LUKHDHIRJI ENGINEERING COLLEGE

MORBI-2

DEPARTMENT OF POWER ELECTRONICS

ENGINEERING

LAB MANUAL

Power Electronics for Power System Application

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LUKHDHIRJI ENGINEERING COLLEGE – MORBI

CERTIFICATE

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Experiment No: 01

Aim: To study applications of power electronics in solar energy connected to grid.

Theory:

Solar power generated from *photo-voltaic* (PV) cells is gaining increased importance as a renewable source due to advantages such as the absence of fuel cost, little maintenance and no noise and wear due to absence of moving parts. So in theory this is an ideal power source, but in practice there are several problems that needs to be addressed. There is still a high installation cost, low energy conversion efficiency and issues concerning the interaction with other systems.

The energy from PV panels is in the form of DC-current, and in order to utilize this energy in the grid, the current must be transformed into AC-current. The most convenient way to this is by the use of *electric power converters*. Using these converters as a grid interface for PV panels is not a new technology, and much of the same technology is used in e.g. fuel cell converter, wind power converters and also converters for motor drives. Even though they use much of the same technology, there are always some special considerations for the different cases.

PV compatibility: The inverter is designed to take advantage of solar modules configured as high voltage PV string arrays—single crystalline, poly crystalline, or thin film—with an input voltage Maximum Power Point range (depending on inverter model) of 195 to 550 Vdc, 240 to 550 Vdc, 240 to 480, or 200 to 400 Vdc.

Utility grid compatibility: The inverter can operate on either 240 V or 208 V nominal grid voltage. The inverter senses the phase-to-phase voltage and automatically changes the power limit value for each grid voltage. The disconnect thresholds remain the same because both nominal voltages have the same 120 Vac phase-to-neutral thresholds.

Maximum Power Point Tracking (MPPT): The inverter uses a proprietary Maximum Power Point Tracking (MPPT) technology to harvest the maximum amount of energy from the solar array. MPPT learns your array's specific characteristics, maximizing its output at all times.

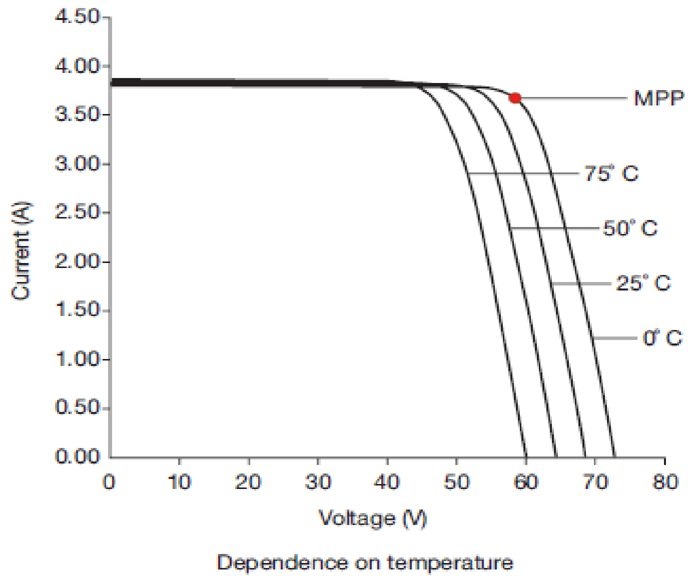


Fig. The knee, or maximum power point, of the I-V curve varies dramatically according to the effects of both cell temperature, as shown here, and irradiance.

Expandable: Multiple inverters may be networked together for increased net metering capacity or future system growth. The inverter has adjustable voltage and frequency disconnect settings and can be aggregated above 30 kW on a single point-of common- coupling (PCC).

Inverter type, size and voltage	Voltage range [V]	Clearing time(s) (seconds)	Frequency range [Hz]	Clearing time(s) (seconds)
Residential 240 Vac	V < 211.2	2.00	f > 60.5	0.16
	211.2 < V < 264	operational	f < 59.3	0.16
	264 < V	1.00	59.3 < f < 60.5	operational
Commercial, 3-phase 208 Vac, <30 kW inverter	V < 104	0.16	f > 60.5	0.16
	104 < V < 183	2.00	f < 59.3	0.16
	183 < V < 228.8	operational	59.3 < f < 60.5	operational
	228.8 < V < 249.6	1.00	—	—
	249.6 < V	0.16	—	—
Commercial, 3-phase 480 Vac, >30 kW inverter	V < 240	0.16 [1]	f > 60.5	0.16
	240 < V < 422.4	2.00 [1]	57.0< f < 59.8	0.16 [1]
	422.4 < V < 528	operational	f < 57.0	0.16
	528 < V < 576	1.00 [1]	59.8 < f < 60.5	operational
	576 < V	0.16 [1]		

Table 1 shows the voltage and frequency limiting values and the time periods that the inverter has to be offline, referred to as *clearing times.* Notice that some values are different for inverters under 30 kW and those over 30 kW. Three-phase commercial inverters over 30 kW have limits that can be adjusted with the permission of the local utility. This can be very useful in an area with a fluctuating grid, which often results in a significant loss of energy. Long utility lines, areas with heavy load cycling or an unstable island of power grids can all contribute to as a result (beyond nuisance tripping), adjusting the inverter limits can be beneficial.

UL 1741 and IEEE 1547 also require that inverters not create a power island. This means that if the utility goes out, the inverter cannot remain on, producing power to any load or portion of a building load, including rotating or oscillating loads. For example, even if the building's load is similar or exactly balanced with the output of the PV system, the inverter may not remain on if the utility is not present. Algorithms for detecting anti-islanding must constantly check to see that the utility grid is really present. A specially tuned "resonant load" set up to mirror the utility tests this inverter function. The resonant load is made up of a very specific inductive, capacitive and resistive network with many settings. Its goal is to attempt to trick the inverter's ant islanding algorithm into thinking that the utility is really there, at many different prescribed power levels called out in the UL 1741 standard. This load is connected to the inverter operating at full power, and the grid is connected. The resonant load is set to the exact output power of the inverter. When the whole system is stable, the utility is disconnected while the resonant load maintains voltage and frequency within the inverter's limits. The inverter has a maximum of 2 seconds to successfully recognize that the grid is disconnected and shut off.

<u>Integration and packaging.</u> Other required equipment built into or included with an inverter includes: ac disconnection means, both manual and automatic; dc disconnection means; EMI and RFI filtering equipment; transformer (if the inverter is transformer-based); cooling system; GFDI circuit; LED indicators or LCD display; communication connections for PC or Internet data monitoring; and the product packaging.

Manual ac and dc disconnection means are designed into inverters or PV systems so that the inverter can be disconnected from the grid and the PV array if service technicians, installers or other qualified personnel need to turn off the inverter or access the main inverter enclosure. Automatic ac disconnection means—such as an ac contactor—are used to minimize or totally eliminate night-time tare losses and reduce susceptibility to damage from night-time power surges and lightning strikes. Disconnecting power supplies, chips and components of all types at night also extends their service life. Inverter packaging brings all the components into a single, shippable unit. (The largest 3-phase inverter packages, for commercial and utility scale applications, may ship as more than one enclosure.) Packaging also protects the inverter from the outside elements and keeps unintended guests, human or otherwise, away from the equipment. The use of high quality materials and finishes is necessary to meet the needs of the application. The service life of a PV inverter, for example, requires the use of corrosion-resistant fasteners, like stainless steel screws, to ensure that individual components can be accessed and serviced over 25 years.

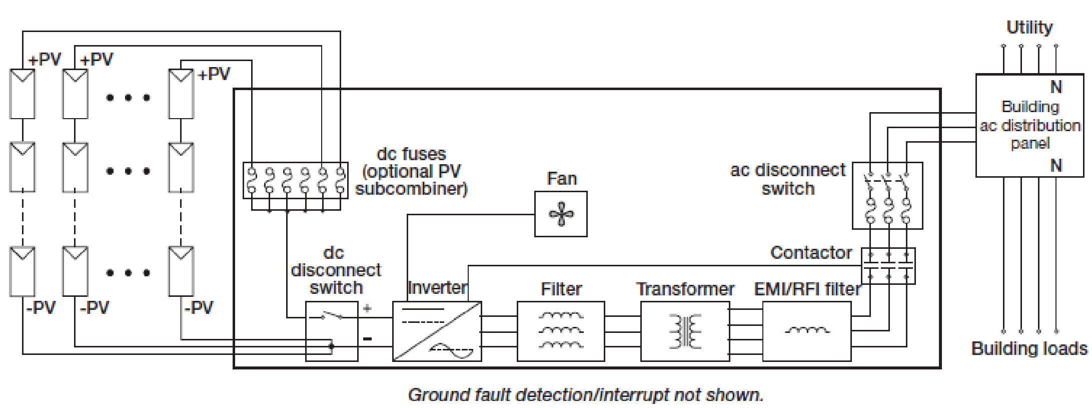


Fig. Solar Inverter with components

<u>Solar Inverter Components:</u> As a starting point, basic inverter operation is illustrated by looking at a single-stage, single-phase, 50 Hz transformer-based inverter. Additional inverter topologies are explained subsequently. Solid state switches. All inverters today use some combination of power semiconductors—IGBTs, MOSFETS or both in some cases—to invert dc to ac power. Other key components in the main power inversion circuit are inductor(s), capacitors and a transformer, either 50 Hz or high frequency. The latter is used in transformer-based inverters to adjust voltage levels as needed by the topology and to provide galvanic isolation between the solar dc input on one side and the inverter's ac output to the grid on the other. Single stag products like 50 Hz transformer-based string inverters typically use an H-bridge for inversion from dc to ac. All the key components in a single stage inverter, including the H-bridge circuit. The switches at the far left represent the power semiconductor switches. By alternately closing the top left and bottom right switches, then the top right and bottom left switches, the dc voltage is inverted from positive to negative, creating a rectangular ac waveform.

In a grid-interactive, 50 Hz transformer based inverter, however, the output current needs to be a sine wave form. This requires a more complex operation. The H-bridge puts out a series of on-off cycles to draw an approximated sine wave shape. This is known as *pulse width modulation* (PWM). With a 250 Vdc to 600 Vdc input, the H-bridge circuit for a typical 50 Hz transformer-based string inverter will put out an approximated sine wave with an ac voltage of about 180 Vac. The role of the components after the H-bridge is to smooth and change the magnitude of that approximated sine wave.

3-phase, 50 Hz transformer-based inverters: The operation of a 50 Hz transformer-based, 3-phase inverter is very similar to that of the string inverter. The difference is that a central inverter has three phase outputs instead of two. In order to generate three phase outputs, 50 Hz transformer-based central inverters typically use a 3-phase bridge. This is a bridge with a 6-switch design. 3-phase, 6-switch Bridge. The RMS voltage of the PWM-created sine wave is typically 200 Vac or 208 Vac. This voltage is derived from a minimum PV voltage of 300 Vdc or 330 Vdc, depending on the inverter model and options. As with the previous single-phase example, the 3-phase, 50 Hz transformer-based inverter includes an inductor to filter out the PWM-created sine wave and a transformer to convert the filtered waveform to the correct ac voltage. The transformer also isolates the PV system from the grid.

