



INTRODUCTION

Rotating machines are crucial for running manufacturing units, capital goods items and infrastructure projects. Generators bridge the gap between demand and supply of power from the grid while motors are drivers of machinery.

The need for electricity is generally well accepted, but the big importance of a specific product, as the rotating electrical machine, is usually not explicitly recognized. To many people, it comes therefore as a surprise when they start to realize to which extent they use electrical machines, mainly motors, in their daily lives. There is of course a significant difference in the use of electrical motors between industrialized and developing countries, but the trends towards increased use are similar.

Almost 100 percent of all electric power is generated by generators, which are driven by various types of turbines or, to some extent, reciprocating engines. Diesel engine-driven generator sets are mainly used for stand-by power and mobile applications. The electrical machines are, in this aspect, a basic prerequisite for the “modern electrified society”.

The fixed frequency fed induction motor has been dominating and is so even today, but variable speed induction motors as well as permanent magnet motors are becoming more and more common. Unofficial estimates indicate that more than 1/4 of the total number of industrial motors are for variable speed. The reason is partly increased process efficiency and partly improved motor control.

The rotating electrical machines are fascinating in several ways. The size of such a machine can be defined in different ways, but the most common and usually also most relevant measure is its power

rating. With this definition of size, these machines cover quite a unrivalled power range, around 15 orders of magnitude. The smallest motors used for wristwatches and other instruments have an output as low as 1 μ W while the largest generators are well above 1 GW. There is no other type of machinery, which can match this.

STATE OF INDUSTRY

The Generator Industry has large number of players especially in the lower range. The value of estimated production in the country is Rs.1,200 crores. Organised sector accounts for about 50% in the lower range going upto 80% at the top end. Original Equipment Assemblers (OEAs) buy engines and alternators and assemble the generator and sell to customers. Portable gensets are used mainly by shops, restaurants, small offices and business establishments. Stationary generators < 125 kVA used in large residential and commercial complexes, hotels, hospitals. Generators of capacity > 125 kVA are used in large core sector and process industries.

Motors manufactured in the country during the year is in the region of Rs 4,200 crores. DC Motors, FHP, Flameproof; Squirrel cage, Slipring motors are commonly used. Major market for lower HP motors is in the agricultural sector - used in irrigation pump sets. FHP is used in Water coolers, ACs, Deep freezers, Pumps, Washing machines, Wet grinders, Garage compressors, Sewing machines, etc. Other motors find application primarily in the industrial sector.

Most of the international players manufacturing these electrical equipments are present in India either as JVs or subsidiaries. The segment has a fragmented structure with large no. of manufacturers in the organized sector with a turnover of less than Rs100

crores. Product segments like higher capacity electric motors, generators and alternators are witnessing a consolidation phase in India. In the low voltage equipment categories where the technology barrier is not high and is highly competitive, the industry is witnessing fragmentation with smaller and emerging manufacturers cornering greater share of the market. This is in evidence mainly in the product categories which are of standard nature. In power generation equipment and HT motors, where the emphasis is mainly on projects, the market is dominated by a few large players.

2008-09 recorded negative growth in most of the segments. The robust growth in the first half of the year was more than off-set by the drop in the second half resulting in decline of 10 -20% over the year. The industry, overall, shrunk for the first time in 5 years while the FHP segment has remained flat in the last 10 years. In Squirrel Cage Motors there has been a double-digit drop in lower frame sizes. The reduction decreases with higher frame sizes. There has been a steep increase in the largest segment viz. frames 400 and above. Slip Ring motors exhibit a similar trend.

In the HT segment, there has been a more than 20% growth in Squirrel Cage Motors accompanied by a dip in Slip Ring Motors. On the whole this segment is in the positive terrain. DC motors' trend is similar to AC LT motors. Among Alternators, Brushless category has grown by about 20% while Slipring has declined, probable indication of a shift in technology. By and large, lowest frame sizes are the worst hit; larger ones are doing better.

Industrial Pumps and Water Supply projects in higher ranges are doing well. Petrochemical segment doing exceedingly well as also Hydrocarbons. Investment in Hydrocarbons is on track. Enquiries and orders for HT / Larger Machines are good. HT Machines' requirement worldwide is encouraging. Sugar and Paper Industries are faring well. Trade has reduced inventory of smaller motors and is dependent on Manufacturers' stocks. Power Sector is doing well too. Chemical segment is on low gear while the Non-ferrous industry has been watchful.

