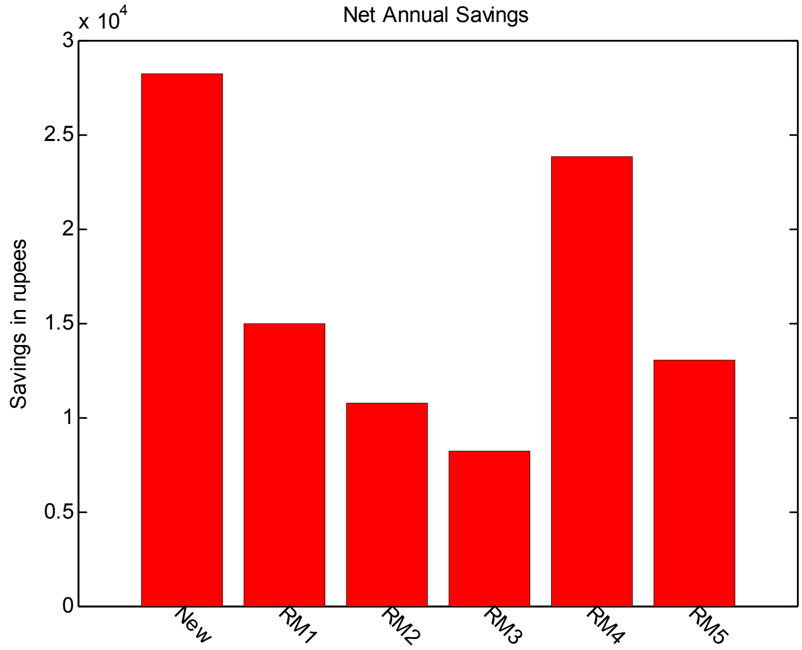


Figure 5.3: Bar graph for annual saving of 15 hp motor

The bar graph of payback period is shown in figure 5.4 which shows that for this motor too our proposed scheme performs well and payback period is decreased than in the M. Kumar's work and the difference is more than 0.4 years.

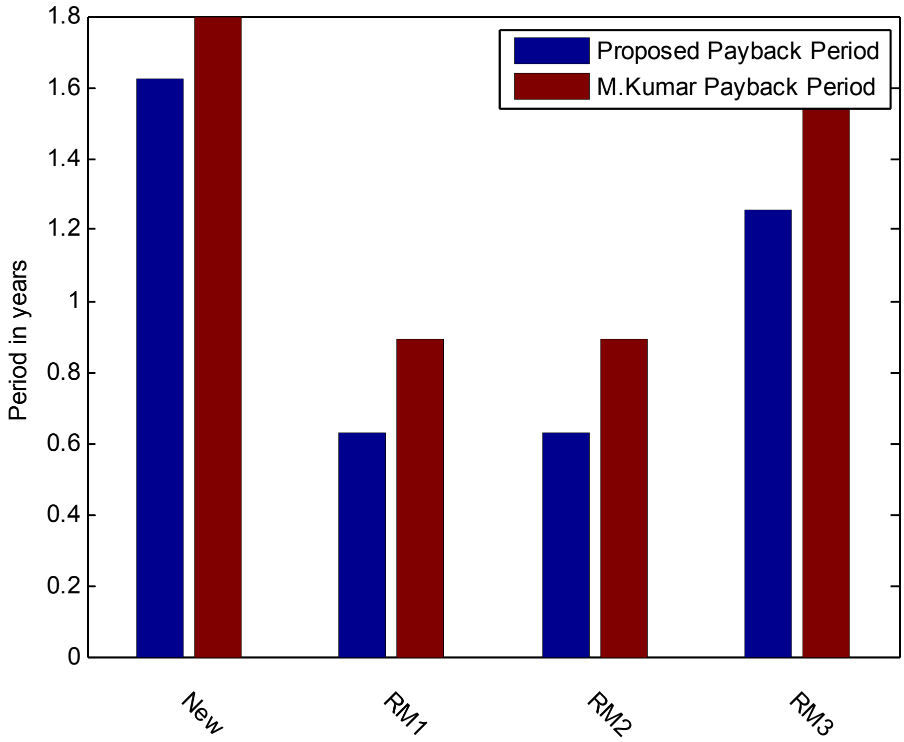


Figure 5.4: Bar graph of payback period for 20 hp motor

Even installation of new motors of 20hp will cost high and high payback period. So in this case capacitor installation is considered and value of capacitors is provided in table 5.2 for each motor. The net saving graph is shown in figure 5.5. the net annual saving is high for new motor but with that payback period is high too.

