# Performance Analysis And Energy Saving Opportunities For Agricultural Implements And Tractor Trailer Industries

**Shankara Naik, S B Mallur**

**Abstract**: The economic growth and technological advancement of every nation depends on energy conservation. Energy conservation is a viable tool to promote economic efficiency. The commercial energy consumption percentage rose sevenfold during last four decades in India. Industrial sector consumes around 40% of the total energy in India. The industries have all the types of energy consuming equipment which are driven by motors. Agricultural implements and tractor trailer industries are using different varieties of equipment. All equipment used in industries consuming energy by motors are selected for this study, as these motors are energy intensive and consume around 15 % of the total energy. The aim of this study is to identify energy saving opportunities in motors by energy performance assessment to enhance their energy efficiency. The energy audit revealed that, the replacement of energy efficient motor with existing one can save 1.33 GWh of energy annually. Also the payback period less than 1.5 years.

**Index Terms**: Energy consumption, Energy saving, Efficiency, Agricultural implements and tractor industries, Energy efficiency, Energy audit, Energy conservation opportunities,

## 1 INTRODUCTION

The MSMEs considered as economic main pillar generate substantial employment aiding the economy, industrial production, GDP and exports[1]. They greatly contribute to large enterprises in spite of pronounced influence for their closure due to high pollution levels [2]. Energy constitutes an essential input to any MSME prompting governmental agencies to facilitate supply of reliable and continuous energy [3]. The effective energy supply network has been the major contributor to economic development [4] and uninterrupted energy at a reasonable cost as a must to modern industry [5]. The developing economies contribute more to global warming due to lack of cleaner production methods; hence increase in energy efficiency in MSMEs provides dual benefit of reduced cost and pollution levels. The MSMEs often tend to ignore energy consumption pattern anticipating a higher capital investment to bring in changes through better monitoring of consumption and primary energy needs [6]. These observations lend a thought towards study the MSMEs to suggest the adoption of modern technology for cleaner production as well energy efficient techniques. It is important due to industrialization, population and energy consumption has led to rapid depletion of natural resource [7]. In the present work, the motor performance is considered for the study as each individual machine is coupled with motors. This is compared with the standard motors and energy efficient motors by replacement of existing motors.

## 2 METHODOLOGIES

The present section concentrates on selection of industries, pre energy audit phase, and detailed energy audit phase. Detail audit involves the energy consumption and losses of each and every machine/equipment and processing techniques driven by motor of different rating in the industries. The standard procedure adopted for energy audit includes,

- Study the operational characteristics of different machine/ Equipment driven by motor.
- Collect and analyze energy consumption pattern.
- Identify the energy saving opportunities and pollution reduction.
- Perform an engineering and economic analysis of potential modifications.
- Prepare a rank-order list of appropriate modifications.
- Prepare a report to document the analysis process and results.

### 2.1 Selection of Industries

Enterprises are grouped into clusters by Government of India. Clusters are geographic concentrations of industries related by knowledge, skills, input, demand, and other linkages [8]. In Karnataka state of India, 19 clusters have been identified by the United Nations Industrial Development Organization (UNIDO) [9]. According to the report, machine tools, electronic goods, leather products in Bangalore (Karnataka state, India) and agriculture implements in Hubli–Dharwad (Karnataka state, India). India is the clusters potential for technological up-gradation which is for energy conservation and safety needs. There has been limited studies reported in agriculture implements and tractors trailers (AITT). Hubli-Dharwad AIIT industrial cluster has about 130 industries in that fifteen industries were selected for detailed energy audit based on which preliminary energy audit has been carried out in fifty industries for a period of two months (September – October 2018).

### 2.2 Pre Energy Audit Phase

The pre energy audit involves investigation of the industries by observation and communication beginning with shop floor workforces till superiors of the industry. Audit has been conducted to identify the measuring instrument necessary for energy audit, to build good relation for detailed energy audit and energy saving opportunities in that industrial sector. Pre energy audit phase inspection has yielded the power rating of machines and equipment used in

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the respective industry. The available equipment and machine for Agricultural implement and tractor trailer in Hubli-Dharwar industrial cluster are given Table 1 with their respective capacity (power ratings).