On the external front, Generator imports was less by 14.3% and exports up by 13.6%. Motor imports and exports were higher by 24% and 6.8% respectively. Raw material prices have been benign though the uncertainty prevails. There have been quite a few new entrants like BCH, Havells, L&T and WEG in this Sector.

TRENDS

Application

19th century was characterized by invention of many different electrical machine concepts. Most of the types, which still are dominating, were introduced before the previous turn of century. This was followed by a long period of steady growth. The development was focused on increased output, higher utilization, i.e. more kW/kg, improved production methods and lower costs. Important factors for this development have been availability of better insulation materials, replacement of cast iron structures with welded etc.

Electrical machine R&D has partly changed character during the last decades. Many new topologies have been presented. Important prerequisites for this development are new materials, such as rare earth metal-based permanent magnets, improved power and control electronics and computational tools such as FEM simulation programs. Equally important are new applications.

High-speed electrical machines have been developed during later years both for generator and motor applications. They are typically operating in the speed range 20 000 to 100 000 rpm. They are used as generators driven by small gas turbines in micro-turbine units for distributed power generation. Motor applications are compressor drives and machine tools, e.g. grinding spindles. The high-speed machines are either of permanent magnet type or induction machines. Essential for the development is the possibility to operate with high frequencies, access to high strength material for the rotors and suitable bearings. The main advantages with high-speed machines are that they become very small for a given output and it is possible to avoid complicated gearboxes. These machines are mechanically entirely integrated with the driving or driven objects.

Directly driven wind power generators are in some respect contrary to high-speed machines. They operate usually with speeds below 50 rpm. They are very large in relation to their output, especially the diameter, and they have pole numbers above 100 when the high-speed machines have 2 or 4 poles. Permanent magnet concepts are interesting due to their ability to take fairly large airgaps, which is necessary when the diameter is large. The efficiency is also improved, as there is no rotor winding losses. The development focus on problems related to the extreme mechanical dimensions and the control, which has to cope with stochastic variations in wind. Variable speed is a means to optimise energy production.

Another very interesting application is automotive drivelines. This application is not new, but it has been revived due to the increased focus on electrical and hybrid vehicles in recent years. The automotive industry is very demanding. The drivelines require much larger machines with high performance but at low costs. The requirements are in many respects tougher than for industrial motors of similar sizes. High efficiency is important in order to give a good fuel economy and a long driving range. High specific torque and power is necessary due to the limited space available. These specific key numbers are often a factor five or higher than for standard motors, something which leads to special designs and liquid cooling. The environmental conditions are also tough. Very high but also very low ambient temperatures, vibrations and shocks, humidity and dust are some of these. New requirements from a powerful industry may result in some significant changes in the electrical machine industry.

Operations

The ongoing globalisation has brought about many changes. Earlier, motor manufacturers used to have complete, vertically integrated production lines. The factory had its own foundry for casting stator housings and end shields in aluminium or cast iron. Stator and rotor laminations were punched and stacked in the next section of the production line. It continued with die casting of the rotor cage windings, insertion of machined shafts and balancing. The stator cores continued to the winding section, automatic or manual, and impregnation. After that remained final assembly and testing. The factory made more or less everything in house except for ball bearings and some sensors.

This has changed. Today many components are outsourced to specialized sub-suppliers, often in countries with lower labour costs. Cast components are made by external foundries. Punched segments and even stacked cores can be obtained from other companies. Winding work can also be sub-contracted. Companies with manufacture of similar products in several factories try to rationalise their production and send different semi-finished products between their units. These steps are being followed to reduce investments as also to reduce costs.

A significant level of contract manufacturing and subcontracting of non-core manufacturing activities is taking place. Generally, low value added labour intensive activities, assembly work and coil processing jobs are subcontracted. This is done basically due to capacity constraints and cost considerations.

The organisation of the production and the methods used in the production has always had a big impact on the development work. The new situation requires a much more flexible attitude from the development engineers and a willingness and competence for international cooperation.

In this sector value added as a percentage of net sales is on the decline for two reasons. The unprecedented increase in the cost of raw materials like copper, aluminium and CRGO steel and the inability of the industry to increase prices to that effect has made a dent on the profit margins and value addition. Secondly with the reduction in customs duties, companies find it economical to import complete equipment, test it and sell thereby value addition is only in terms of profit margin and testing charges.

The global leaders have a much higher cost of wages to sales at 30-35%. This is the main reason why international companies are looking at India to outsource components and products for their sales worldwide.