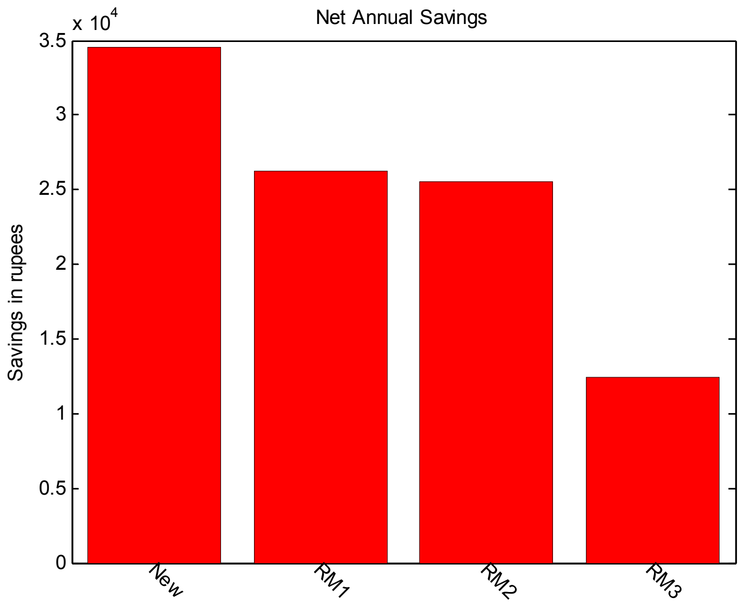


Figure 5.5: Net annual savings in case of 20 ho motor.

Case 3: 50 hp motor

The procedure followed in case 1 is also followed for 50 hp motor. The resulting observed parameters are tabulated in table 5.3 below.

Table 5.3: Calculated payback period for 50 hp motor

	Capacitor Value	Capacitor cost in rupees	Net savings (in rupees)	Total capital cost (in rupees)	Payback period(in years)
New	2.2485	404.7334	91400	1.6997e+05	1.8597
RM1	3.8658	695.8390	34200	2.6196e+04	0.7660
RM2	2.3291	419.2325	51250	2.5919e+04	0.5057
RM3	2.7143	488.5671	40600	2.5789e+04	0.6352
RM4	4.0174	723.1314	23035	2.4223e+04	1.0516
RM5	2.5075	451.3432	49500	2.5251e+04	0.5101
RM6	2.7595	496.7128	38200	2.4597e+04	0.6439

Bar graph for comparison purpose is shown in figure 5.6. In this also like in previous case the payback period is less than M.Kumar's proposal of rewounding of motors. All six 50 hp motors will payback in less period and also new motor installation is not a good option to opt. Capacitor installations of rated values are best. The net annual saving for this is shown in figure 5.7.