*Table. 1. Different Rating Motors and Machines*

| AITT Industries | Sl No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Equipment / Machinery | Arc Welding M/C | Angle/ Hand Grinder | Bench Grinder | Cutting machine | Cut off Saw | Drilling | Lathe | Power Hacksaw | Painting Set Up | Shearing /Power presss | Ligthing and Fan load (hp) | Toatl Load in hp |
| A | No. | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 0.66 | 111.66 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | 15 hp | 3 hp | 2 hp, 3hp | 3 hp, 5hp | 2 hp | 2 hp | 15 hp | | |
| B | No. | 3 | 2 | 1 | Nil | 1 | 1 | 2 | 1 | 1 | Nil | 0.48 | 83.48 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 2 hp, 3hp | 3 hp, 5hp | 2 hp | 2 hp | Nil | | |
| C | No. | 2 | 2 | 1 | Nil | 1 | 1 | 1 | 1 | 1 | Nil | 0.76 | 53.76 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 1 hp | 3 hp | 1 hp | 2 hp | Nil | | |
| D | No. | 2 | 2 | 1 | Nil | 1 | 2 | 1 | 1 | 1 | Nil | 0.5 | 57.5 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 1 hp, 3 hp | 3 hp | 2 hp | 2 hp | Nil | | |
| E | No. | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0.56 | 79.56 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | 10 hp | 3 hp | 2 hp, 5 hp | 3hp | 1 hp | 2 hp | 10 hp | | |
| F | No. | 3 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 109 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | 15 hp | 3 hp | 2 hp ,3hp | 3 hp | 2 hp | 3 hp | 15 hp | | |
| G | No. | 3 | 2 | 2 | Nil | 1 | 1 | 1 | 1 | 2 | Nil | 1.05 | 75.05 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 1 hp | 3 hp | 1 hp | 2 hp | Nil | | |
| H | No. | 2 | 2 | 1 | Nil | 1 | 1 | 1 | 1 | 1 | Nil | 0.75 | 52.75 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 1 hp | 3 hp | 1 hp | 1 hp | Nil | | |
| I | No. | 3 | 2 | 1 | Nil | 1 | 1 | 1 | 1 | 1 | Nil | 0.54 | 52.54 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 1 hp | 3 hp | 1 hp | 1 hp | Nil | | |
| J | No. | 3 | 2 | 1 | Nil | 1 | 1 | 1 | 1 | 1 | Nil | 0.76 | 52.76 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 1 hp | 3 hp | 1 hp | 1 hp | Nil | | |
| K | No. | 3 | 2 | 1 | Nil | 1 | 1 | 1 | 1 | 1 | Nil | 0.75 | 68.75 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 1 hp | 3 hp | 1 hp | 1 hp | Nil | | |
| L | No. | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1.6 | 102.6 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | 12.5 hp | 3 hp | 2 hp | 3hp, 5 hp | 1 hp | 1 hp | 12.5 hp | | |
| M | No. | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0.32 | 75.32 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | 10 hp | 3 hp | 2 hp, 3 hp | 3 hp | 1 hp | 2 hp | 10 hp | | |
| N | No. | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0.32 | 61.32 |
| | Capacity | 18 hp Each | 3 hp Each | 1 hp | 10 hp | 3 hp | 2 hp,3 hp | 3 hp | 1hp | 2 hp | 10 hp | | |
| O | No. | 2 | 2 | 1 | Nil | 1 | 2 | 2 | 1 | 1 | Nil | 1.04 | 58.04 |
| | Capacity | 18hp Each | 3 hp Each | 1 hp | Nil | 3 hp | 2 hp,3 hp | 3 hp,5 hp | 1hp | 1 hp | Nil | | |

The most commonly used equipment in industries are found to be arc welding machine, lathe, drilling machine, cut off saw, power hack saw, painting set up, bench grinder, and shearing machine. In addition to these lighting and fan load is also considered in pre audit**.**