Drives

It is virtually impossible to imagine modern production machinery without variable speed drives. These drives are essentially solid state and have proven to be highly effective in recent years.

In most applications, motors are operated directly from a supply line under their own inherent torque-speed characteristics and at operating conditions determined by the mechanical load. However, in many other applications, the motors are provided with control equipment by which their characteristics can be adjusted and their operating conditions with respect to the mechanical load varied to suit the particular requirements. The most common control adjustment is motor speed, but torque and acceleration can be adjusted as well.

Earlier thyristor controlled DC drives were used to provide an effective and efficient means of speed control of DC motors. However, application of the DC motors, particularly in a harsh environment presented maintenance problems. Subsequently adjustable frequency AC drives and resistance control wound rotor drives came into use. However, these resistance control drives were found to be inherently inefficient at low speed. This led to usage of frequency converters and slip recovery controllers from resistance type control.

Development in the domain of inverters has been rapid viz. from voltage source and current source

inverters to pulse width modulated (PWM) inverters. With the advent of modern power devices like GTO's (gate turn off thyristor) and control components like ASICs/microprocessors, AC drive technology using VWF (variable-voltage variable frequency) techniques for AC machines has come to the forefront.

The applications requiring speed variation cover a wide range such as Fans, Extruders, Pumps, Centrifuges, Mixers, Conveyors, Blowers, Compressors, Stackers, Machine Tools, Agitators, Printing Machines, Kilns, Separators. The key benefits are:

- (i) Soft start characteristics resulting in reduced voltage dips and reduced starting impact shock on motor windings, couplings, shafts, gears and other driven equipment.
- (ii) The drive's torque speed characteristics can be varied to suit the actual requirements of speed, torque, tension by pre-programming. This results in increased life and energy savings.
- (iii) Higher system efficiency.
- (iv) Enhanced product quality.

In India, a beginning has been made in the field of AC drives. An indigenous production base has been created to a limited extent to produce AC drives mainly of the PWM variety and mostly of imported designs. Use of advanced control techniques is at its nascent stage.

Energy Efficiency

There is considerable scope for improving energy efficiency in industries dealing with iron and steel, chemicals, cement, pulp and paper, fertilizers, textiles, etc. If such industries can promote energy conservation, it could lead to substantial reduction in their costs of production.

It has been estimated that the total conservation potential of this sector is around 25% of the total energy used by it. Of the total electricity consumed in the industrial sector, electric motors account for approximately 70%. Increased efficiency is therefore one of the main targets for the motor manufacturers. Electricity consumption in these motors can be reduced if the cooling is improved along with the controls, if they are operated at the rated voltage, and are regularly maintained. More active material (copper and iron), higher quality of the core lamination, special attention to the layout of stator and rotor windings are used to reach the targets. This will of course result in somewhat more expensive motors, but the life cycle costs should be lower due to the energy savings.

Governments worldwide have introduced legislation, or encouraged voluntary industry agreements, that will dramatically shift the market to higher efficiency motors. Three quarters of the world's industrial AC induction motors being sold each year do not meet the efficiency standards that will be required under these new agreements. It is estimated that the market for higher efficiency motors is going to triple in revenue by 2011. This represents a significant opportunity for motor manufacturers.

In India, the response to voluntary Standards & Labelling (S&L) programme for Motors, launched by Bureau of Energy Efficiency, has been lukewarm. Similar S & L programmes for household appliances and other equipments have generated quite a bit of interest. This may be attributed to the consumer being the decision maker for appliances while the motor is rarely purchased by the user directly. The industrial sector has taken big strides in this area. The average kWh per tonne of cement in India is among the lowest worldwide.

Conclusion

Rotating electrical machines are one of mankind's best servants both as a mean for generating electricity and for performing mechanical work.

The development of electrical machines is dependent of the applications but also on development in some other fields as material technology, electronics and computer aided engineering. The development work is cross disciplinary and requires competence not only in electrical engineering but also in mechanical engineering, thermodynamics, control theory and many other fields. Computer aided engineering and production technology are two of them.

The emphasis on improved efficiency helps to reduce the energy consumption. This is of importance both in developing and industrialised countries. This is in some countries subject to legislation. Increased cost-effectiveness is of course always also one of the main objectives for design engineers.

The industry is in a global transition phase aiming at more rational production and lower total investments. This is opening up opportunities even for countries with little tradition in this particular field.



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