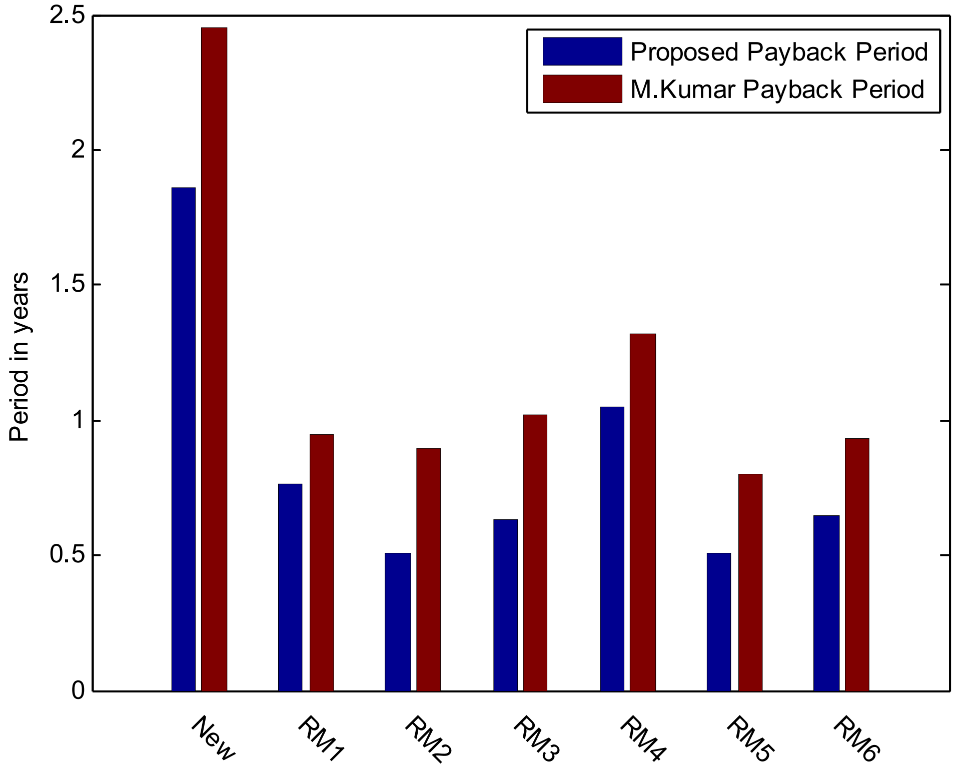


Figure 5.6: Bar graph comparison for 50 hp motor

The comparison of capacitor value for all three cases is shown in figure 5.8. small value of capacitors are required in 50 hp motor that means in this category of motor, losses are less. The average payback period of all types of motor is shown in figure 5.9. this comparison shows that minimum payback period is of 20 hp motor and maximum is for 15hp motor.

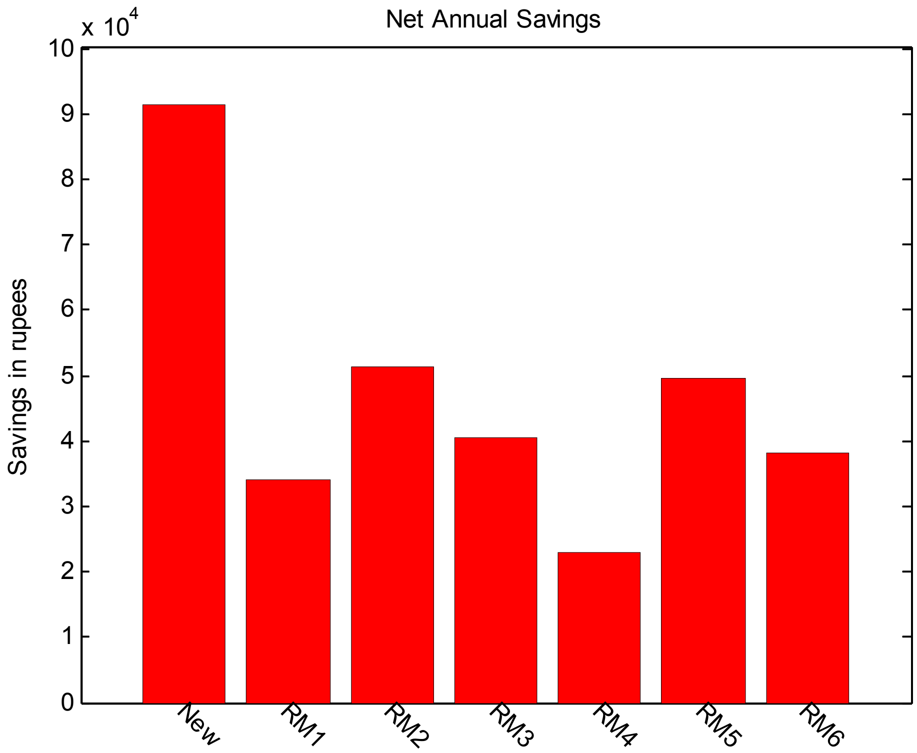


Figure 5.7:Net annual saving in case of 50 hp motor.