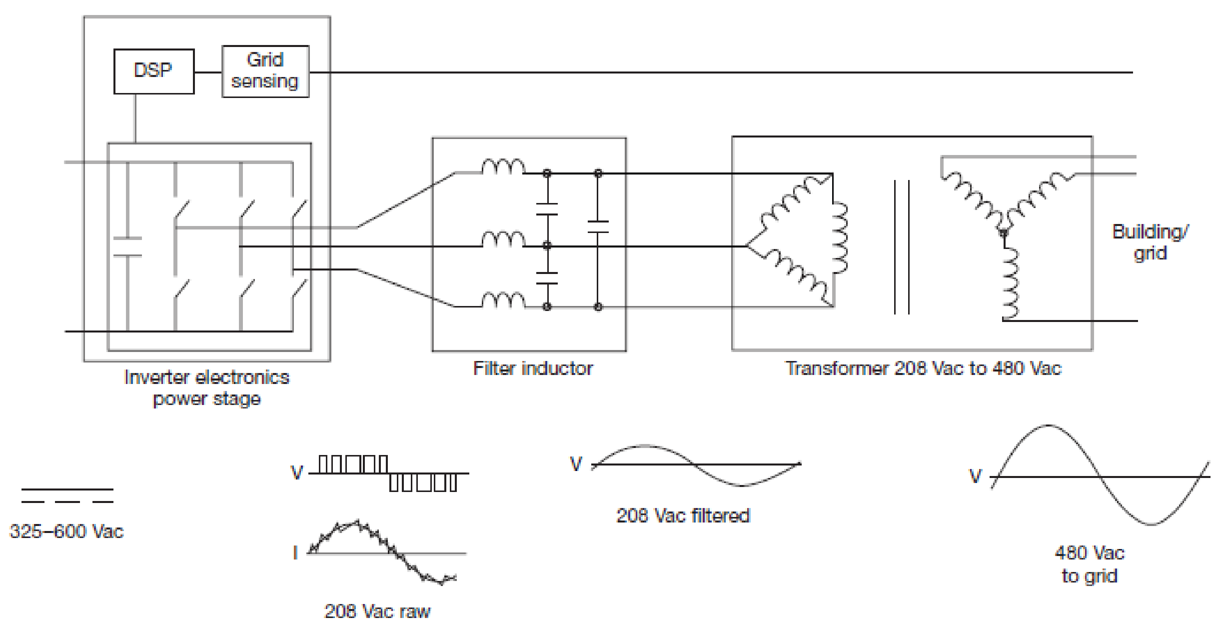


Fig. 3 phase 6 – switch

Experiment No: 02

Aim: To study applications of power electronics in wind power.

Theory:

Wind energy has continued the worldwide success story as the wind power development is experiencing dramatic growth. According to statistical data the cumulative installed wind power capacity in 2006, 2009 and 2012 were 74.0, 158.86 and 282.43 GW respectively; almost doubled in every three years. The dynamic growth of wind power directly pushes the wind technology into a more competitive area. Therefore, it is essential for scientists and researchers to find out the effective technologies for the wind power generation systems. The variable nature of wind energy sources (in terms of the real power, reactive power, output voltage, and frequency) is a major challenging issue. The conversion of an input AC power at a given frequency and voltage to an output power at different frequency and voltage can be obtained with static circuits called power converters, containing controllable power electronic devices. Various power converters have been developed to fulfil the requirements of the wind power generation. Each of them has some advantages and some disadvantages. The traditional converter voltage level is in the range of 380–690 V due to the low generator voltage rating and the use of two-level converter topology. To reduce the electrical losses, a power frequency (50/60 Hz) power-transformer is commonly used in wind power generation system (usually installed inside the turbine nacelle) to step-up the voltage to medium voltage level (e.g. 11–33 kV), This heavy and bulky transformer significantly increases the weight and volume of the nacelle as well as mechanical stress of the tower. Nowadays components can handle higher current and voltage ratings, the power loss decreases and the devices become more reliable for the control of megawatt scale power thanks to the power electronics as a rapidly developing technology. The price is still decreasing, and power converters are becoming more and more attractive which means improving the performance of wind power generation systems. With the advent of new power semiconductor devices, different soft magnetic materials with high magnetic saturation flux density and low specific core loss are conceived to reduce the weight and volume of medium or high frequency. These recent advances have led to the development of new medium voltage converter system, which would be a possible solution to eliminate the transformer of the wind turbine generator systems. This chapter aims to a comprehensive study of traditional converter technologies for wind turbine generator systems. In addition the challenges, current research and development trends, possible future directions of the research to develop new converter topology for future wind turbine.

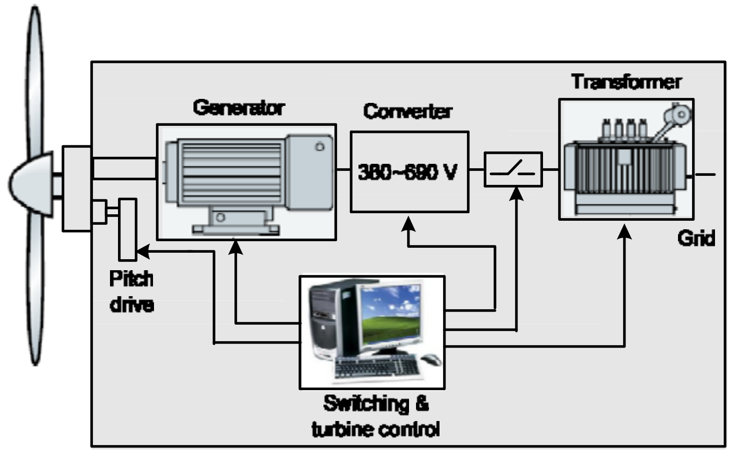


Fig. 1 Fully-rated converter based wind turbine generator system.

Converters for wind turbine generator systems

In the last two decades different converter topologies have been investigated for power conditioning of wind turbine generator systems. All the proposed converters have some advantages and some disadvantages. Only diode rectifier based unidirectional converter and back to back bidirectional converter topologies are commonly used in the commercial wind turbine generator systems.

1. Diode rectifier based converter

In this converter system a variable frequency and variable magnitude AC power from the wind turbine generator is firstly converted to a DC power by a diode rectifier circuit and then converted back to an AC power at different frequency and voltage level by a controlled inverter. The diode rectifier (uncontrolled rectifier) based converter system transfers power in a single direction e.g. from generator to the grid. This type of power converter is normally used in a wound rotor synchronous generator (WRSG) or a permanent magnet synchronous generator (PMSG) based wind power generation system instead of an induction generator.

In WRSG based system, to achieve variable speed operation the systems use an extra excitation circuit, which feeds the excitation winding of WRSG. The PMSG based wind turbine generator systems are equipped with a step-up chopper circuit. The step-up chopper adapts the rectifier voltage to the DC-link voltage of the inverter. Controlling the inductor current in the step-up chopper can control the generator torque and speed. The diode rectifier with step-up chopper based power conditioning system is illustrated.

The output voltage and input current of the diode rectifier and step-up chopper based converter system are shown in Figs. 3 and 4, respectively. The frequency spectrum of the output voltage of diode rectifier and step-up chopper based wind power conditioning system is depicted. In this converter system the grid side inverter controls the active and reactive power delivered to the grid. The output voltage of this converter system is in the range of 380–690 V. Therefore, a step-up transformer is commonly installed inside the nacelle to feed-in the energy into a medium voltage grid. Many power semiconductor vendors such as Semikron, ASEA brown boveri (ABB), IXYS, and Mitsubishi Electric produce devices specially designed for this type of converter in a module form, all the devices in a single pack, which reduces the cost and complexity of the power conditioning system. Semikron developed SKS 660F B6U+E1C+B6CI 250 V06 and IGDD6-4-426-D3816-E1F12-BL-FA modules for diode rectifier based power conditioning systems.

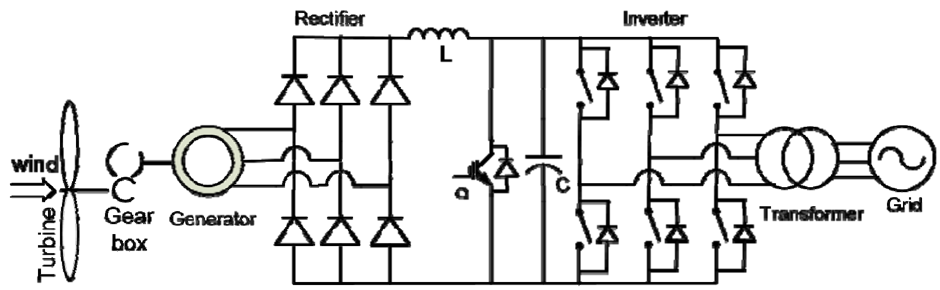
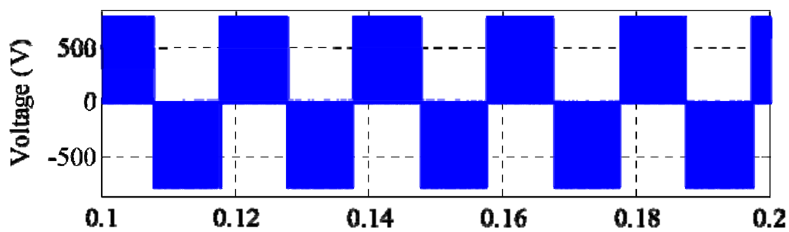


Fig. 2 Diode rectifier based converter topology



2. Back to back converter

The controlled rectifier and controlled inverter based converter is called back to back converter consisting of two conventional pulse width modulated (PWM) voltage source inverters (VSIs). It differs from the diode rectifier based converter for the rectification stage, where the diode rectifier with chopper circuit is replaced by controlled rectifier. The controlled rectifier gives the bidirectional power flow capability, which is not possible in the diode rectifier based power conditioning system. Moreover, the controlled rectifier strongly reduces the input current harmonics and harmonic losses. The output voltage and input current waveforms of a back to back converter are illustrated. The grid side converter enables to control the active and reactive power flow to the grid and keeps the DC-link voltage constant, improving the output power quality by reducing total harmonic distortion (THD). The generator side converter works as a driver, controlling the magnetization demand and the desired rotor speed of the generator.

The decoupling capacitor between grid side converter and generator side converter provides independent control capability of the two converters. A simulation analysis of back to back converter based wind turbine generator system was carried. The harmonic spectrums of the back to back converter. Due to some special features this converter topology has received great attention recently. Many power semiconductor manufacturers such as Semikron, ASEA brown boveri (ABB), Hitachi, Siemens, IXYS, and Mitsubishi Electric produce components in a module form, all the devices in a single pack; suitable for this converter, which makes the converter compact and lightweight. As an example, Semikron developed SKS C 120 GDD 69/11-A3A WA B1B module for power conditioning of synchronous and double-fed generator based wind power systems. The back to back converter can be used for PMSG and squirrel cage induction generator (SCIG) based wind power generation systems. Siemens employs back to back converter for power conditioning of SCIG based wind turbine generator systems. The Repower employs 6.6 kV DFIG. Therefore, converter voltage level is also in the range of 380–690 V due to the low generator voltage rating and the use of two-level converter topology. In order to integrate the wind turbine with local medium voltage grid a step-up transformer is normally installed inside the nacelle of the wind turbine. In the last two decades a lot of research or systems.