## 2.3 Detailed Energy Audit Phase

The detailed energy audit has been carried out in fifteen industries for duration of three months (October to December 2018). During this period the energy consumption pattern of each equipment/machinery data were collected. Different instruments are used for the detailed audit in order to obtain accurate results viz., speedometer, tang tester, power factor meter, energy meter. Fig.1 shows the summary of energy consumption pattern in different industries of agricultural implements and tractor trailers at Hubli –Dhaward industrial cluster during November 2018. The welding machine has found to be significant energy consuming equipment of about 83% of the total energy consumption and least is noticed for bench grinder consuming 0.59% by the industry. During working condition of arc welding machine it consuming 51 % while in the idling condition 32%. [10] Min Wu, and Xiao Gang Xiong, & [11] Timothy K. Kangogo studied the technology used in the inverter-type welding machines (IWM) to understanding about improved portability, energy efficiency, and eases the use of welding machineries. Comparison is also made between IWM and traditional (pure transformer) arc welding machines.

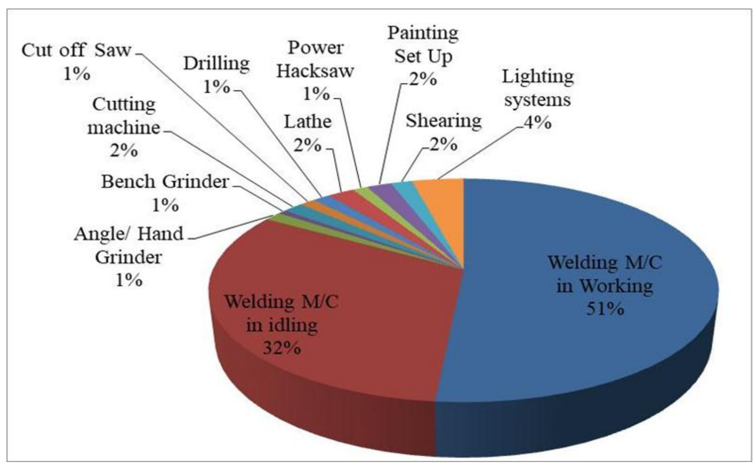


***Fig.1. Energy Consumption Pattern***

Further, the keen observation reported that the major losses in motors driven by the different equipment AITT industries. The common equipment in all the machines apart from the welding machine is found to be motor. In most of the cases the motor needs to be replaced with energy efficient motor when there is slight damage of insulation or core, if the small diameter wire is used in rewinding. The efficiency of a rewound motor is affected by the type of iron in its core and the temperature to which causes loosen the old, burned-out windings. Some motor reminders are able to control accurately this temperature and keep it below the desired maximum of 343°C; others are not. Thus the present article concentrates majorly on motor performance to analyse the energy consumption and saving opportunity.

### 2.3.1 Performance of Different Rating Motors

The performance of the different rating motors was conducted during the audit to access the energy consumption and saving opportunities. During the performance test, the different data are collected viz., number of working hours, and idling hours per day and per month, power consumption, and load carrying capacity of the different rating motors. Thus the collected data is analysed to know the energy consumed by each individual machines or equipment used in agricultural industrial cluster. Similar methods are used in estimating machines /equipment during the energy audit is carried out in different countries [12–14]. Figure 2 shows, the performance variation with energy consumption, load and efficiency of 1hp motor, driving different equipments, viz; bench grinding, power hacksaw and painting machine in different industries, viz; A, B,..,O. For example $D_d$ is D industry operated with drilling machine, $H_b$ is H industry operated with bench grinder machine and $I_h$ is I industry operated with power hacksaw machine.

