

# **EXECUTIVE SUMMARY**

Drives and Drive controls are the workhorses of an industrialised society. It is virtually impossible to imagine modern production machinery without thinking of variable speed drives. These drives are essentially solid state, and have proven to be highly effective in recent years.

## **0.1 INVERTERS AND AC DRIVES**

### **0.1.1 Inverters**

The purpose of the inverter is to change the direct voltage from the rectifier or the battery to alternating voltage, which in turn can be shaped and filtered to produce a sinusoidal voltage that meets the requirements of the load. This voltage must be of stable amplitude and frequency, contain a low percentage of distortion and be a clean waveform. The type of inverter is selected keeping in view the end use application viz. drive or non-drive.

### **0.1.2 Drive Systems**

The combination of the motor and the control equipment is called a drive system. 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.

## **0.2 DEVELOPMENT OF THE INDUSTRY**

In the early 1960s, 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.

The 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 VVVF (variable-voltage variable frequency) techniques for AC machines has come to the forefront.

### **0.3 APPLICATIONS**

The applications requiring speed variation cover a wide range. They include applications like :

- |                                       |                          |
|---------------------------------------|--------------------------|
| * Fans                                | * Extruders              |
| * Pumps                               | * Centrifuges            |
| * Mixers                              | * Conveyors              |
| * Blowers                             | * Compressors            |
| * Stackers                            | * Machine Tools          |
| * Agitators                           | * Printing Machines etc. |
| * High Efficiency<br>Seperators, etc. | * Kilns                  |
|                                       | * Grate Coolers          |

### **0.4 IMPORTANCE OF VARIABLE SPEED DRIVES**

Variable Speed Drives find wide applications in several industries for use in the appliances indicated above. The industries are varied and include railways, chemical, mining, textile, fertilizer, cement, pharmaceutical, petro-chemical, rubber, plastic, paper, food processing, steel, automotive, metal working and allied.

This is mainly because of several important advantages like:

- (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) The system efficiency will be higher.
- (iv) End product quality is enhanced.

Another very prominent application of these AC drives has currently been towards energy savings in areas like the following:

- (i) ID/FD fan drives in power plants, large pump drives, compressor drives, etc.
- (ii) Microprocessor based digital inverter drives, with facility for serial communication, with plant programmable controllers.
- (iii) High Capacity AC drives of rating greater than 30 MW. As per the latest CIGRE report, 60 MW AC drive is under development.

## **0.5 INTERNATIONAL SCENE**

### **0.5.1 Industry Profile**

The total US shipments for adjustable speed drive controls increased from US \$ 339 million in 1985 to 690 million in 1991. As a percentage of total industrial control shipments, this represents an increase from 15.9 per cent in 1985 to 25.8 per cent in 1991.

Internationally, manufacture of inverters and AC drives is concentrated in a few countries, viz. USA, Japan, UK, Germany, France and Switzerland. Some of the prominent manufacturers in the domain of inverters and AC drives are as follows :

- IMO Industries Inc., USA
- GE Drive Systems, USA
- Fuji Electric, Japan
- Mitsubishi, Japan
- Sumitomo Heavy Industries Ltd., Japan
- Sansha Electric Manufacturing Co., Japan
- Yaskawa Electric Corporation, Japan
- Brook Crompton International Ltd., UK
- Control Techniques, UK
- Siemens AG, Germany
- AEG, Germany
- CGEE Alsthom, France

- Jeumont Schneider, France
- Telemecanique, France
- Asea Brown Boveri AG, Switzerland

## 0.5.2 Technology Status

Similar to the rest of the electrical industry, development in inverters and AC drives is rapidly changing with respect to the way motors are controlled. The following are some of the major trends in this area:

- Use of GTO'S for high power systems employing PWM inverters along with 16 bit microprocessor controls.
- Use of power transistors/MOSFETS etc. in the lower power ranges, e.g. 100-200 KW.
- Load commutated inverters with synchronous motors for very high power applications, say for 1000 KW and above.
- Use of modern control theory, like vector control, to realise high response and wide range of speeds
- Use of intelligence like "smart devices" with in-built control circuits and self protection features, etc.

## 0.6 INDIAN SCENARIO

In the field of AC drives, a beginning has been made. In the Indian context, though it need to be said that we are still behind the international level regarding the development/application of the latest technology in power electronics, it must be mentioned that the scenario is changing fast.