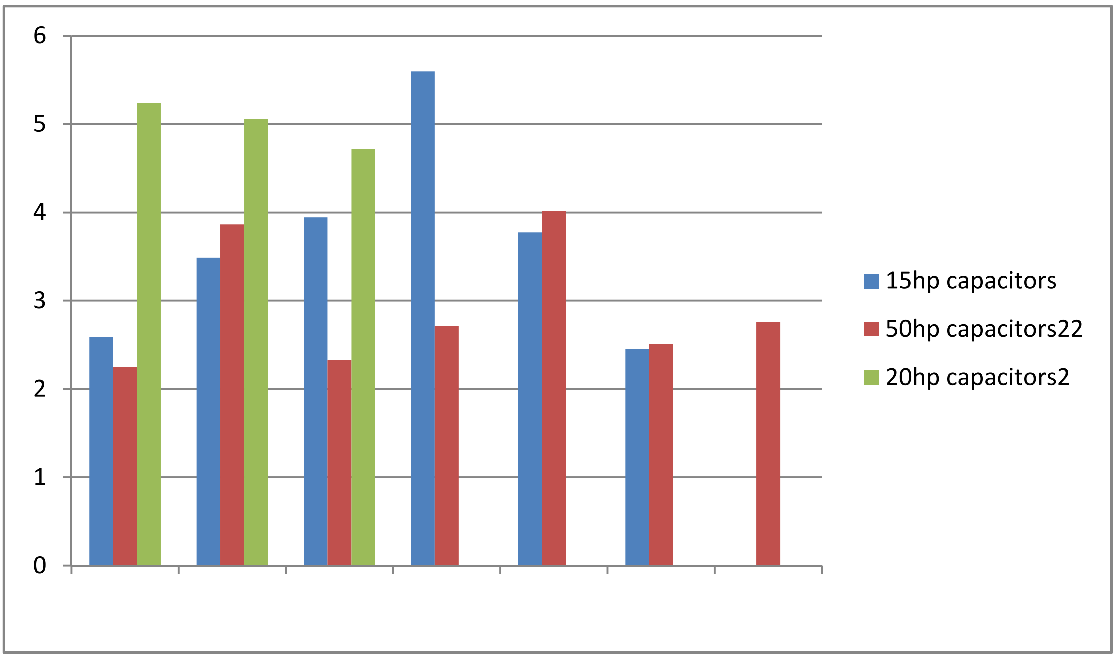


Figure 5.8: Capacitor rating for installation in three type of motors in KVAr

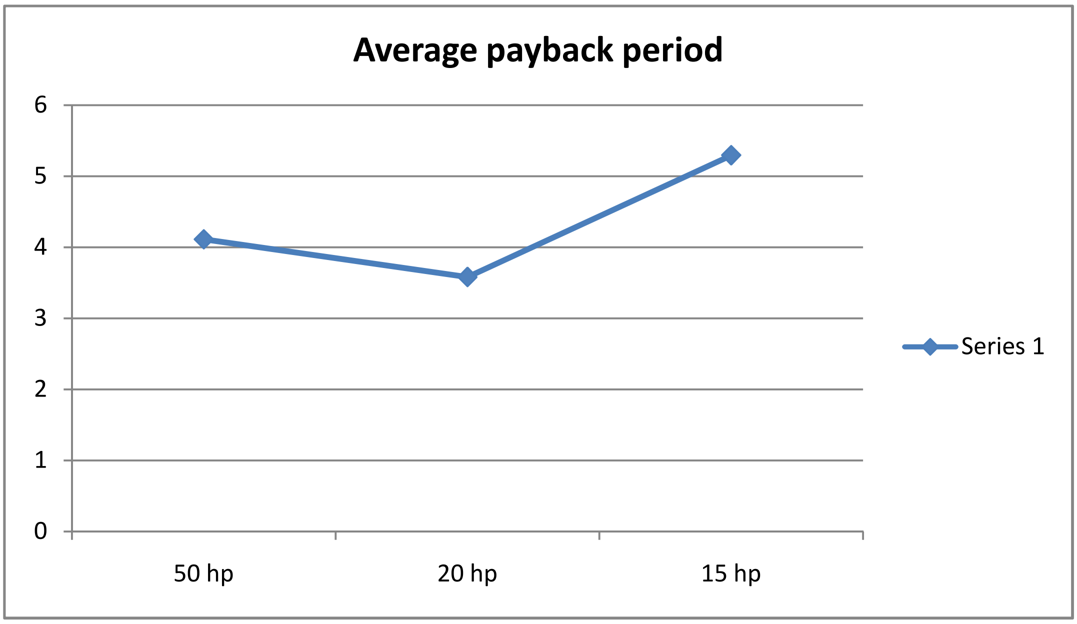


Figure 5.9: average payback period of all categories of motor

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.

Energy auditing also has been done after power factor improvement by installing capacitor bank to the different motors for energy saving purpose. For installation of capacitor rating bacterial foraging optimization is used which worked towards an optimum value which cost less and minimum payback period. By using this algorithm payback period is sincreased and it has been found that average payback period is least for 20 hp motor and maximum for 15 hp motor. 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. For 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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Appendix

Table A.1 Rated Parameters of 15 HP Rewound Motors

MOTOR IDENTIFY.	MOTOR MODEL	MOTOR TYPE	NO. OF POLES	RATED POWER (W)	RATED VOLTAGE (V)	RATED CURRENT (A)	F.L RATED SPEED (RPM)	SUPPLY FREQ. (Hz)	RATED O/P POWER (W)
New	New	15hp	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	11016
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 A.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 A.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 A.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 A.3 (b) Calculated Parameters of 15 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	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	210.25	210	12194.447	101.6203916	0.79	87.10319284	9600	6000