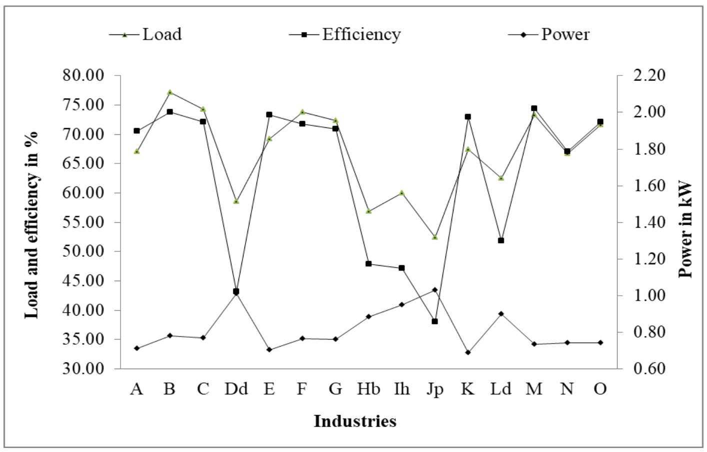


*Fig. 2. Performance of 1hp Motors*

The average efficiency of the agricultural industrial is 63.91%. Figure 2, shows that industry D operated with drilling machine and Industry J operated with painting setup are consumed more than the rated power and efficiency, load are less than the industrial cluster average value, due to improper maintenance of power transmitters and motor winding is not protected from the atmospheric condition. Industries A,C,E,F,G,K,M,N and O are operated with more efficiency than industrial cluster average and consume less power. The detailed calculation of energy consumed by the existing motors and energy efficient motors are shown by Eq. (1)-(7). Further the savings and payback period of corresponding motors are also calculated. The eefficiency of the motor is calculated by using Eq. (1).

#### 2.3.1.1 Estimation of efficiency, energy use, energy savings and payback period

$$\eta = \frac{0.7457 \times h_p \times Load}{P_i} = \frac{0.746 \times 1 \times 0.67}{0.782} = 63.91\% \quad (1)$$

Where: η = Efficiency as operated in %,
$h_p$= Nameplate rated horsepower,
Load= Output power as in % of rated power,
$P_i$ = Three-phase power in kW.

$$Load = \frac{N_S - N_M}{N_S - N_R} = \frac{1500-1460}{1500-1440} = 66.91 \quad \textbf{(2)}$$

Where: $N_S$ = Synchronous speed in rpm,
$N_R$ = Nameplate full load speed,
$N_M$ = Measured speed in rpm

$$\text{Power input } (P_i) = \frac{\sqrt{3} \times V_i \times I_i \times \cos\theta}{1000} = \frac{\sqrt{3} \times 455 \times 1.16 \times 0.85}{1000} = 0.782 \text{ kW} \quad (3)$$

Where: $V_i$ = Average input voltage
$I_i$= Average input current
$\cos\theta$= Power factor.
Annual energy consumed by 1hp motors driving different machines, in agricultural industrial cluster (existing) and energy efficient motors is estimated [15-16] by using Eq. (4).

$$\frac{hp \times 0.7457 \times Load \times hr}{\eta} \quad (4)$$

Where: hr =Number of working hours per year

Energy consumed per motor by an existing 1hp motor is 731.03kWh and energy consumed by energy efficient (EE) motor is 568.37annually

Annual energy saving by different rating motors of standard and energy efficient motors is estimated [15-16] by using Eq. (5).

$$AES_{ee} = hp \times 0.7457 \times L \times \frac{hr}{day} \times \frac{no.day}{/year} \times \left(\frac{100}{\eta_e} - \frac{100}{\eta_{ee}}\right) \quad (5)$$

Where: $\eta_e$ =Efficiency of the existing motor
$\eta_{ee}$ = Efficiency of the EE motor
$\eta_{std}$ = Efficiency of the standard motor
Annual energy saving per motor by an EE and standard motor is 162.66kWh and 109.75kWh respectively (Table 2.)

Calculation of energy saving and payback period by replacing with standard and EE motor per year in terms of Indian rupee (sign: □; code: INR), is given Eq. (6 - 7)

$$\text{Savings in terms of ₹} = \frac{\text{Rupees}}{\text{kWh}} \times \frac{\text{Saving in kWh}}{\text{year}} \quad (6)$$

$$\text{The payback period for the standard motor} = \frac{\text{Initial investment (₹)}}{\text{Yearly saving (₹)}} \quad (7)$$

The energy savings by EE motor and payback period are □1032.89 and 7.41 years.

