ENERGY EFFICIENCY IN ELECTRICAL MOTORS

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Introduction

Electrical motors are the driving mechanism for majority of operations in industries, agriculture, commercial complexes etc. In India, 80% of the electrical power consumed in industries, 50% of power consumed in domestic and commercial connections and about 90% of power consumed in agricultural connections are through electrical motors. Hence, electrical motors are the major component to address when we talk about energy efficiency.

Today is the day of energy efficiency. In good old days, when electrical power was a cheap commodity, none was giving due importance to the efficient use of power. However, there is a sea change in the situation now. Power is no cheaper and for most of the industries, electrical energy has become almost a raw material. Most of our traditional industries like sugar, textile etc. are dying down. One of the main reasons is the in-efficiency in operation and the comparatively high operating cost, which makes the product incompetent in the current global market.

The recent initiatives taken by the government by way of enacting the energy conservation act 2001 and electricity act 2003 are to help the industries in coping with the efficiency crisis and to make them energy efficient, thereby leading them to become competitive.

If we analyse the Indian power scenario, it is being reported that the transmission and distribution losses is about 25-30% or even more. At the same time, a critical analysis of the performance of electrical motors reveals that the power loss due to in-efficient electrical motors is also as high as 25-30%.

This shows the importance of maintaining proper operational efficiency of the electrical motors.

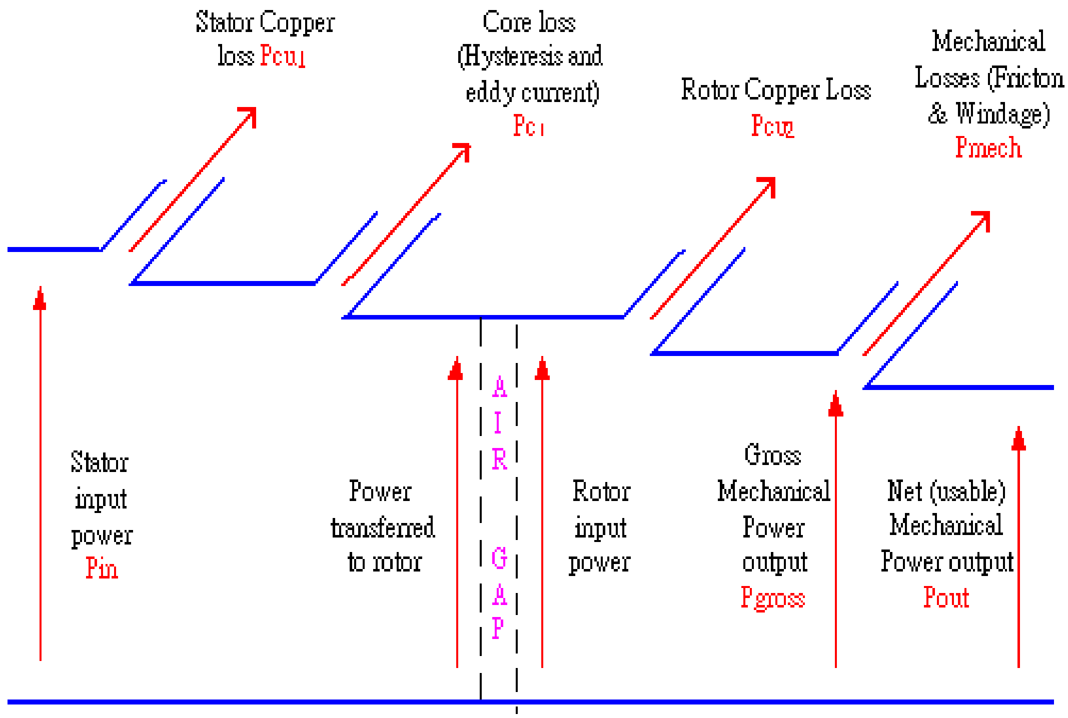
Types Of Motors In Industry

Majority of the population of motors in industry are induction motors. There are synchronous motors and DC motors as well but their numbers are comparatively low. Each type of motor has its own advantages and applications. Hence it is not advisable to relate efficiency of a particular type of motor in general.