Table A.3 (C) Calculated Parameters of 15 HP Rewound Motors

MOTOR IDENTIFY	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 A.4 Rated Parameters of 20 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	20hp	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 A.5(A) Measured Parameters of 20 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
New	415	11	615	1490	20	0.25
R.M.1	410	10	660	1490	24	1.2
R.M.2	410	10	660	1490	23.5	0.91
R.M.3	410	10.5	680	1490	30	0.77

Table A.5(B) Measured Parameters of 20 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
New	39	137	410	30	17000	1475	0.298
R.M.1	41	141	410	31	17300	1475	0.262
R.M.2	40	131	410	34.5	17200	1475	0.211
R.M.3	47	150	415	33	18000	1475	0.248

Table A.5(C) Measured Parameters of 20 HP Rewound Motors

MOTOR IDENTIFY	Capital Cost	Installation Cost	Running Cost	Running Time	Electrical Expenses	Benefit
New	50040	5000	180	20	1679.6	36372.1
R.M.1	10600	5000	185	20	1709.24	28202.57
R.M.2	10100	5000	180	20	1699.36	27346.03
R.M.3	9700	5000	190	20	1778.4	14376.73

Table A.6 (a) Calculated Parameters of 20 HP Rewound Motors

MOTOR IDENTIFY	Sync Speed	Stator Resistance at no laod	Statore cu Loss	F& W Loss	F.L. rotor loss	Stray Loss	F.L o/p Power
New	1080	0.7366	0.1128	614.8872	268.2	255	1.59E+04
R.M.1	1080	0.734	0.4766	659.5234	251.782	259.5	1.61E+04
R.M.2	1080	0.7514	0.3623	659.6377	251.1427	258	1.60E+04
R.M.3	1080	0.7325	0.3143	679.6857	270.072	270	1.68E+04