Similar methods are used in estimating different rating machines /equipment during the energy audit is carried out. The summarised results of the energy audit, connected to all the 15 industries, give a clear idea of energy consumption, energy saving opportunities and payback period in these agricultural industries as given in the Table 2. The first, second and fifth column gives name of the industry along with different types of machine motors, defective, and average value studied industries, power rating and motor efficiency respectively.

*Table 2. Performance and energy saving opportunities for different rating motors*

| Industries | Motor capacity in hp | Standard motor efficiency in % | EE motor efficiency in % | industries motor efficiency in % | load in % | Energy savings per motor in kWh | | Energy savings (₹) | | Initial investment (₹) | | Payback period year | | Energy consumed by existing | % age of Energy by replace with | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Standard | EE | Standard | EE | Standard | EE | Standard | EE | | Standard | EE |
| Average | 1 | 75.2 | 82.2 | 63.91 | 66.91 | 109.75 | 162.66 | 696.926 | 1032.89 | 5613 | 7652 | 8.05 | 7.41 | 731.03 | 15.01 | 22.25 |
| $D_d$ | 1 | 75.2 | 82.2 | 43.23 | 58.57 | 402.19 | 448.50 | 2553.9 | 2847.98 | 5613 | 7652 | 2.20 | 2.69 | 946.03 | 42.51 | 47.41 |
| $H_b$ | 1 | 75.2 | 82.2 | 47.89 | 56.92 | 301.40 | 346.40 | 1913.87 | 2199.67 | 5613 | 7652 | 2.93 | 3.48 | 829.92 | 36.32 | 41.74 |
| $I_h$ | 1 | 75.2 | 82.2 | 47.18 | 60 | 330.87 | 378.31 | 2101.03 | 2402.29 | 5613 | 7652 | 2.67 | 3.19 | 887.99 | 37.26 | 42.60 |
| $J_p$ | 1 | 75.2 | 82.2 | 30.07 | 52.5 | 731.62 | 773.14 | 4645.81 | 4909.42 | 5613 | 7652 | 1.21 | 1.56 | 1219.10 | 60.01 | 63.42 |
| $L_d$ | 1 | 75.2 | 82.2 | 51.84 | 62.5 | 261.51 | 310.93 | 1660.57 | 1974.39 | 5613 | 7652 | 3.38 | 3.88 | 841.84 | 31.06 | 36.93 |
| Average | 2 | 78.5 | 84 | 61.93 | 65.53 | 311.92 | 388.25 | 1980.66 | 2465.36 | 7849 | 10787 | 3.96 | 4.38 | 1477.69 | 21.11 | 26.27 |
| $C_p$ | 2 | 78.5 | 84 | 39.62 | 54.29 | 947.78 | 1011.02 | 6018.39 | 6419.95 | 7849 | 10787 | 1.30 | 1.68 | 1913.60 | 49.53 | 52.83 |
| $E_d$ | 2 | 78.5 | 84 | 35.12 | 58.77 | 1291.41 | 1359.87 | 8200.48 | 8635.18 | 7849 | 10787 | 0.96 | 1.25 | 2336.93 | 55.26 | 58.19 |
| $N_p$ | 2 | 78.5 | 84 | 37.1 | 53.33 | 1058.70 | 1120.82 | 6722.75 | 7117.21 | 7849 | 10787 | 1.17 | 1.52 | 2007.44 | 52.74 | 55.83 |
| Average | 3 | 81.5 | 87.5 | 63.76 | 64.05 | 458.04 | 570.93 | 2908.55 | 3625.38 | 9537 | 13226 | 3.28 | 3.65 | 2104.30 | 21.77 | 27.13 |
| $C_1$ | 3 | 81.5 | 87.5 | 45.73 | 58.33 | 1172.70 | 1275.51 | 7446.66 | 8099.47 | 9537 | 13226 | 1.28 | 1.63 | 2671.94 | 43.89 | 47.74 |
| $G_1$ | 3 | 81.5 | 87.5 | 34.18 | 55 | 1957.10 | 2054.04 | 12427.6 | 13043.1 | 9537 | 13226 | 0.77 | 1.01 | 3370.75 | 58.06 | 60.94 |
| $K_1$ | 3 | 81.5 | 87.5 | 35.98 | 46.67 | 1517.60 | 1599.85 | 9636.76 | 10159.1 | 9537 | 13226 | 0.99 | 1.30 | 2717.14 | 55.85 | 58.88 |
| Average | 5 | 84.3 | 87.5 | 61.88 | 63.44 | 951.93 | 1048.02 | 6044.76 | 6654.91 | 12327 | 17496 | 2.04 | 2.63 | 3579.30 | 26.60 | 29.28 |
| $E_d$ | 5 | 84.3 | 87.5 | 41.81 | 55 | 2314.87 | 2398.17 | 14699.4 | 15228.4 | 12327 | 17496 | 0.84 | 1.15 | 4592.69 | 50.40 | 52.22 |
| Average | 10 | 85.6 | 89.5 | 62.67 | 68.73 | 2051.31 | 2295.61 | 13025.8 | 14577.2 | 20238 | 30612 | 1.55 | 2.10 | 7657.75 | 26.79 | 29.98 |
| $E_s$ | 10 | 85.6 | 89.5 | 41.59 | 62.22 | 5370.73 | 5591.89 | 34104.1 | 35508.5 | 20238 | 30612 | 0.59 | 0.86 | 10446.14 | 51.41 | 53.53 |
| Average | 15 | 87.4 | 91 | 77.37 | 82 | 1273.90 | 1662.65 | 8089.29 | 10557.8 | 31759 | 47662 | 3.93 | 4.51 | 11100.62 | 11.48 | 14.98 |
| $F_s$ | 15 | 87.4 | 91 | 38.7 | 50 | 7540.19 | 7777.24 | 47880.2 | 49385.4 | 31759 | 47662 | 0.66 | 0.97 | 13532.09 | 55.72 | 57.47 |