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. It appears that the use of GTO'S/microprocessors, advanced control techniques is at its nascent stage. However, there is enough awareness about these and it is expected that GTOs and microprocessor based AC drives will be used extensively in the near future.

In contrast to product development efforts within the country, significant expertise has been developed with respect to overall system design, installation, commissioning and maintenance of power electronics equipment.

## **0.7 PRODUCT RANGE**

Inverters and AC drives available indigenously can be classified into the following three categories:

- (a) Motors upto 100 HP using PWM techniques and utilising high grade transistors for small AC squirrel cage motors.
- (b) Motors from 100 HP to 400 HP using inverter grade thyristors/transistorised inverters for medium range squirrel cage motors.
- (c) Motors above 400 HP using GTOs/Line commutated inverters for variable speed control of large synchronous/ induction motors.

## **0.8 STRUCTURE OF THE INDUSTRY**

The industry is rather fragmented with a diverse profile of manufacturers viz. subsidiaries of foreign companies, Indian companies both in the organised sector and in the small scale sector. The larger companies cater to design of drive systems, manufacture and supply of large motors and installation and commissioning of drive systems. The small scale sector companies are predominantly involved in manufacture of low power motors and related drive circuits. Some of the prominent companies in the domain of inverters and AC drives are as follows:

- ABB Ltd., Bangalore
- BHEL, Bangalore
- Crompton Greaves Ltd., Bombay
- GEC of India Ltd., Calcutta
- Kirloskar Electric Co. Ltd., Bangalore
- Larsen & Toubro Ltd., Bombay
- NELCO, Bombay
- NGEF, Bangalore
- Siemens India Ltd., Bombay

## **0.9 PRODUCTION**

The production of power electronics increased from a level of around Rs. 1510 million in 1986 to Rs 4030 million in 1990, showing a growth rate of around 20% per annum. The production of inverters and variable speed drives during the same period increased from a level of Rs. 250 million to Rs. 535 million.

## **0.10 EXPORTS**

The export trend has not registered a significant growth over the years. At present, it is difficult to sustain export market in the field, because of the level of quality and sophistication required and because the production cost is to be made competitive in comparison with that of the world market.

## **0.11 DEMAND PROFILE**

The study team on control instrumentation and industrial electronics for the Eighth Plan period for Electronics Industry constituted by the Department of Electronics has projected a demand of Rs. 62,460 million for control instrumentation and industrial electronic equipment systems in various sectors. The major sectors constituting demand of over Rs. 5000 million during the Eighth Plan period are as follows:

- Railways
- Steel
- Refineries and Petrochemicals
- Fertilisers
- Power Sector

## **0.12 TECHNOLOGY TRANSFER**

Transfer of technology has been the cornerstone of indigenous development of the control and instrumentation segment. There have been few cases of technology tie-ups in the 60s and 70s. The real thrust came in the decade of 80s. Initially, the major focus was in the area of conventional drive systems. This has shifted in favour of microprocessor based drive systems and smart energy controller automation interfacing drives. A few prominent collaborations in the domain of inverters and AC drives are as follows:

<b>Party</b>	<b>Actual Item</b>	<b>Collaborator</b>
1. Bharat Heavy Electricals Ltd., Bangalore	Variable Speed AC Drive Controls	General Electric Co. USA
2. Crompton Greaves Ltd., Bombay	Electric Motors and Control Systems	Newage Interna- tional Ltd., UK
3. General Electric Co. of India Ltd., Calcutta	Electronic Controller for variable speed drives etc.	GEC, UK
4. Kirloskar Electric Co. Ltd., Bangalore	Variable Speed Drive Control System	Thorn Automation Ltd., UK
5. Kirloskar Electric Co. Ltd., Bangalore	Static Inverters	Fuji Electric Co., Japan
6. Larsen & Toubro Ltd., Bombay	AC Inverters	Jeumont Schneider, France
7. National Radio & Electronics Co. Ltd., Bombay	Solid State Inverters	Emerson Electric Co. USA
8. NGEF Limited, Bangalore	Vector Control Micro- processor and GTO based PWM Inverter.	AEB, Germany

## **0.13 TECHNOLOGY STATUS**

The present trends in different industry segments are as follows:

### **Cement Industry**

Although both AC and DC variable speed drives are used, AC drives are primarily used for speed control of fans, stacker/reclaimer drives, belt conveyor drives etc. Frequency converters and slip recovery controllers are now being preferred to Resistance type controls.