Efficiency of a Motor

Earlier, it was mentioned that substantial amount of power is being consumed through motors. However, it should be understood that it is through and not by motors. Motors are only the driving mechanism. So, the actual power is being consumed by the driven equipment and not the motor. At the same time, motors also consume power of their own, which we call as the losses of the motor. It is necessary to clearly distinguish between these two aspects. Improving the efficiency of the motor leads to the efficiency of the operation but a substantial part of the overall efficiency depends on the action being performed by the motor. So, in order to achieve overall energy efficiency, due importance should be given to both the areas.

Losses In a Motor



Induction motors have five major components of loss; iron loss, copper loss, frictional loss, windage loss and sound loss. All these loss add upto total loss of the induction motor. Frictional loss, windage losses and sound loss are constant, independent of shaft load and are typically very small. The major losses are iron loss and copper loss. The iron loss is essentially constant, independent of shaft load whereas copper loss is I^2R loss, which is shaft load dependent. The iron loss is voltage dependent and so will reduce with reducing voltage. For a motor with 90% full load efficiency, the copper loss and iron loss are of the same order of magnitude with iron loss typically amounting to 25-40% of the total losses of the motor at full load. If we consider for example, an induction motor with full load efficiency of 90%, then the iron loss is between 2.5% and 4% of the motor rating.

Energy Audit Of Motors

Energy audit of motors operating at any facility comprises of two distinctive aspects, the operating efficiency of the motor and examination of the work being performed by the motor.

Operating Parameters

During a typical energy audit, the operating parameters of the motors like operating current, voltage, power factor and the running kW is measured using sophisticated instruments. These measurements will show the load factor at which the motor is operating etc. The operating load factor is important when we talk about efficiency of the motor. The efficiency will be comparatively lower if the operating load on the motors is lower than rating. However, the reduction in efficiency loss is not much with under loading and in most of the cases, it will not justify replacement of the motor with a lower capacity motor. If the operating load is less than about 25%, then it would be possible to replace the motor with a lower capacity, provided the nature of load permits. If the load requires high starting torque like in case of ball mills etc. or will have high intermittent loads like in case of crushers, replacement with lower capacity motor will not be viable though most part of the time the motor will be operating less than 25% of rated capacity.

No Load Tests

No load tests are conducted on motors during energy audits. These no load tests are an indication of the rewinding quality of the motors. Typically, the no load current of a motor is about 35-40% of the full load current. Normally, when the motor is coming after rewinding, the industries check the no load currents only. If the no load currents are found within the limits, the motors are sent to the plant for operations. However, no load currents are not the only indicator of the performance of the motors. The actual kW consumption at no load needs to be examined before pressing the motor back to service. Typically, the no load power factor of a motor will be in the range of about 0.2. However, with repeated rewinding, due to changes in the air gap, the power factor of the motors increases, which in turn increases the no load power consumption. Hence, it is necessary to examine the no load power consumption of the motors after each rewinding. There is a notable reduction in performance of the motors after every rewinding and a stage will come when it is beneficial to replace the motor with a new motor than using the rewound motors for considerations of energy costs as well as inventory cost.

Efficiency Tests

Efficiency tests are normally not carried out during a typical energy audit. However, in specific cases, the efficiency tests are also being carried out, at least for a selected group of motors. The major hindrance in performing the efficiency test is that the motor need to be de-coupled from the driven equipment for the test and in a continuous process industry, it will be difficult to perform this. In normal efficiency tests, the winding resistance method is followed alongwith no load measurements to evaluate the efficiency. Other techniques like torque measurements etc. are also in practice.

Measurements

The three phase induction motors are three-wire circuit with a power factor, which can vary from 0.1 to 0.95. Three phase power measurement techniques must be involved in order to achieve meaningful results. The standard methods of measuring the input power on three-phase three wire circuit are either to use the single watt meter method, one per phase and sum the results. Measurements made on one phase and multiplying by three can be extremely erroneous, especially under light load conditions. The kW loading on the three phases at light loads can be severely unbalanced even though the currents may not be unbalanced to the same degree. Measurements made by multiplying voltage, current and power factor on each phase can work with a continuous sinusoidal current provided that each phase is individually measured and the power consumption from each phase is then summed to give the three-phase power consumption.