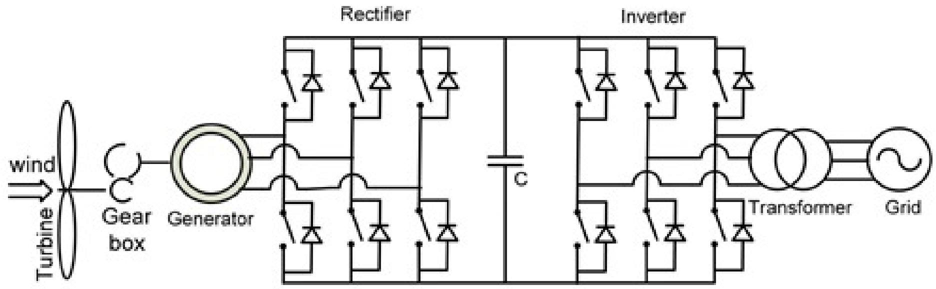
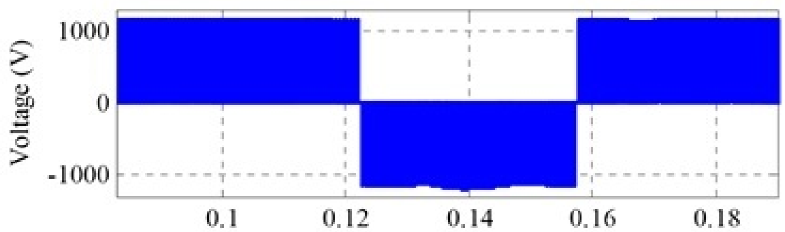


Fig. 3 Back to back converter based wind turbine generator system



3.Matrix converter

The matrix converter (MC) is a unique topology of AC to AC power converter that eliminates the need for an intermediate DC conversion and the passive reactive filter components associated with this DC-link. It is a direct or single stage AC to AC converter topology. The converter consists of an array of bidirectional switches positioned at the intersection points of the input and output phases. The output is synthesized by selective closings and openings of the switches. A filter on the input side aids commutation and prevents switching generated harmonics from propagating to the power input.

MCs offer the potential for significant size and weight reductions in power converter applications due to the absence of any large energy storage elements, such as DC-link capacitors. Compared to a conventional back to back converter the MC is of much smaller size. Due to these special features MC has attracted great attention in the last few years. A high power MC was patented in 1999. In 2005, a 150 kVA MC has been fabricated and tested for electric vehicle applications. The MC topology was implemented commercially in 2008. Recently MC has attracted interest for wind power applications.

A matrix converter based wind power generation system is depicted. The output voltage and input current waveforms are close to sine wave, as illustrated. Therefore, the THD coefficient of MC is much better than those of the back to back and diode rectifier based converters. The frequency spectrum of output voltage is depicted. Several literatures have introduced the application of matrix converter in variable speed wind turbine generator systems. In 2009, an MC was implemented for induction generator based wind turbine generator system.

In the same year, for performance enhancement and efficiency optimization a modified MC was proposed for SCIG based wind turbine generator systems and a simulation work was reported. Due to its advantages compared with back to back converter the MC is currently replacing the back to back converter from DFIG based wind turbine generator systems. The layout of an MC converter with DFIG based wind turbine generator system is illustrated. An MC was fabricated and tested with DFIG based wind turbine generator system where space vector modulation (SVM) scheme was used to control the MC, regulating the rotor torque and magnetizing currents.

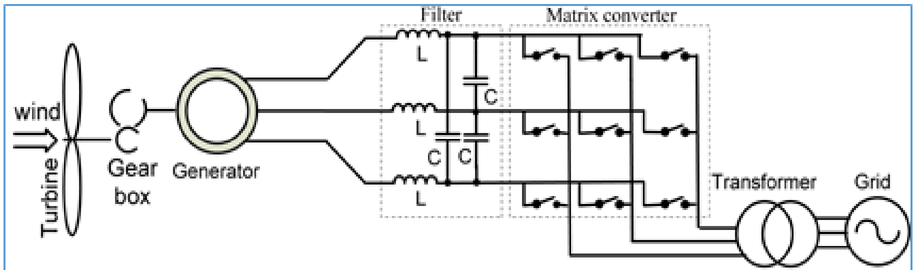
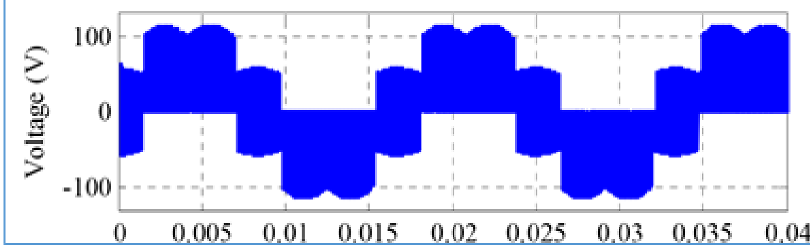


Fig.4 Matrix converter based wind turbine generator system.



Conclusion

By summarising the above discussion it is concluded that the matrix converter is suitable for AC to AC power conversion, which is an attractive solution for adjustable speed wind turbine generator, specially DFIG based variable speed wind turbine generator systems. The SCHB converter topology may be the only possible option to design medium voltage converters economically, which enables transformer-less direct grid connection of wind turbine generator systems. The advanced magnetic materials such as Metglas amorphous alloy and nano crystalline alloy based medium or high frequency-link might be the natural solution to generate isolated and balanced multiple DC supplies for SCHB converter from a traditional wind generator.

Experiment No: 03

Aim: To study applications of power electronics in tidal power.

Theory:

The range, flow and periodic behaviour of tides at most coastal regions are well documented and analysed because of the demands of navigation and oceanography. The behaviour may be predicted accurately, within an uncertainty of less than ±4%, and so tidal power presents a very reliable and assured form of renewable power. The major drawbacks are:

1. The mismatch of the principal lunar driven periods of 12h 25min and 24h 50min with the human (solar) period of 24h, so that optimum tidal power generation is not in phase with demand.
2. The changing tidal range and flow over a two-week period, producing changing power production.
3. The requirement for large water volume flow at low head, necessitating many specially constructed turbines set in parallel.
4. The very large capital costs of most potential installations.
5. The location of sites with large range may be distant from the demand for power.
6. Potential ecological harm and disruption to extensive estuaries or marine regions.

Tidal current/stream power

Near coastlines and between islands, tides may produce strong water currents that can be considered for generating power. This may be called tidal-current, tidal-stream or tidal-flow power. The total power produced may not be large, but generation at competitive prices for export to a utility grid or for local consumption may be possible.

The theory of tidal stream power is similar to wind power. The advantages are (a) predictable velocities of the fluid and hence predictable power generation, and (b) water density 1000 times greater than air and hence smaller scale turbines. The main disadvantages are (a) small fluid velocity and (b) the intrinsically difficult marine environment.

The power density in the water current is,

$$q = \frac{\rho u3}{2}$$

For a tidal or river current of velocity, for example, $3ms^{-1}$,

$$q = \frac{(1025kgm^{-3})(27\,m^{3}s^{-3})}{2} = 138kWm^{-2}$$

Only a fraction of the power in the water current can be transferred to useful power and, as for wind will not exceed about 60%. In practice, may approach a maximum of 40%.

Tidal current velocities vary with time approximately as

$u = u_0 \sin 2t/\tau$

where, is the period of the natural tide, 12h 25min for a semidiurnal tide, and u_0 is the maximum speed of the current.

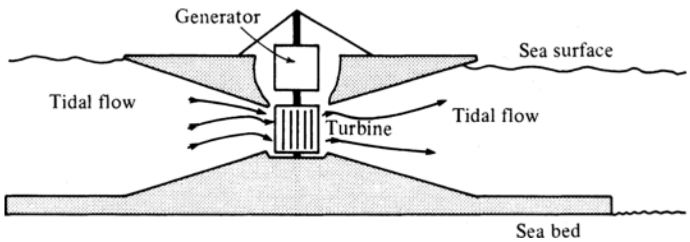


Figure 1. Tidal current power device

If the intercepted area is a circle of area 100m^2 then the total average power generation would be 1.4MW.

The periodic nature of the power generation would lead to complications, but we note that tidal flow power lags about $\pi/2$ behind range power from a single basin, so the two systems could be complementary.

<u>Tidal range power</u>

The basic theory of tidal power, as distinct from the tides themselves, is quite simple. Consider water trapped at high tide in a basin, and allowed to run out through a turbine at low tide. The basin has a constant surface area *A*that remains covered in water at low tide. The trapped water, having a mass *AR* at a centre of gravity *R/*2 above the low tide level, is all assumed to run out at low tide. The potential maximum energy available per tide if all the water falls through *R/*2 is therefore (neglecting small changes in density from the sea water value, usually =1025kgm^{-3})

$$\text{energy per tide} =(ARp)g \quad \frac{R}{G}$$

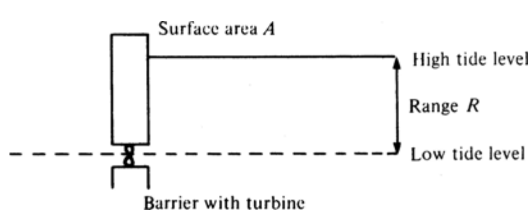


Figure 2. Power generation from tides.

If this energy is averaged over the tidal period, the average potential power for one tidal period becomes

$$P = ^{-}\ \frac{AR^{1}g}{2}$$

The range varies through the month from a maximum $R_s$for the *spring* tides, to a minimum $R_n$for the *neap* tides. The envelope of this variation is sinusoidal, according to Figure 2. with a period of half the lunar month.

Application

The maximum potential power of a tidal range system cannot be obtained in practice, although high efficiencies are possible. The complications are:

1 Power generation cannot be maintained near to low tide conditions and so some potential energy is not harnessed.
2 The turbines must operate at low head with large flow rates a condition that is uncommon in conventional hydropower practice, but similar to 'run-of-the-river' hydropower. The French have most experience of such turbines, having developed low head, large flow bulb turbines for generation from rivers and the range tidal scheme. The turbines are least efficient at lowest head
3 The electrical power is usually needed at a near constant rate, and so there is a constraint to generate at times of less than maximum head.

Efficiency can be improved if the turbines are operated as pumps at high tide to increase the head. Consider a system where the range is 5m. Water lifted 1m at high tide can be let out for generation at low tide when the head becomes 6m.

World range power sites

The total dissipation of energy by water tides in the Earth is estimated to be 3000GW, including no more than about 1000GW dissipated in shallow sea areas accessible for large civil engineering works. The sites of greatest potential throughout the world are indicated in Figure 13.9 and detailed in Table 13.1. They have a combined total potential of about 120GW. This is about 12% of near-shoreline potential and 10% of the total world hydropower (river) potential.

