Green Rameswaram - Energy Efficient Motors – I

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In the earlier articles, the importance & rationale of energy efficiency prior to deployment of renewable energy was explained. The role played by electric motors in the utilisation of electric energy was also brought out in details. About 65% of the electricity that is produced is consumed by electric motors in a variety of applications, in industrial, commercial and consumer segments. While heavy industries and high power equipments need motors of larger power rating, it is to be emphasised that billions of electric motors are used in low and extra low power applications. As per one survey the production of electric motors is estimated to be around 7 - 8 billion in numbers, the bulk of them in the fractional and sub-fractional horse power range. In fact about 90% of the volume will be in the range of 5 HP (3.7 kW) or lower.

It is also to be noted that a substantial proportion of these motors are operating from Alternating Current (AC). Technically called as AC Induction Motor, this has been the workhorse of the industry ever since Tesla introduced it in 1889. The three phase induction motor, invented by Nichola Tesla and later brought into the market by Westinghouse Electric Company, revolutionised the industry when many mechanical equipments could be easily powered. The AC distribution network that followed worldwide with rapid adoption, ensured that the 3 Phase AC motor was virtually the ruler of the market. The classic battle between Edison and Tesla still remains folklore in the electrical industry, with Tesla winning the same conclusively.

Ever since the induction motor has been the major driving force for many industrial and domestic equipments and appliances. But for limited applications which required variable speed operation of the motor, AC Inductin Motor dominated the field and continues to do so even now. It is only in the limited arena where variable speed operation is required, the DC motor continued to be deployed. The ease with which the speed of a DC motor can be varied enabled it to occupy a niche market, while for a variety of fixed speed application it is the AC motor which ruled the roost in the mass market

There was an off-shoot of the 3 phase AC motor when the domestic appliances appeared on the scene. Appliances like Fan, Pump, Refrigerator, Room Air Conditioners, Compressors, etc., started occupying the minds of the consumer and most of them had to be worked from single phase supply which was the norm for homes and small commercial establishments. A lot of work went into the adaption of the Tesla motor to make it operate from single phase AC supply. The result was a resounding success and the ubiquitous single phase AC induction motor easily became the largest produced electric motor, volume wise.

While the induction motor was very reliable and durable, its main drawback was the inability to operate over a range of speeds. Its speed was necessarily dependent on the supply frequency and hence it is essentially a single speed motor. A limited variation in speed is possible by varying the input voltage but it was restricted to fans and pumps mainly. Also depending on the line frequency, the speed was limited to 3600 or 3000 rpm respectively for 60 or 50 Hz input supply. Thus except for limited applications where the speed variation or higher operating speeds were required, the single phase motor was often the inevitable choice. But in automobiles, due to the nature of the power source, which is mainly battery, the DC motors were invariably used.

While the DC motor has the ability to operate over a wide range of speeds, it is often considered to be not so reliable and requires careful maintenance. This is mainly because of the electro-mechanical device called commutator, to which the current is injected through a set of carbon brushes. Apart from producing additional frictional losses, this also makes the machine vulnerable in terms of reliability and durability. Thus the preferred choice of engineers was the induction motor except in cases where a variable speed or higher speed necessitates the need for a DC motor.

However both the single phase AC and the conventional DC motors suffer acutely in terms of their overall efficiency. Being deployed in small power ratings, the efficiency is inherently lower than for larger power motors. This is mainly because the losses in both these types of motors are disproportionately higher with respect to the output power. Moreover the motor manufacturing industry is also to be blamed for the lower efficiency. Price is the main driver and nobody bothers about efficiency of operation and hence they use inferior and lesser active materials and production process with the consequent sacrifice on the efficiency of the machine. It is only recently that BEE (Bureau of Energy Efficiency) has started imposing energy efficiency norms for certain class of appliances. But many equipments are still outside the purview of BEE. Additionally both BIS (Bureau of Indian Standards) and MNRE (Ministry of New & Renewable Energy) are also culprits in the slow rate of adoption of energy efficiency norms.