### **Railways**

A few main line locos of DC drive technology are being used in Indian Railways and there is indigenous capability to design/manufacture such systems. Usage of AC drive systems is limited. 6000 HP GTO based locomotives with imported technology are now being developed.

## **Mining Industry**

The mechanisation of open cast and underground mines, which is now underway includes a substantial component of power electronics control viz. AC drives with dynamic braking facility for winders, speed control of pump motors etc.

## **Steel**

AC drives are being selectively introduced in SAIL plants mainly for energy saving purposes viz. AC drives for soaking pit blowers, exhausters, ID fans, roller table drives etc. Cyclo converter based large drives are specifically required.

## **Refineries and Petrochemicals**

In this industry, inverter fed AC drives are preferred as compared to the resistance control drives used earlier.

## **Paper and Pulp Industry**

AC drives have had a limited penetration in the area of pulper, ID fans, BF pumps, compressors, etc. used in the paper and pulp industry. Here DC drives are used by and large.

## **Fertilizer Industry**

This industry primarily employs AC drives viz. adjustable frequency drives and wound rotor drives with switchgear control.

## **Sugar Industry**

Indian sugar plants primarily deploy steam turbines for drive purposes because of the availability of bagasse as boiler fuel. However, most of the equipments can be replaced by variable frequency AC drives.

## **Textile**

AC drives are now being used in the textile industry for controlling machine speed and acceleration especially in weaving operations.

Small synchronous motors supplied from a static frequency converter are advantageously used. This results in accurate speed relationships, especially, in group drive applications in the synthetic fibre industry.



## **0.14 R&D STATUS**

R&D in the domain of drives and drive controls have been carried out by Government Research Institutions, public and private sector companies and also through projects sponsored by Department of Electronics, Government of India. Some of the major projects undertaken are as follows:

### **0.14.1 Government Sponsored R&D**

Recognising the need of this specialised sector, Department of Electronics, through plan projects, has taken up the promotion and support of new technologies in the user sectors.

- Chopper Drive System developed for coaches of Indian Railways.
- Microprocessor Based Control System for Locomotives

### **0.14.2 R&D at Central Government Research Institutions**

#### **- CEERI, Pilani**

The institute has a major programme in the domain of transportation covering the areas of semiconductor devices and electronic systems through a number of sponsored research programmes. A few of the prominent research programmes are as follows:

- \* UNDP project on solid state devices technology and drives
- \* Development of microprocessor based AC motor drive for transportation with University of Bradford, UK under MOU with British Council.
- \* Transistorised excitation control system for 2500 HP diesel-electric locomotive of Indian Railways (Sponsored by BHEL).
- \* Development of 150 KVA single phase to 3-phase converter for WAM4 Electric Locomotives of Indian Railways (Sponsored by RDSO).
- \* 40 KVA PWM thyristor inverter for mining locomotives (Sponsored by BHEL).
- \* Fast switching thyristor (Sponsored by BHEL).

## **RDSO, Lucknow**

A number of collaborative projects have been initiated by RDSO in the domain of transportation:

- \* Single phase to 3-phase static convertor of 180 KVA capacity for auxiliary motors through indigenous sources.
- \* Development of 3-phase drive in EMU motor coach application through indigenous manufacturers and educational institutions.

### **- R&D by Major Manufacturers**

A few major projects in drives and drive controls undertaken by major manufacturers are as follows:

- \* Thyristor controlled DC drives (ABB)
- \* GTO based drives for AC traction (BHEL)
- \* Microcomputer based transistorised AC drives (Crompton Greaves)
- \* Current fed inverters upto 500 KW (L&T)
- \* Transistorised AC variable speed drives (NELCO)

## **0.15 INDIGENISATION**

The existing manufacturing facilities available with various manufacturers by and large meet the country's requirements of drives and drive controls. The major gap is on account of non-availability of the latest generation of devices and other components.