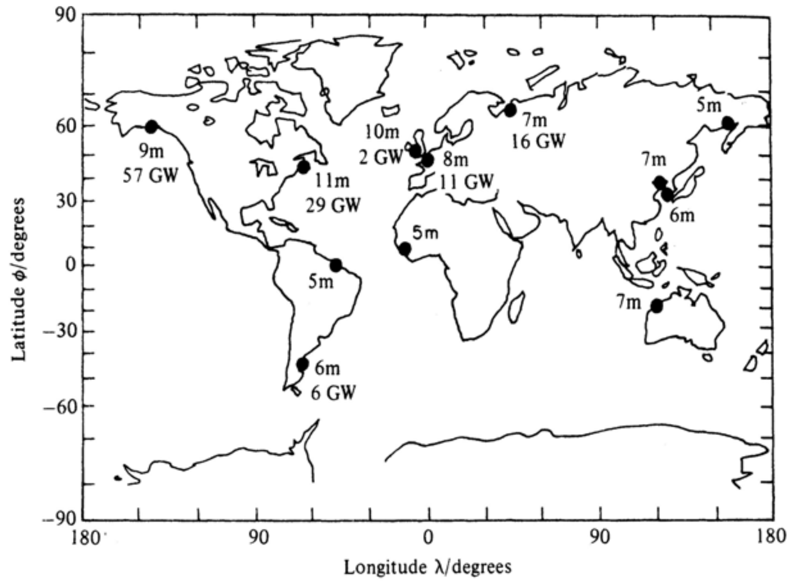


Figure 3. Location of major world tidal power sites, showing the average tidal power range and power potential.

This is a significant power potential and of great potential importance for certain countries, e.g. the UK, where, in principle, about 25% of annual electricity could be generated by tidal power from known estuaries with enhanced tidal range.

<u>Social and environmental aspects of tidal range power</u>

These mechanical factors are the driving functions likely to cause the following effects:

1 The areas of exposed mud flats are reduced, so significantly reducing the food available for birds; usually including migratory birds habitually passing such special habitats. The change in flow, depth and sea waves can be expected to change many other ecological characteristics, many of which may be unique to particular sites.
2 Visual impact is changed, but with a barrier the only necessary construction.
3 River flow can be controlled to reduce flooding.
4 Access for boats to harbours in the basin is increased.
5 Controlled depth and flow of the basin allows leisure activities such as sailing.
6 The barrier can be used as a viaduct for transport and for placing other constructions, e.g. wind turbines.

A developer's main criterion for the success of a tidal power plant is the cost per unit kWh of the power produced. As with other capital-intensive energy technologies, the economic cost per kWh generated can be reduced (i) if other advantages can be cost as benefit to the project, including carbon abatement, (ii) if interest rates of money borrowed to finance the high capital cost are small, and (iii) if the output power can be used to decrease consumption of expensive fuels such as oil. With such economic and environmental complexity, large-scale (~1000MW) tidal power plants may not be best. Smaller schemes may perhaps be more economic.

Problems

1. Consider the lunar-related force F_Z on a mass m of seawater along the Earth's radius E_Z. Since D r, show that $F_Z = mr^2$.Hence show that the difference in the lunar-related force on this mass between high and low tide is the tide raising force

$$F_t = F_X - F_Z = 2MmGr/D^3$$

The tide raising force must equal the difference in the Earth's gravitational attraction on m between low and high tide. Hence show that the tidal range R is 0.36m and is given by

$$R = \frac{Mr^4}{MD^3}$$

Experiment No: 04

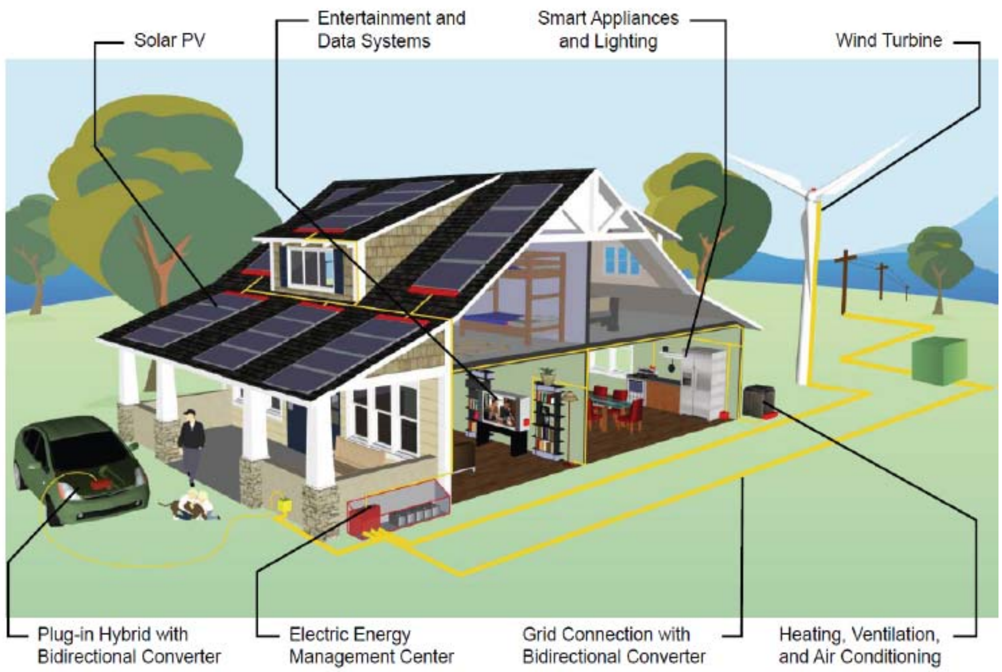
Aim: To study applications of power electronics in house hold appliances.

Requirement:

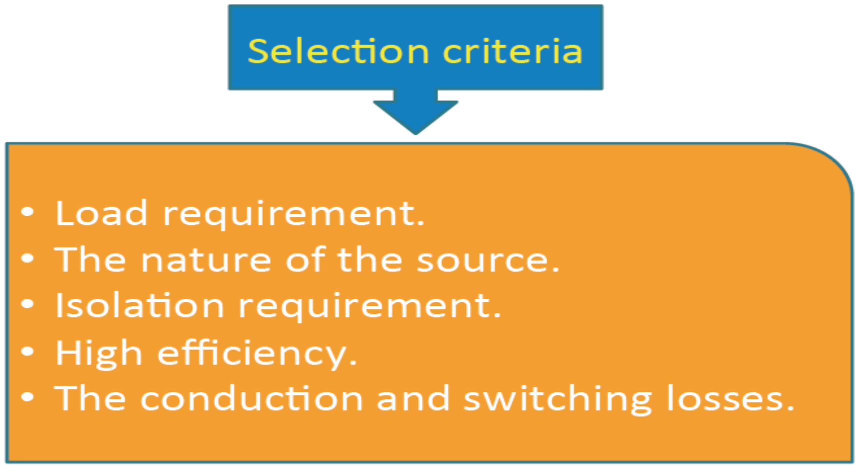
Different house hold appliances like air conditioning, cooking, lighting, refrigerators, electric-door openers, dryers, fan regulator, BLDC fan, personal computers, vacuum cleaners, washing machine, food mixers, audio power amplifiers etc.

Theory:

Applications:



How to work power electronics in such application

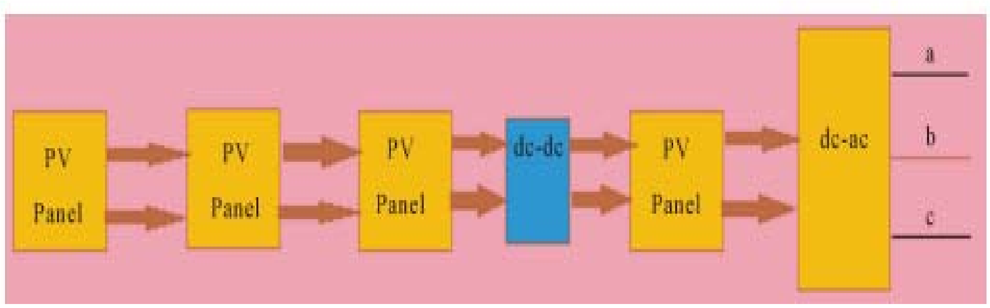


Residential and home appliances

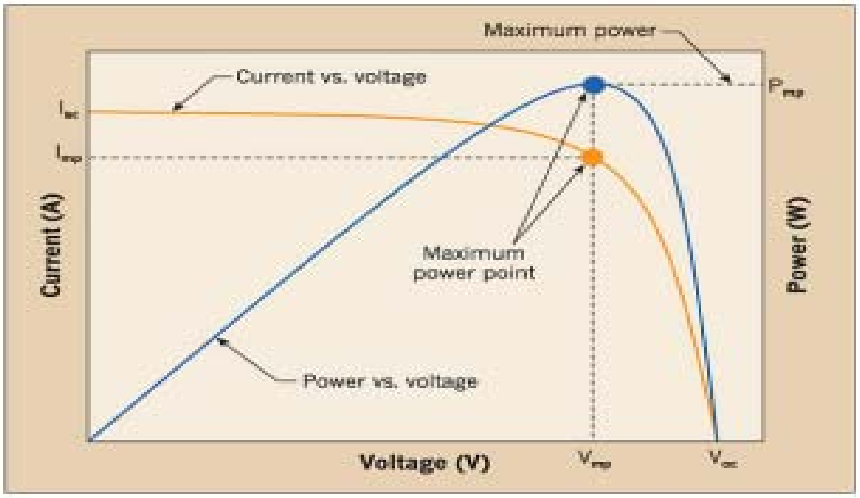
Solar pv system

Out of many renewable energy resources, solar energy is one of the conspicuous sources of energy which can supply the increasing demand of energy. As of May 2014, India has an installed PV capacity of 2.5 GW. The solar photovoltaic project includes power electronics with high quality performance devices, incorporated with smart energy management principles. Power electronics is used to improve the energy efficiency of apparatus, and help the generation of environmentally clean energy. In this article the explanation of role of power electronics and the discussion about similar and future concepts in solar photovoltaic systems related to reliability and advancement of each technology in India has been presented.

This section includes review on power generation based on photovoltaic and its implication on the related power electronic circuits. In applying power electronics, the system engineering is indispensable for improving the performance of the whole system. The major role of Power Electronics is as follows: To interconnect the individual solar panels in series and parallel according to requirement. A dc-dc converter interfacing the two solar panels that cannot be identical will help to maintain the required current and voltage, and with regulation improve the overall efficiency. Several non-isolated dc-dc converters have been employed. Buck, buck-boost, boost and Cuk topologies with suitable modifications can be employed for this purpose.



Graph:



Interfacing the dc output of the PV system to the grid or the load, this includes dc-dc-ac and dc-ac-ac conversion. Where the grid is not present and the use of batteries to store energy is required, off-grid PV systems are used, in order to cover the demand during the night or whenever energy is needed. To prevent the batteries to discharge on the modules during the night, blocking diodes are used which also protect the batteries from short circuit. They also provide over-current protection of the strings in case of short circuits, if more than one string is used. Charge regulators control the charging of the batteries. There is the need to use dc voltage and current with stable characteristics, independent from irradiance fluctuations, in off-grid systems. Hence, a DC-DC conversion topology is used. Switch mode DC-DC converters are used to match the dc output of a PV generator to a variable load. The system types can be used as grid-direct and battery-based systems. The grid-direct systems use inverters to connect the PV array to the electric utility grid. Battery based systems acts as energy storage systems. Battery-based systems are divided into two subsystems: a stand-alone system and electric utility backup system. The classification utility-interactive system is used to analyze these systems. Utility-interactive is a general term; it can apply in grid-direct and backup systems as well, that are in parallel with the electric utility. In photovoltaic systems, PV array is connected directly to an inverter.