While the BIS standards for electric motors classifies and grades electric motors as per the output of the motor, the standards for household appliances are invariably rated by the input of the equipments. For instance the standard for a household fan or mixer-grinder talks of the input power of the appliance. This often leads to anomalous situation where the user is mislead by the manufacturer into believing that the appliance having more input watts is more powerful. Typically in the case of mixer/grinder for many years the motor was rated for 400 W and these were doing a very good job and considered ideal for the Indian cuisine and kitchen. But recently for the last 10 - 15 years it is not uncommon for the manufacturers to claim that their mixer is rated at 650, 750 and even 950 Watts. They also claim that these are more powerful, while the established fact is that 400 W is more than sufficient for the Indian Kitchen. The specification is only about the input of the motor but what is its output is never specified. The input can often be more due to the inefficiency of the appliance.

Similarly MNRE gives subsidy for solar operated pumps based on the power rating of the solar panels. Certain amount is given as subsidy per kW of the panel. If the pump is inefficient, as is often the case, the input power to the pump will be higher and this would require a higher power solar panel. Whereas when manufacturers introduce a pump with improved energy efficiency the input power required would be lower and so is the consequent solar panel rating. As per present norms the latter will be eligible only for a lower subsidy! Thus the situation that prevails is that more subsidy is given to inefficient products.

Reverting back to efficiency of small motors, inherently lower efficiency was the norm till about 15 - 20 years back. However rapid advances in Magnetics (The science of magnetic materials) and Power Semiconductors in the 80’s completely opened up a new era of design and application. Coupled with even more rapid progress of micro controllers and digital signal processors, which paved the way for software implementation of controls, the old Edison Vs Tesla argument is now revived again.

Normally a motor has two windings, one for establishing the magnetic field and other for injection of current. The electromagnetic interaction between a magnetic field and the current results in the production of torque which moves the rotor of the machine. This is the basic explanation of an electric motor! While in both AC and DC motors the magnetic field is produced one winding (it is called electromagnet), it is possible to produce similar magnetic field with the help of a permanent magnet. While this fact was well known to electrical engineers of the yesteryears, the requirement of the permanent magnet is often very stringent for electric motors. Permanent magnets lose their magnetism due to two key reasons: one due to high temperature and the other due to demagnetising field by the other winding of the motor. Under overload or stalled conditions of a motor, a strong demagnetising field is produced by the windings and magnets are demagnetised. Thus for successful application in electric motors, the permanent magnets should be capable of higher temperature operation and also be more resistant to demagnetising fields.

While permanent magnet (PM) motors were deployed with relatively weaker magnets produced from ceramic materials, the application was often limited to very low power equipments like Toys, Tape Recorders, CD/DVD disc drives and automobile applications like windshield wiper, power window, etc. The power rating of such motors are often very low in the range of few watts only. Ceramic magnets were sufficient for such low current applications but for larger motors for compressors, pumps, etc., there was difficulty in adopting such magnets to ensure reliability and ruggedness. If, for any reason the magnets in a PM motor are demagnetised the motors stop working satisfactorily and the torque production would be zero. Another category of magnets made out of rare earth materials (Samarium) and Cobalt were known but they were very expensive and the deployment was often restricted to Military and Aero Space applications only. They were too expensive for household appliances.

It was in late eighties, 1987 to be exact, that the Japanese Company. Sumitomo, patented a unique rare earth material based permanent magnet which opened up the PM motor application very wide. This material, an alloy of Neodymium, Iron and Boron (called NdFeB) had very good properties both in terms of temperature and demagnetisation. It can operate without any problem at around 150^0 C and is also highly resistant to demagnetisation. More importantly as all the materials that go into the alloy are relatively inexpensive, the cost incidence for such magnets in a motor is not very high. Iron and Boron are easily available, particularly in India and the unique Nd (Neodymium) is often a byproduct of Thorium extraction. It is well known that Thorium is extractable from beach sands in the vast Indian coastline. A government company called Indian Rare Earths Ltd does this and enough Nd is available.

The Japanese patent expired in 2007 and China was well prepared to exploit the open market since then. They had lined up the supply of all the three essential ingredients, viz., Neodymium, Iron and Boron and ever since they are dominating the global market. Even though India is well endowed in all these three basic ingredient materials, it was not at all prepared for the game. In fact China flooded the global market since 2007 and drove many magnet companies in the developed world out of the market. Even now India is still importing this key material, which is very important for brining energy efficiency in Electric Motors. The next part of this series will talk about the importance of this alloy and also other key developments in driving energy efficiency and how this pans out in the electric motor market.

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