## **0.16 TECHNOLOGY GAPS**

Technology gaps have been identified in the following areas:

### **Process Industries**

- Large power drives for application in refineries, power stations and steel plants.
- Networking of drives and supervisory control
- Vector control drives

## **Transportation**

- Thyristor equipments including control for Electric Locomotives and EMU motor coaches.
- Single phase to 3-phase static converters for auxiliary motors (capacity 200 KVA approx).
- Single phase to 3-phase GTO based converters with 800 KVA capacity.
- DC 100 V to AC 415 V, 50 Hz three phase inverters or AC package units.
- Three phase drives for traction motors of Electric locomotives and EMU motor coaches.
- Chopper equipment for AC/DC locomotives and DC EMUs.

## **Mining**

- AC winders with 550 V devices.
- Slip recovery systems for winders, haulage controls and drag lines.

### **0.17**

## **CONCLUSIONS**

The major share of investment is accounted for by the printed board assembly and testing activity. This implies that to make the facility economically viable, there must be a large volume of printed circuit boards produced. This realisation gives rise to the concept of a central printed circuit boards manufacturing facility which would cater to the needs of a number of product manufacturing units of a company.

Indian industry as yet is dependent on foreign standards. Bureau of Indian Standards (BIS) is in the process of preparing standards for the thermal power sector. As the requirement of standardisation in other sectors is also acute, they should be taken up subsequently.

TTL and CMOS ICs, opto isolators, crystals, different types of switches, etc. are important components required for development and manufacture of drives and drive controls. They are in short supply. Among these, the domain of ICs is most crucial. BEL is the largest manufacturer in this field, though its yield is not upto

international standards. Though this segment is open to the private sector, investors are reluctant to commit a large investment which is required in this area for a number of reasons. Hence, under the circumstances import of ICs seems to be the only option left for the present.

The requirement of power semiconductor devices, viz silicon rectifiers and silicon control rectifiers is being catered by BHEL, NGEF, Usha Rectifiers and Hind Rectifiers. NGEF has entered into a new collaboration agreement with Westcode, UK for the manufacture of the entire range of state-of-the-art Power Semiconductor Devices, with the latest manufacturing technology, on par with the rest of the world.

The drives and drive control industry in the country is more than 20 years old. During these years, both users and manufacturers had built a reasonably trained manpower base to operate conventional drive control systems, especially DC drives. With the technology moving into the digital domain, the manufacturers have been able to build sufficiently good facilities for engineering, manufacturing, erection and commissioning. The same is not true with the user industry, as proper training facilities are not available at the national level.

Testing laboratories and certifying agencies in India have yet to instil a greater level of confidence in the users towards accepting indigenously manufactured drive systems, by ensuring a certain minimum standard of excellence in quality and reliability.

R&D in the domain of drives and drive controls has been carried out by Government Research Institutions, private sector and also government sponsored R&D. However, investment on R&D is incurred by a few large units and is essentially restricted to those units approved by DSIR. The units surveyed do not indicate any consistency in the level of investment in R&D.

There are already certain incentives for investment on R&D but these do not appear to be attractive enough to make real commitments in-house R&D.

## **0.18 RECOMMENDATIONS**

- 0.18.1 Assignment to a central body, work relating to C & I encompassing process control, power electronics and analytical instruments, to oversee guidelines and adherence.
- 0.18.2 Technology watch cells may be created in order to report on prevailing technology trends and indigenous capability. It is

desirable that these cells estimate the requirement of design and the need to productionise a particular product and assess capabilities of R&D laboratories that claim resources for delivering products. The cells may also serve to screen R&D proposals and help in proposal monitoring.

- 0.18.3 The technology for the manufacture of various electrical and electronic components like relays, push buttons, circuit breakers, terminal blocks, and others should be updated to meet increasingly stringent and sophisticated requirements.
- 0.18.4 The facilities existing with certifying agencies require in-depth evaluation. They may be updated when necessary so as to provide certification work for intrinsic safety, on the same lines as FM, BASEFA, etc. Electronic Research and Testing Laboratories (ERTLs) under Department of Electronics may be updated to evaluate the performance and design parameters of indigenous products.
- 0.18.5 A study on 'Impact of fiscal incentives on in-house R&D' needs to be undertaken to ascertain the underlined factors for boosting in-house R&D among manufacturing units.
- 0.18.6 Thrust areas for R&D need to be defined for the following fields in different sectors:
- Machines
  - Circuits
  - Computer and Automation
  - Operational Reliability and Savings
  - System Design Capability
- 0.18.7 The consultants require to focus more attention with regard to the formulation of specifications, considering the level of indigenisation of imported technologies, which are likely to be manufactured in India by technology absorption.