Lighting:

Today more and more lighting applications make use of electronics, and are replacing traditional magnetic ballasts with electronic versions primarily for energy efficiency reasons. Low-voltage halogen lamps are driven by electronic transformers; the classic magnetic ballast for fluorescent lighting is being replaced by the electronic ballast and the new high-power, high-efficacy LEDs are driven by switched mode current sources.

Depending on the application, the return on investment when replacing magnetic with electronic ballasts can be as short as one year, though the electronic version is much more expensive. However, an electronic ballast provides higher performance and instant, flicker-free start without degradation of lamp lifetime at a lower weight and volume, which is a great advantage in state-of-the art fixtures and designer lamps.

While in domestic applications the incandescent lamp — mainly in the form of halogen lamps — is still used most often, in professional applications such as office lighting, the fluorescent lamp dominates, which is the topic of our discussion.

Fluorescent lighting and electronic ballast

A fluorescent lamp (FL) consists of a glass tube with filaments at both ends, filled with low pressure noble gas, and an active component, mercury vapor. A current flow through this gas excites the mercury to emit invisible ultraviolet light. The ultraviolet radiation is converted into visible light by means of the phosphor coating of the tube. Prior to a current flow, the gas has to be ionized by applying a high-ignition voltage. After ignition, the ionized state is maintained by the continuous current flow. Ignition of the lamp is much easier and lifetime is considerably increased by preheating the filaments to at least 600° to 700°C.
The gas discharge has negative differential resistance, i.e., current increases while operating voltage drops. Consequently, any gas discharge needs a current limiting element in a series. The classic magnetic ballast together with the starter as shown in Fig. 1 perfectly implements the requirements to operate a fluorescent lamp. Initially, the starter switch S1 is closed and a current flows through L1 and the filaments of the lamp. When the starter opens after a certain time — how this is implemented is beyond the scope of this article — the filaments are at high temperature and the abrupt change in current induces a high voltage in the inductor and across the lamp.
After ignition the impedance of the inductor limits the discharge current. Some disadvantages of this simple ballast are obvious, others not. First, the starter switch may open when the line voltage is close to crossing zero volts. Current flow is small at this time and the same is true for the ignition voltage. The lamp may not strike and one can easily identify a magnetic ballast by recognizing several attempts to start the lamp. A less obvious disadvantage is the poor system efficiency due to two reasons. First for the sake of cost, a high loss in the inductor itself is acceptable. Secondly, the ions in the discharge recombine during zero crossing of the line voltage and have to be re-ionized in the next half-cycle. The latter effect results in a considerable loss of energy.

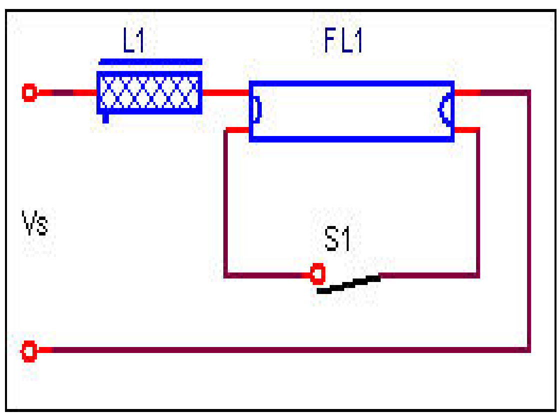


Figure 1: Magnetic FL ballast with starter

One of the main advantages of the electronic ballast is that the lamp is driven with a much higher frequency of 30 to 60 kHz typically. Due to the higher frequency, the recombination of ions does not happen and the efficacy of the lamp itself increases about 10% compared to operation at 50/60 Hz. Moreover, the electronic ballast itself is designed to achieve efficiency of more than 90% and together with state-of-the-art high-efficiency FL (so called T5 lamps) the energy savings can easily achieve 30% compared to a magnetic ballast at line frequency. Consequently, the European standard EN 50294 lists four efficiency classes of magnetic ballast and according to directive 2000/55/EG, the class D with "very high" losses has been abandoned since 2002 and class C with "moderate losses" since 2005.
Fluorescent lamp technologies are classified according to their diameter in multiples of an 8th of an inch, e.g., T8 means a Tube with 8/8" (~26 mm) diameter. In most domestic applications in Europe

the T8 fluorescent lamp is still used most often while in professional applications the T5 lamp is used more often. For the latter the operation with magnetic ballast is no longer specified within the standards.

Other advantages that an electronic ballast may have are perfect preheating of the filaments, making lifetime of the lamp virtually independent from the number of switching cycles, along with flicker-free start and operation, constant light output with variable input voltage and high power factor. Finally, important for emergency lighting, the electronic ballast can be operated with a DC input voltage (from batteries). The topology for the most popular FL ballast in Europe is the voltage-fed series resonant half-bridge shown in Fig. 2.

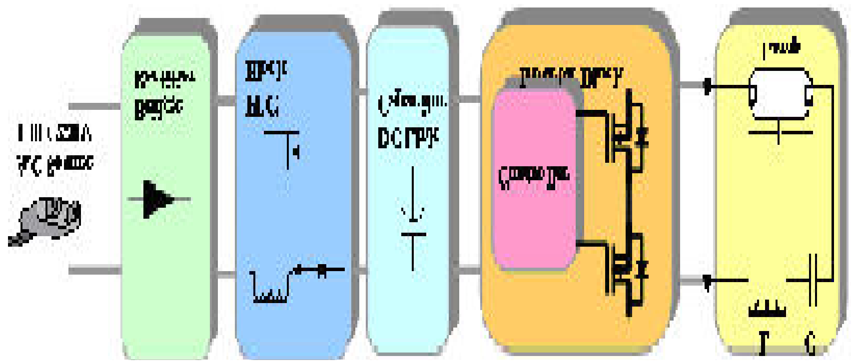


Figure 2: Block diagram of a FL ballast used in professional applications

The half bridge is driven with variable frequency and a duty cycle close to 50%. At startup, as long as the FL is not ignited, the ballast controller generates frequency well above the resonant frequency of L1/C1. Thus a high current flows through the lamp filaments heating them up to the desired temperature. After a time that is normally determined by external components, the controller starts to lower operating frequency towards the resonance. A high voltage across the lamp is generated as a result and the lamp will ignite. After ignition the impedance of the FL damps the resonant circuit fairly well and the voltage across the lamp drops close to the operating voltage.

Air conditioning,Refrigeration & freezers

Use of power electronics in refrigerator and air conditioner is very common now a days as power electronics application can control the cooling, it can be fast if the temperature difference of ambience and desired is high and cooling slows down when the temperature reaches towards desired value. This is achieved by adjusting the frequency of mains, first ac of 50 Hertz is converted to dc and then dc is inverted to ac of different frequency, this converted ac is fed to compressor, fast speed of compressor leads to fast cooling and vice versa.Furnace fans consume a significant amount of energy. Modern air conditioning and heating systems need to be more energy efficient, easier to use and maintain, and able to be programmed to optimize comfort and costs. Energy savings can be increased using variable frequency drives or high efficiency torque motors with performance-optimized power electronics. Highly efficient switching power devices, such as IGBTs and MOSFETs, help increase the efficiency, power density, and reliability of power switches, and to provide lowest conduction losses.Power semiconductors also enable high efficiencies for inverters at reduced system costs. New inverter technologies above 1kW provide notable increases in power density. IGBTs allow the use of these devices for all power ranges at frequencies above 16kHz to increase the comfort function of the inverters.

Advantages:

 High system controllability, reliability, responsiveness.

 Increased availability.

 Reduced size and weight.

 Increased energy efficiency.

Issues:

 System interaction (power flow, power quality, EMI, thermal).

 Complexity.

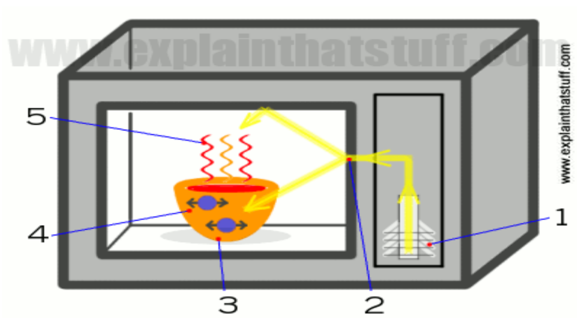
 Reliability and life-time.

 Cost.

OTHERS APPLICATION

1. Cooking

How do microwaves cook food?



How does a microwave turn electricity into heat? Like this!

1. Inside the strong metal box, there is a microwave generator called a magnetron. When you start cooking, the magnetron takes electricity from the power outlet and converts it into high-powered, 12cm (4.7 inch) radio waves.
2. The magnetron blasts these waves into the food compartment through a channel called a wave guide.
3. The food sits on a turntable, spinning slowly round so the microwaves cook it evenly.
4. The microwaves bounce back and forth off the reflective metal walls of the food compartment, just like light bounces off a mirror. When the microwaves reach the food itself, they don't simply bounce off. Just as radio waves can pass straight through the walls of your house, so microwaves penetrate inside the food. As they travel through it, they make the molecules inside it vibrate more quickly.
5. Vibrating molecules have heat so, the faster the molecules vibrate, the hotter the food becomes. Thus the microwaves pass their energy onto the molecules in the food, rapidly heating it up.

Inside out?

In a conventional oven, heat has to pass from electric heating elements (or gas burners) positioned in the bottom and sides of the cooker into the food, which cooks mostly by conduction from the outside in—from the outer layers to the inner ones. That's why a cake cooked in a conventional oven can be burned on the edges and not cooked at all in the middle. People sometimes say microwave ovens cook food from the "inside out," which is a bit of a gloss and isn't quite correct. When people say this, what they really mean is that the microwaves are simultaneously exciting molecules right through the food, so it's *generally* cooking more quickly and evenly than it would otherwise.

Exactly how the food cooks in a microwave depends mostly on what it's made from. Microwaves excite the liquids in foods more strongly, so something like a fruit pie (with a higher liquid content in the center) will indeed cook from the inside out, because the inside has the highest water content. You have to be very careful eating a microwaved apple pie because the inside may be boiling hot, while the outside crust is barely even warm. With other foods, where the water content is more evenly dispersed, you'll probably find they cook from the outside in, just like in a conventional oven.

Another important factor is the size and shape of what you're cooking. Microwaves can't penetrate more than a centimeter or two (perhaps an inch or so) into food. Like swimmers diving into water, they're losing energy from the moment they enter the food, and after that first centimeter or so they don't have enough energy left to penetrate any deeper. If you're cooking anything big (say a joint of meat in a large microwave oven), only the outer "skin" layer will be cooked by the waves themselves; the interior will be cooked from the outside in by conduction. Fortunately, most of the things people cook in small microwave ovens aren't much more than a couple of centimeters across (think about a microwaveable meat or fruit pie). You'll notice that microwaveable dinners specify a "cooking time" of so many minutes, followed by a "standing time" that's often just as long (where you leave the cooked food alone before eating it). During this period, the food effectively keeps on cooking: the hotter parts of the food will pass heat by conduction to the cooler parts, hopefully giving uniform cooking throughout.