Table A.6 (b) Calculated Parameters of 20 HP Rewound Motors

MOTOR IDENTIFY	% Loading	Actual Efficiency	Rated Efficiency	Total Capital Cost	Net Saving	Payback Period
New	1.09E+03	7.93E+04	36500	55040	3.45E+04	1.5948
R.M.1	1.10E+03	6.72E+04	36500	15600	2.63E+04	0.593
R.M.2	1.10E+03	6.82E+04	36500	15100	2.55E+04	0.5929
R.M.3	1.15E+03	5.59E+04	36500	14700	1.24E+04	1.1847

Table A.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	20hp	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	34780
R.M.5			3	4	37000	50	415	62	1480	50	34780
R.M.6			3	4	37000	50	415	62	1480	50	34780

Table A.8(a) Measured Parameters of 50 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
New	415	21	1290	1495	25	0.11
R.M.1	415	10.202	660.15	1495	28	0.79
R.M.2	415	10.22	660.169	1495	23.05	0.99
R.M.3	410	10.519	680.175	1495	29	0.83
R.M.4	420	21.5	2003.5	1495	23	0.67
R.M.5	415	23	1800	1490	37	0.87
R.M.6	410	21.5	1700	1495	38	0.91

Table A.8(b) Measured Parameters of 50 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
New	39	110	415	51	41000	1485	0.082
R.M.1	43	120	415	62	41900	1485	0.063
R.M.2	47	132	415	62.5	42000	1485	0.054
R.M.3	45.5	127	415	61.5	41275	1485	0.054
R.M.4	45	119	410	58	41050	1485	0.048
R.M.5	43	141	415	63	43000	1480	0.053
R.M.6	40	130	410	63.5	44300	1485	0.052

Table A.8(c) Measured Parameters of 50 HP Rewound Motors

MOTOR IDENTIFY	Capital Cost	Installation Cost	Running Cost	Running Time	Electrical Expenses	Benefit
New	164570	5000	200	20	4050.8	95678.58
R.M.1	20500	5000	250	20	4139.72	38556.39
R.M.2	20500	5000	260	20	4149.6	55659.6
R.M.3	20300	5000	270	20	4077.97	44947.97
R.M.4	18500	5000	250	20	4055.74	27340.74
R.M.5	19800	5000	280	20	4248.4	54028.4
R.M.6	19100	5000	300	20	4376.84	42876.84

Table A.9 (a) Calculated Parameters of 50 HP Rewound Motors

MOTOR IDENTIFY	Sync Speed	Stator Resistance at no laod	Statore cu Loss	F& W Loss	F.L. rotor loss	Stray Loss	F.L o/p Power
New	2480	0.7942	0.2274	1.29E+03	213.282	615	3.89E+04
R.M.1	2480	0.7831	0.3395	659.8105	242.172	628.5	4.04E+04
R.M.2	2480	0.7684	0.4902	659.6788	210.9375	630	4.05E+04
R.M.3	2480	0.7749	0.4497	679.7253	204.2415	619.125	3.98E+04
R.M.4	2480	0.791	1.918	2.00E+03	161.472	615.75	3.83E+04
R.M.5	2480	0.7394	2.1879	1.80E+03	210.357	645	4.03E+04
R.M.6	2480	0.7534	2.0062	1.70E+03	209.677	664.5	4.17E+04

Table A.9 (b) Calculated Parameters of 50 HP Rewound Motors

MOTOR IDENTIFY	% Loading	Actual Efficiency	Rated Efficiency	Total Capital Cost	Net Saving	Payback Period
New	2.63E+03	1.56E+05	37000	169570	9.14E+04	1.8547
R.M.1	2.73E+03	1.44E+05	37000	25500	3.42E+04	0.7463
R.M.2	2.74E+03	1.76E+05	37000	25500	51250	0.4976
R.M.3	2.69E+03	1.37E+05	37000	25300	40600	0.6232
R.M.4	2.59E+03	1.66E+05	37000	23500	23035	1.0202
R.M.5	2.73E+03	1.09E+05	37000	24800	49500	0.501
R.M.6	2.82E+03	1.10E+05	37000	24100	38200	0.6309