## 3 RESULT AND DISCUSSION

As explained in the section 2.1, preliminary audit is conducted in 130 agricultural industries in which 15 industries are selected for the detailed audit to access energy consumption profile and energy saving opportunities. During the detailed audit the performance of each motor is carried out to access the existing working efficiency and load. The result analysis shows that most of the motor are working with obsolete technology. Hence, it is essential to adopt new/modern or energy efficiency to enhance energy saving opportunity and reduced emission. By implementation of energy efficient and standard motors, has resulted in the saving of 32% and 29 % of indirect emission, energy respectively. Based on industrial audit report energy consumed by jeans industrial cluster is 4.03GWh annually. The implementation of energy efficient motors, a saving of 1.33GWh achieved annually. The survey result shows that the working efficiency of the existing motors are less than the standard as well as energy efficiency motors and some of them are found to be defective due various reasons and few are listed below,

- Poor protection of motor winding from environmental conditions
- Improper maintenance of
  - Power transmitter
  - Mechanical parts
  - Motor bearings
  - Operating pressures (compressors and boiler)
  - Air leakages (compressors)
  - Steam leakages (boilers)
  - Insulation
- Improper alignment of shaft and bearing
- Use of local rewinding motors
- Inadequate seals in bearing
- Corrosive and humidity damage insulation in motor winding
- Contamination air drawn in compressors

## 4 CONCLUSIONS

The survey is carried out in different industrial clusters for performance analysis of motors of different capacities. The performance study of motor shows 1.33GWh energy saving potential for different rated motor. The implementation of energy efficient and standard motors, may result in the saving of 33% and 29% of indirect emission, energy respectively. The replacement of existing motors with standard and EE motors resulted in higher investment for industries. Hence, the present work suggests the replacement of the defective motors identified during the survey by standard and EE motors. This has resulted in significant minimum payback period of four to eight months.

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