Measurements on non-sinusoidal currents and or voltage must be made with true integrating wattmeters. The kW formula of multiplying voltage, current and power factor apply only in case of a continuous sine wave current and voltage. The introduction of SCR or triac switching elements into the circuit to control voltage results in non-sinusoidal current and voltage and under these conditions current, voltage and power factor measurement are meaningless to determine the power consumed. By definition, power is the integral of instantaneous volts x amps of the period of one or more cycles. At the instance that current is flowing, the SCR or triac is turned on resulting in full line voltage at that instant of time. Therefore, there is no difference between measurements made on the input of the energy saver or the out put of the energy saver with the exception that there is some loss in the energy saver which will appear on input measurements but not in out put measurements.

Ways to Save on Motor Energy Costs

Turn it off

The simplest and most obvious method of saving motor energy is simply turn it off when its not needed. Motors often run un-noticed when they are not needed, increasing energy costs. Motors can be switched manually and this is a fine solution for many applications but there are timers and sensors available that will turn them off automatically.

Reduce the Speed

Another simple method of reducing motor energy costs is to reduce the speed of the driven equipment, especially pumps and fans. Energy consumption of pumps and fans varies according to the third power, so small change in speed can make big changes in energy consumption.

Use of Variable Speed Drives

Some loads driven by motors does not need to operate at the same speed all the time. These types of loads offer big opportunities for saving by moderating their speed according to their load.

Specific Energy efficient Motors

When replacing an existing motor or when specifying new equipment, consider using a high efficiency motor. High efficiency motors use better quality materials and are manufactured to higher quality specifications than standard efficiency motors. The major benefit of these motors is comparatively less drop in efficiency with respect to the load factor on the motors.

Properly Sized Motors

Many motor systems are oversized and a significantly oversized motor will run at low efficiency, increasing energy costs. Motors loaded below 50% are candidates for replacement provided other conditions are met like starting torque requirements, intermittent loads, availability of a lower capacity motor in spare etc. In some of the cases, the motors can be made to run on star connection to save energy.

Reduce the Load

Often it is possible to reduce the load on a motor and save energy. This could be done by reducing pressure losses in pipe and duct runs with low pressure loss elbows and fittings, aligning the motor and drive properly, use of better transmission systems, direct drives etc.

Perform Regular Maintenance

For maximum performance and greatest energy efficiency, lubricate drivetrains like bearings, chains and gears etc; keep drive belts at their proper tension, clean fan blades, check pump impeller blades for wear, replace the filters regularly etc. Most maintenance actions pay for themselves with longer lasting equipment and less downtime even without the energy savings.

Reducing Power Factor Cost

Low power factor is expensive and inefficient. Many utility companies imposes penalties if the power factor is lower than a specified level of 0.85 or so. Low power factor also reduces the distribution capacity of the electrical system by increasing current flow and causing voltage drops.

Low power factor is caused by inductive loads such as transformers, electric motors and high intensity discharge lighting etc. Unlike resistive loads that create heat by consuming kilowatts, inductive loads require the current to create a magnetic field and the magnetic field produces the desired work.

Lightly loaded motors are one of the main reasons for low power factor. In fact the major method of improvement of power factor is by ensuring optimum loading on the motors. Other methods of improving the power factor are operating the motor on star connection; reducing the operating voltage to the motor, minimize idle operation of motors and use of energy efficient motors. Installation of capacitors near the load ends will help in minimizing the problems associated to the network due to low power factor but the power factor and current of the motors remain unchanged irrespective of the amount of capacitors connected to the system.

Performance Monitoring

Continuous monitoring of performance is the key to energy efficiency, safety and maintaining quality. The Energy Management System (EMS) is the answer to most of the monitoring related issues. The Energy Management System is a software based energy management tool.

There are hundreds of motors operating at different sections of the plant. In case of important motors, the operating parameters are recorded manually once in a while to make sure that the system is operating within specified limits. However, such manual recording of parameters has a lot of limitations. Human errors can creep into the recording of data, the recording is of a particular instant and hence not reliable, data recorded are not real time, such measurement cannot be related with product out put etc.

The energy management system is a hardware / software package, which can meet all the above requirements. The important motors of a process sections are installed with energy meters, which can give output signals to the eLAN® software package. Hence the meters of all the important motors can be connected to a single network. Thereafter, the operating parameters of all the motors can be viewed and recorded at a centralized computer. Such recordings enables real time data, accurate measurements, elimination of human errors totally and also will help in online calculation of specific energy consumption if production details can be fed into the system. This accumulated data can be used as a record and lot of useful analysis can be made from such records.