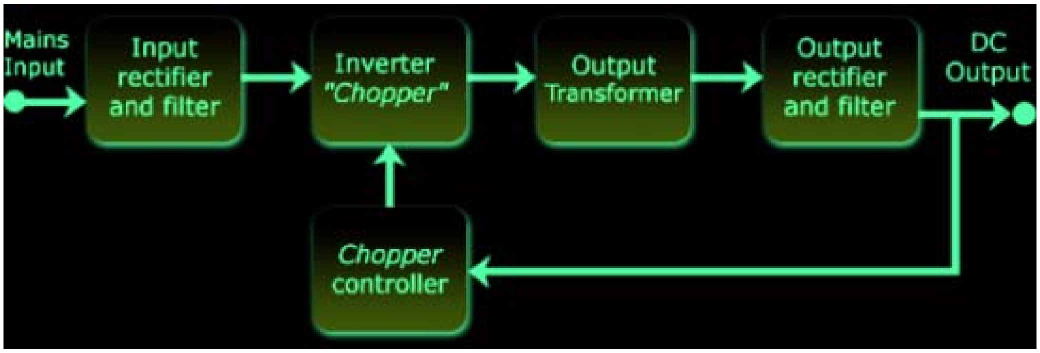
Personal computers

SMPS:-

Computer SMPS

Switched Mode Power Supply uses a switching regulator to convert electric power efficiently. SMPS transfers electric power from a source (AC mains) to the load by converting the characteristics of current and voltage. SMPS always provide a well regulated power to the load irrespective of the input variations. SMPS incorporates a Pass transistor that switches very fast typically at 50Hz and 1 MHz between the on and off states to minimize the energy waste. SMPS regulates the output power by varying the on to off time using minimum voltage so that efficiency is very higher compared to the linear

What is inside?



Block diagram of SMPS

The SMPS essentially has

1. Input rectifier
2. Inverter
3. Voltage converter
4. Output regulator

Input rectifier

The AC input from mains is first rectified in the SMPS using a rectifier to convert it into DC. The rectifier consisting of a full wave diode bridge or module that produces an unregulated DC voltage to the Smoothing capacitor. The input AC passing into the rectifier has AC voltage pulses that may reduce the power factor. So control techniques are used to force the average input current to follow the sine wave.

Inverter

This stage converts the rectified DC into AC using a power oscillator. The power oscillator has a small output transformer with a few windings at the frequency 20-100 kHz. Switching is controlled by a MOSFET amplifier. The output AC voltage is usually isolated optically from the input AC by using an Optocoupler IC for safety reasons.

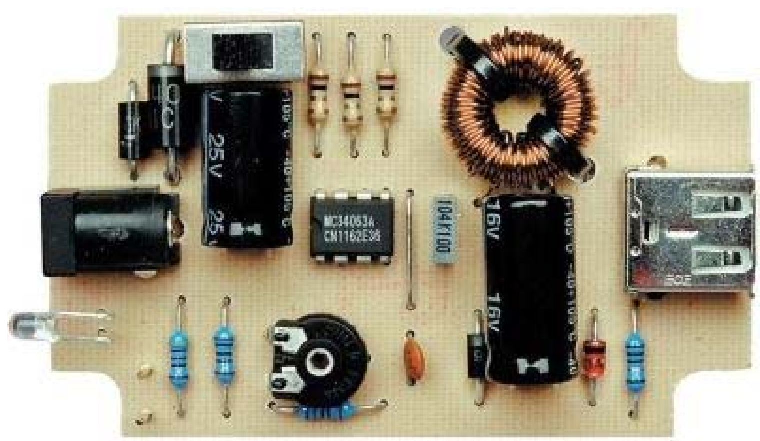
Voltage converter

This stage has a high frequency transformer and the inverted AC drives its primary windings. This creates the up and down voltage at the output. If DC is required, the output AC is converted to DC using a rectifier circuit using Silicon diodes or Schottkydiodes(fast recovery and minimum loss of current and low forward voltage drop) . The rectified output DC is then filtered using the filter section consisting of inductors and capacitors. Some non isolated SMPS contains an inductor instead of the transformer and the circuit act as boost converter or buck converter. In high voltage SMPS, Capacitor-Diode multiplier is used instead of inductors or transformer.

Output regulator

The output stage always monitors the output voltage by comparing with a reference voltage using a feedback system. For safety reasons, the output stage is isolated by an optoisolator as seen in the SMPS of computers. In some SMPS, Open loop regulation is used without feedback circuit and constant voltage is fed to the transformer input.

The feedback circuit needs power to run before it can generate power, so an additional non-switching power-supply for stand-by is added.



SMPS Mobile Charger

Added advantages of SMPS over the conventional linear power regulators are:

1. Light weight since the transformer is too small and it it operates at high frequency of 50Hz-1MHz.
2. Output voltage is well regulated and controlled by duty cycle and there is little resistive loss since the transistor fully on or off during switching.
3. Greater efficiency since the switching transistor dissipates very little heat. The SMPS can fail and can cause very high output voltage that destroys the equipment.

Experiment No: 05

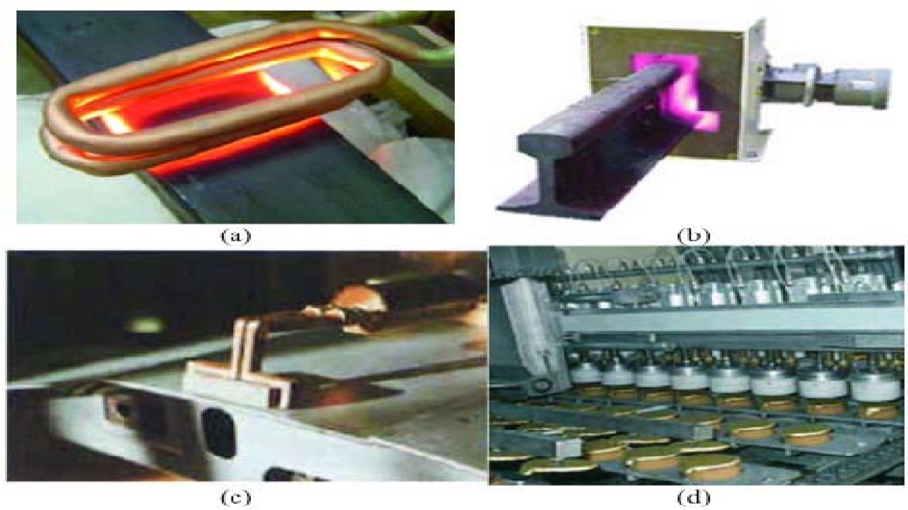
Aim: To study applications of power electronics in industrial heating applications.

Apparatus: SCR, IGBT, MOSFET, THYRISTER, ETC….

Theory:

- Industrial Heating

Power Electronics, a recognized technology and application expertise leader, manufacturers its SCR Controller, Transformer, and Power System products for the Industrial Heating market. Spang's complete line of Analog and Digital based SCR Power Controllers coupled with custom transformer capabilities satisfy the unique requirements of Industrial Heating applications.

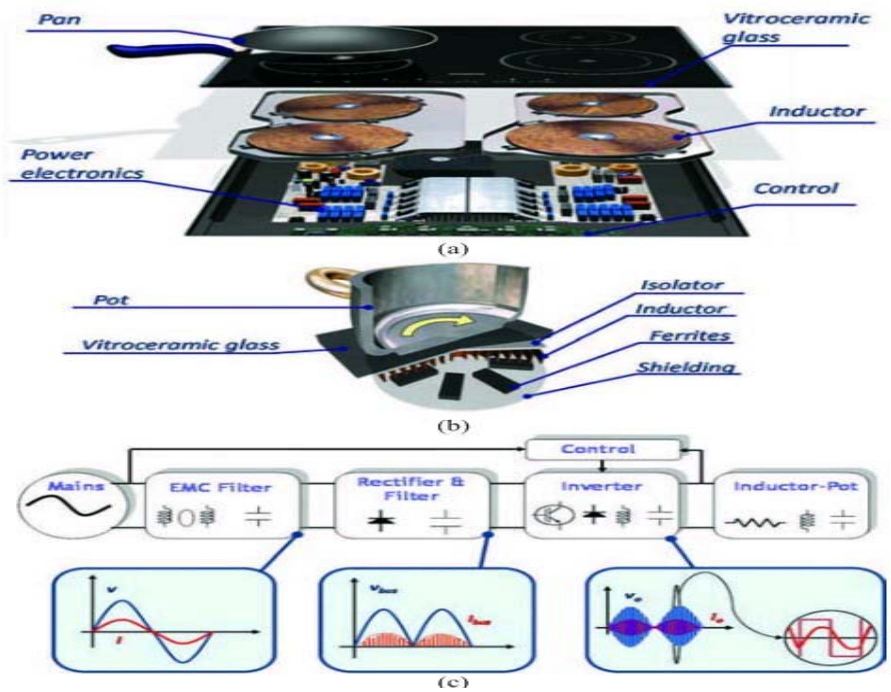


(a) and (b), for high power level, or in Fig. (c) and (d), for lower power level

The Industrial Heating market demands reliable equipment integrated into process lines. Spang understands the importance of quality runtime and delivers products focused on uninterrupted power control to maintain stable temperatures within continuous and batch processes thereby creating value-based partnerships with OEMs, integrators, and end users.

- **SCR Power Controllers**
- **Transformers**
- **Power Systems**

The method in Fig (c) consists in accelerating the polymerization of the glue by heating the metal parts to be glued by induction. The temperatures required are generally low (150 to 300°C). Fig (d) is an elegant means of sealing aluminum covers on jars of food product. Inductive heating of the aluminum film increases the temperature of the sealing product applied to the side of the cover in contact with the jar. Depending on the final application and the material to heat, the power converter operating frequency is significantly different, varying from a few Hz for high power systems, typical for metal melting, to several hundreds of kHz, for surface heat processing. As a consequence, semiconductors used in industrial heating converters are thyristors, operating at frequencies up to 3 kHz, for power ratings of several MWs, while IGBTs, operating at frequencies up to 150 kHz for power ratings up to 3 MW are normally used. MOSFETs are used for higher frequencies, up to several hundreds of kHz and output powers lower than 500 kW. Fig. 15 summarizes the semiconductor device utilization area depending on the switching frequency, the power level, and the type of resonant tank, series or parallel, used. Certain applications require more advanced topologies that aim to improve the heating characteristics or expanding.



Induction heating appliances: (a) exploded view, (b) inductor system detail, and (c) power conversion diagram.

1. **<u>SCR Power Controllers</u>**

Power Electronics' analog and digital SCR power controllers can be used in a wide range of manufacturing and processing applications.

- Digital SCR Power Controllers
- 1050 Series - 1PH/3PH (AC) - Phase Angle & Zero Cross
- 850 Series - 1PH/3PH (AC/DC) - Phase Angle & Zero Cross
- Analog SCR Power Controllers
- 450 Series - 1PH (AC) - Phase Angle
- 650 Series - 1PH/3PH (AC/DC) - Phase Angle / Zero Cross
- 750 Series - 1PH (AC) - Phase Angle
- C Series - 1PH/3PH (AC) - Phase Angle / Zero Cross
- B Series - 1PH/3PH (AC/DC) - Phase Angle / Zero Cross

1. **<u>Transformer</u>**

Power Electronics designs and manufactures a wide range of dry-type specialty transformers to provide the voltage matching capability and unique application ratings required for the industrial marketplace.

Custom high voltage / high current transformers are available to satisfy production requirements. designs dry-type transformers in 5 to 30 kV classes to step down power from the distribution voltage to any application voltage. Water-cooled transformers are supplied to accommodate most high current applications. Contact for more information on custom application transformers.

Furnace transformers are available to satisfy a wide variety of heating element characteristics. These custom transformers are designed to meet customer's system specifications and can be provided in single phase, three phase, and Scott-T connected power topologies. Transformer designs can be supplied as a core & coil only for customer integration or in a variety of enclosures with accessories such as tap switches and meters. Complete AC / DC power centers can also be provided including Spang SCR Power Controllers.

- Silicon Carbide Heating Application
- Molybdenum and Graphite Heating Applications
- Scott-T Connected Transformers (Phase Changers)

2. Power system

Power Electronics engineers incorporate extensive experience in the custom design of AC and DC power systems for a wide variety of unique industrial applications. For more information on custom power system capability relative to your application, please contact us direct.

- Custom AC Power Systems
- Custom DC Power Systems

➢ **AC Power Systems**

Power Electronics designs AC power systems to precisely match the characteristics of specific heating elements and process requirements. AC power systems are available in both single and multiple zone configurations and can be easily customized and equipped with the level of control, instrumentation, and indication needed. Where required, dry-type transformers can be included for load matching either as an integral component or for remote mounting. AC power systems are designed for many diverse global markets and applications including:

✓ Glass: Flat, LDC, Container, Specialty
✓ Polysilicon Manufacturing & Processing
✓ Fiberglass, Carbon Fiber, and Ceramic Fiber
✓ Industrial Heating Applications

➢ **DC Power Systems**

Power Electronics designs power systems to convert AC voltage / current to DC for a wide variety of industrial applications and to withstand even the harshest of environments.

DC power systems take continuous AC "voltage in" and provide controlled / variable DC "voltage out". DC power systems consist of voltage matching / isolation transformers coupled with SCR bridges packaged in an enclosure that usually includes circuit breakers, metering and pilot light indication.

✓ Automotive and Industrial Electro coating
✓ Polysilicon Processing
✓ Separating Magnets
✓ Fusion

- ✓ Electrolytic Cells
- ✓ Electro winning
- ✓ Electro refining
- ✓ Chemical processing
- ✓ Industrial cranes

- **<u>Application Expertise</u>**

designs Power Systems as well as provides SCR Controllers and Transformers for furnaces, ovens and kilns to precisely match the characteristics of the particular heating elements whether they are: <u>silicon carbide, nichrome, molybdenum, tungsten, graphite, metallic, wire-wound, infrared, and more.</u>

- ✓ Batch Furnaces
- ✓ Aluminum Furnaces
- ✓ Vacuum Furnaces
- ✓ Atmosphere Furnaces
- ✓ Hearth Furnaces
- ✓ Box Furnaces
- ✓ Pusher Furnaces

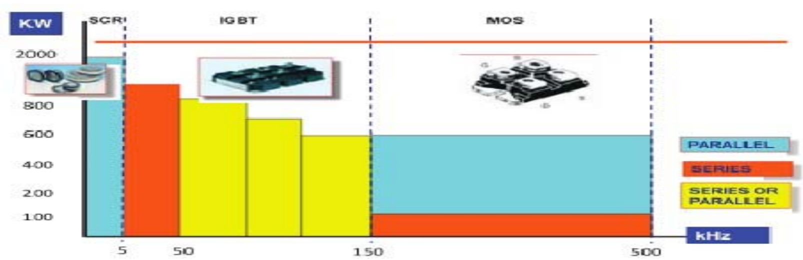
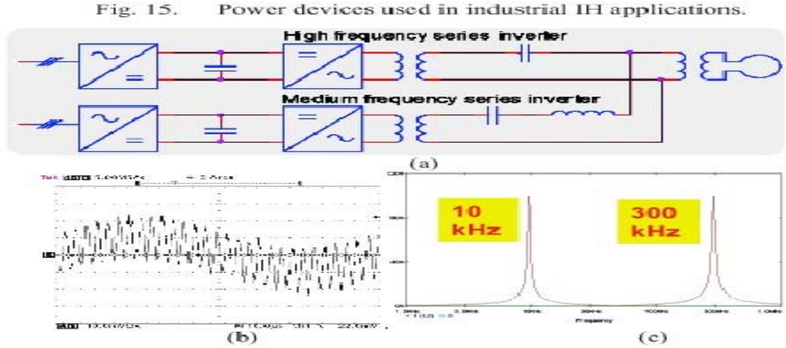


Fig. 15. Power devices used in industrial IH applications.



Double-frequency induction heating generator: (a) block diagram, (b) output current (25 A/div, time 10 µs/div), and (c) output current spectrum.

Application	Power Electronics	Modulation and Control Algorithms	Magnetic Components
Industrial	High power. Improved reliability. Assembly-line read. Low-high operating frequency.	Multi-zone control algorithm. Improved interface and communications. Variable load and power ranges. Multi-load management. Temperature control	High efficiency Variable shape Optimized heat distribution

Experiment No: 06

Aim: To study applications of power electronics in motion control and position control applications.

Theory:

Motion control

Motion control is a sub-field of automation, encompassing the systems or sub-systems involved in moving parts of machines in a controlled manner. The main components involved typically include a motion controller, an energy amplifier, and one or more prime moversor actuators.Motion control may be open loop or closed loop. In open loop systems, the controller sends a command through the amplifier to the prime mover or actuator, and does not know if the desired motion was actually achieved. Typical systems include stepper motor or fan control. For tighter control with more precision, a measuring device may be added to the system (usually near the end motion). When the measurement is converted to a signal that is sent back to the controller, and the controller compensates for any error, it becomes a Closed loop System.

Typically the position or velocity of machines are controlled using some type of device such as a hydraulic pump, linear actuator, or electric motor, generally a servo. Motion control is an important part of robotics and CNC machine tools, however in these instances it is more complex than when used with specialized machines, where the kinematics are usually simpler. The latter is often called General Motion Control (GMC). Motion control is widely used in the packaging, printing, textile, semiconductor production, and assembly industries. Motion Control encompasses every technology related to the movement of objects. It covers every motion system from micro-sized systems such as silicon-type micro induction actuators to micro-siml systems such as a space platform. But, these days, the focus of motion control is the special control technology of motion systems with electric actuators such as dc/ac servo motors. Control of robotic manipulators is also included in the field of motion control because most of robotic manipulators are driven by electrical servo motors and the key objective is the control of motion.

- A motion controller to generate set points (the desired output or motion profile) and (in closed loop systems) close a position or velocity feedback loop.
- A drive or amplifier to transform the control signal from the motion controller into energy that is presented to the actuator. Newer "intelligent" drives can close the position and velocity loops internally, resulting in much more accurate control.
- A prime moveror actuator such as a hydraulic pump, pneumatic cylinder, linear actuator, or electric motor for output motion.
- In closed loop systems, one or more feedback sensors such as optical encoders, resolvers or Hall effect devices to return the position or velocity of the actuator to the motion controller in order to close the position or velocity control loops.
- Mechanical components to transform the motion of the actuator into the desired motion, including: gears, shafting, ball screw, belts, linkages, and linear and rotational bearings.
- Velocity control.
- Position (point-to-point) control: There are several methods for computing a motion trajectory. These are often based on the velocity profiles of a move such as a triangular profile, trapezoidal profile, or an S-curve profile.
- Pressure or Force control.

Impedance control: This type of control is suitable for environment interaction and object manipulation, such as in robotics.

- Electronic gearing (or cam profiling): The position of a slave axis is mathematically linked to the position of a master axis. A good example of this would be in a system where two rotating drums turn at a given ratio to each other. A more advanced case of electronic gearing is electronic camming. With electronic camming, a slave axis follows a profile that is a function of the master position. This profile need not be salted, but it must be an animated function.

Position control

A common type of servo provides *position control*. Commonly, servos are electrical, hydraulic or pneumatic. They operate on the principle of negative feedback, where the control input is compared to the actual position of the mechanical system as measured by some sort of transducer at the output. Any difference between the actual and wanted values (an "error signal") is amplified (and converted) and used to drive the system in the direction necessary to reduce or eliminate the error. This procedure is one widely used application of control theory. Typical servos can give a rotary (angular) or linear output.

Speed control via a governor is another type of servomechanism. The steam engine uses mechanical governors; another early application was to govern the speed of water wheels. Prior to World War II the constant speed propeller was developed to control engine speed for maneuvering aircraft. Fuel controls for gas turbine engines employ either hydromechanical or electronic governing.

Positioning servomechanisms were first used in military fire-control and marine navigation equipment. Today servomechanisms are used in automatic machine tools, satellite-tracking antennas, remote control airplanes, automatic navigation systems on boats and planes, and antiaircraft-gun control systems. Other examples are fly-by-wire systems in aircraft which use servos to actuate the aircraft's control surfaces, and radio-controlled models which use RC servos for the same purpose. Many autofocus cameras also use a servomechanism to accurately move the lens. A hard disk drive has a magnetic servo system with sub-micrometre positioning accuracy. In industrial machines, servos are used to perform complex motion, in many applications.