Some of the major benefits of an energy management system are as follows:-

a. Predictive Maintenance

The instrumentation and eLAN® system enables the user to monitor the health of the major motors and equipments. The continuous monitoring of parameters of particular equipment or motor will help the user in identifying any major variation in operating parameters or any increment in power consumption or decrease in production out put over a period of time. The system will also record run-hour log for major equipments. Based on these history sheets, the user can take timely actions for predictive maintenance. This would help in better, cost effective and need based maintenance compared to the open loop time based systems thereby improving the equipment availability, minimizing break downs, marinating better quality, production rate and enhancing overall UP time of the plant.

Example of screw press motor in oil palm industry:-

The screw press motor, over a period of time, gets overloaded due to various reasons like jamming, lubrication issues etc. As a result of this the power consumption increases gradually, and thus often leads to motor burning. This pattern of power consumption can be used as a diagnostic tool to assess the performance of the press and take decision on schedule of maintenance.

eLAN® screen shows gradual increase in amperage and kW consumption of the motor and an indication of breakdown at a certain stage. eLAN® helped in observing the pattern of loading and an alarm system alerts at a certain load. This helps to take the machine for maintenance. The benefits of this are avoidance extra energy consumption to some extent, eliminating breakdowns and unscheduled stoppage of process, controlling inventory cost of motor rewinding etc.

b. Root Cause Analysis

A properly designed and operated energy management system helps in root cause analysis to a large extent. The continuous recording of energy parameters and the production pattern, most often leads to identification and solution of some basic problems of excess energy consumption, production rate and sometimes even quality of product. Root cause analysis, to some extent, is related to preventive/predictive maintenance also.

The example is of a cement industry where the specific energy consumption of the crusher was going abnormally high. A detailed analysis of the eLAN®, in association with the production control software, revealed that the crusher is operating idle for a considerable period of time due to mismatching of raw material. The substantial power consumption of the crusher, while on no load, was the reason for the abnormal specific energy consumption of the crusher.

eLAN® screen shows frequent high and low loads of crusher and raw material input from DCS system. The high load indicates normal operation of crusher with load and low load indicates crusher operating idle. There was no continuous loading of raw material due to lack of trucks. Later, number of trucks were increased, loaded the crusher fully all the time and switched off the crusher for 4 hours per day, leading to substantial savings. The second eLAN® screen showing constant load for 20 hours, shutdown for 4 hours with same production, better specific energy consumption of the crusher.

c. Power Quality

The quality of power, of the grid supply is one of the major concerns of plant operations now a days, as there is a substantial deterioration in the quality of power available from the grid. Some of the major concerns are fluctuations in supply voltage and frequency, power interruptions, un-scheduled power cuts and more importantly harmonic distortions. For industries like textile spinning etc. fluctuations in frequency has a serious impact as the output of the machines are directly related to the speed. Similarly, fluctuations in voltage will affect the speed, though at a lower degree but it can have disastrous effect on the motors if the fluctuations are on the lower side, especially with heavily loaded motors. The effect of harmonics on power system is known to all. It can lead to over heating of motors, nuisance tripping etc. Harmonics can be imported to the user from the grid or it could be an internal generation. The energy management system, with the EM series meters, record and display all the above parameters. Hence, the plant management can have a constant check on the power quality available to them and based on this corrective decisions can be taken almost instantaneously.

Eg. of a polishing machine in marble industry, the motor was getting overheated and huge blowers were provided to cool the fan. This led to a constant maintenance problem and excess energy consumption. Later on, it was found that the problem was with the drives, generating substantial amount of harmonics.

d. System Efficiency

The data available from the eLAN® system can be used effectively to improve the system efficiency by identifying faulty components etc. The pattern of consumption of different components indicates any appreciable difference in consumption of similar components or scope for improvements in performance etc.

Example of a feed water pump of a thermal power plant. The feed water pump, which was overhauled by the supplier was consuming much more power than that of a similar pump overhauled by the plant themselves. The records show an increase in power consumption after overhauling. Later on it was found that there was a 2 inch hole in the pump, leading to excess power consumption of the pump.

Similar to above, there could be many applications of the energy management system, for a particular motor or a group of motors to measure, detect and control energy efficiency.