Automatic control - past and present Automatic control systems can now be found everywhere in day to day life, both in industry and domestic applications. The field by now (up to the beginning of the new millennium) is about 50 years old and is today well established. The development of automatic control is closely connected to the industrial revolution. Typical examples are the inventions of new power sources and new production techniques. Newly invented power sources had to be properly controlled, while new production techniques had to be kept operating smoothly with high product quality. The centrifugal governor is one classical example from this era of automatic control, which has become a symbol of the field. This was mainly applied in the steam power generation and is still used in some industrial applications. Some other typical application examples from the early stages of automatic control are also worth mentioning here. Industrial process control and automation that occurred in parallel to the invention of governors is one such example. The classical PID controller still widely used in the industry is a result of this. Ship steering was another application problem, which later led the way to the invention of autopilots. Autopilots in flight control were another development that took place as early as the beginning of the century. In the meantime another Introduction to the thesis 3 breakthrough came from the telecommunication area. This was the invention of feedback power amplifier, which has better linear operation characteristics. With this brief description it is clear that the field of automatic control developed simultaneously as a result of attempting to solve some application problems in several different areas. The information sharing in between the application areas was not so effective. This clearly reflects from the following quotation in "Routh and Hurwitz were not aware of each other's contributions and neither knew about the fundamental work on stability by Liyapunov" The Second World War also motivated intensive research and development of automatic control techniques in the United States and across Europe including former Soviet Union. Digital control - the second wave Space missions started in Russia with the Sputnik in 1957 and later in the United States made a break through in automatic control. It was the first time that the computers were used for control applications Thus, physical quantities such as current, voltage, pressure, temperature etc., treated in analog form before, could then be treated as numerical figures inside a computer. This brought about an extensive flow of ideas from mathematics into the field of automatic control. The scientists were also farsighted in using advanced mathematics extensively in formulating design strategies. This brought up new concepts such as optimisation, stochastic control, identification, adaptive control, predictive control and various other control methods. Current status The field of automatic control today is a well-established technology, which has a wide range of application areas. Some of them worth mentioning are · Generation and distribution of electricity · Process control in industries · Manufacturing and robotics · Medical area · Various means of transportation · Structural stabilisation and control of heating, ventilation and air conditioning in buildings · Materials · Instruments · Entertainment Whatever the application area, the approach of a control engineer nowadays to the particular problem is governed by a number of disciplines established inside the automatic control field itself. They can be briefly described as follows.Systems theory All real systems that have to be dealt within automatic control problems can be classified into one of the following system descriptions. These are, linear systems, non-linear systems, stochastic systems, discrete-time systems, time delay systems, distributed parameter systems and decentralised systems. To describe the system behaviour, measures such as stability, observability, controllability, robustness, sensitivity, system structure etc are used. Digital motion control techniques for electrical drives.Modelling and identification Mathematical models of systems are very important in any automatic control application. If the modelling is completely based on the physics of the particular system, it is called white box modelling. Else, it can be done by conducting experiments, which is called black box modelling. Grey box modelling is the method that uses the physics and experiments in the process. With the maturity of the systems theory, a new sub-field within automatic control called system identification was born. Today it is a well-established discipline inside automatic control area. Design For a given process, finding a suitable controller configuration that can tackle either the servo problem or the regulation problem by following a systematic approach, is called as controller design. A lot of creativity has been shown in this area by control engineers. Most of the available methods can now be found in the form of standard textbooks and are also taught at undergraduate and postgraduate levels.Learning and adaptation Processes that are being controlled have the tendency to change their properties and thereby dynamics with ageing. Systems that learn about such changes automatically and re-tune the controllers are very handy to have in many applications that need higher reliability throughout their operating life. Learning and adaptation is the answer for such application problems from the automatic control community.Computing and simulation Automatic control has been tightly linked to computing throughout its development. Analog computing that was used in the beginning was replaced by digital computing later. Today there are so many mathematical computation tools specially meant for control system analysis and simulation. Examples of such tools are Matlab/Simulink, Matrixx. Some computer algebra software tools such as Maple, Mathematica etc. are also available.Implementation This again is a very important aspect in control engineering. Implementation issues form the bridge between the theory and real application. Several practical problems that may sometimes be impossible to incorporate in the theoretical study will have to be overcome at the implementation stage. These implementation aspects are rarely addressed in highly theoretical approaches to problems in automatic control area. However, such research work has a higher possibility of producing novel theoretical contributions to the field. Yet, most of the practical problems associated with the implementation of the methods are not theoretically dealt with in many cases. It is again appropriate to quote one of the great scientists in automatic control, Karl Åström from. “Many important aspects on implementation are not covered in textbooks. A good implementation requires knowledge of control systems as well as certain aspects of computer science. It is necessary that we have engineers from both fields with enough skills to bridge the gap between the disciplines. Typical issues that have to be understood are windup, real-time kernels, computational and communication delays, numerics and man machine interfaces. Implementation of control systems is far too important to be delegated to a code generator. Introduction to the thesis Lack of understanding of implementation issues is in my opinion one of the factors that has contributed most to the notorious GAP between theory and practice.” This thesis is meant to be a contribution that emphasises control aspects all the way down to the implementation stage, starting from the basic control theory.

Experiment No: 07

Aim: To study application of power electronics in electrical vehicles.

The structure of the EV's drive system is depicted in Fig. 1. It consists of a HPS, DC/DC boost converter, DC/AC converter and an induction machine. In this configuration, the FC is interfaced to the dc-bus through a unidirectional boost converter, whereas the energy storage system (ESS) such as SCs and battery is connected to the dc-bus via a bidirectional boost converter. The electrical motor is integrated with the common EV dc-link through DC/AC converter to convert the dc power to a suitable ac power.

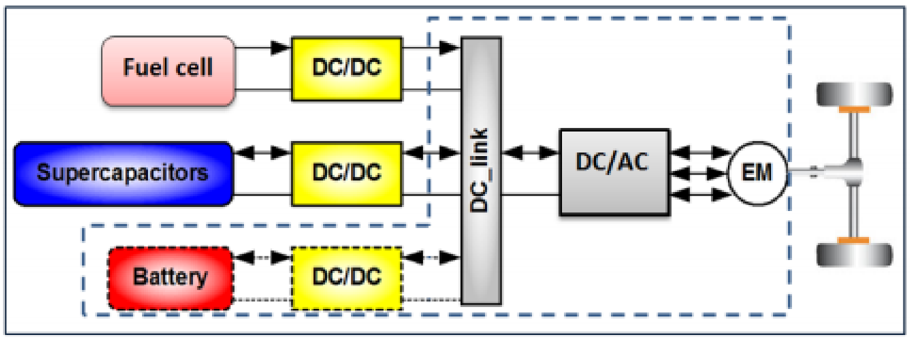


Fig. 1. Block diagram for the proposed system as a part of EVs prototype

Battery modelling

Lithium-Ion (Li-Ion) batteries are increasingly accepted to be an optimal choice for ESS (Energy storage Systems) in EV applications. In this section, the Matlab/Simulink Li-Ion battery module is design and modelled using the equation. The battery module comprises a package with Ns cells that are connected in series and Np batteries that are connected in parallel.

Electric motor

Based on the block diagram shown in Fig. 1. There is electric motor to drive vehicle in this EM two types of motor are generally preferable BLDC (Brushless dc motor) and SRM (switch reluctance motor). But BLDC motor is mostly used in electric vehicle. Study about that is as under.

Brushless DC motor

A BLDC motors is a permanents magnet synchronous motor. Position sensors are used to sense the rotor position according to the rotor position inverter control the stator currents thus the speed of motor. The term dc comes in the name of BLDC because its torque speed characteristics are similar to that of dc motors. BLDC requires an electronic commutation circuit instead of mechanical or brushed commutation used in dc motor.

BLDC motor are divided into mainly two types based on the shape of back-emf waveform induced in the stator are sinusoidal type and trapezoidal type. Sinusoidal motor have a sinusoidal shaped back-emf and its require phase current to be sinusoidal for torque ripple free operation on the other hand trapezoidal motors need rectangular shaped current for torque ripple free operation.

The trapezoidal motor requires position sensors to sense the position of rotor at every instant of time. It's requires a complex hardware for smooth operation. The trapezoidal motor is more popular for most of the application due to its simple operation, low price and high efficiency.

Many different configurations of BLDC motor exists three phase motors with star connected windings are most popular in use today because of its high efficiency and lower torque ripple.

Principle of Operation of Brushless dc motor

The three phase BLDC motor is operated by energizes two phase at a time, i.e. the only two phase are energized at an instant of time while the third phase is off to produce the highest torque. The two phases which are energized determine by an electronic commutation circuit depends on the output of the sensors. Hall-effect sensors are most commonly used to sense the rotor position and feed it to the controller. The signal from the sensors changes every 60° (electrical degree) as shown in figure. Each interval starts with the rotor and stator flux is 120° apart and ends when they are 60° apart. Highest torque is reached when the field are perpendicular to each other. Commutation is done by a Voltage source inverter. The switching devices used are MOSFET or IGBT.

Operation of BLDC motor with Inverter

A trapezoidal PM machine gives performance closer to a dc motor. For this its known as a brushless dc motor (BLDC). It is an electronic motor and requires a three-phase inverter to the driving side for feeding power into the machine, as shown in figure 3. The machine is represented by its equivalent circuit, which consists of stator resistanceRs, self-inductance Ls, and a back-emf. The inverter works as an electronic commutation which performs the switching according to the output from the position sensors. The inverter operates in the following two modes

1) $2\pi 3/$ angle switch-on mode

2) Voltage and current control PWM mode

General BLDC motor drive and motor schematic diagram with hall sensor:

Fig.2 shows general BLDC motor drive with inverter which has 6 power electronics switches s11, s12, s21, s22, s31 and s32. Vdc is DC power supply. There are hall sensor in rotor circuit of motor. As per rotor speed hall sensor gives output to the controller. Controller control the switching speed of the power electronic devices i.e. IGBTS / MOSFET.

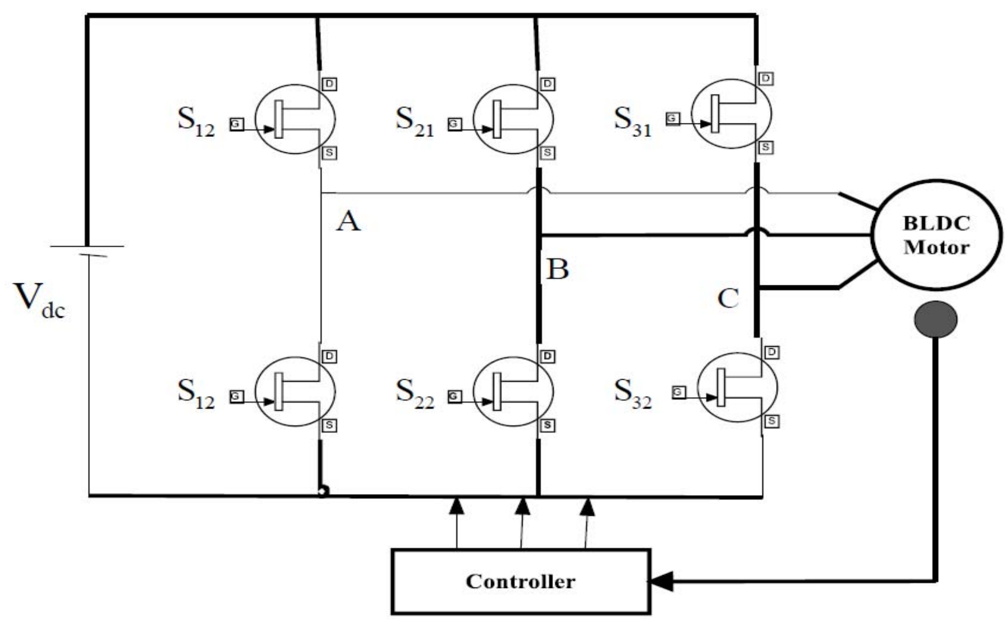


Fig. 2. BLDC motor drive

Conclusion:

There is large application of power electronics in electric vehicle to control speed of motor PWM inverter, to get appropriate voltage dc/dc Boost converter, And to recharge battery ac/dc or dc/dc converter. This all are power electronics application.

Experiment No: 08

Aim: To study power electronics applications for utility supply.

Theory:

Introduction:
Most if not all of the world's electric power supply systems are widely interconnected,involving connections inside utilites own territories which extend to inter-utility interconnection and then to inter-region and international connections.This is done for economic reason,to reduce the cost of electricity and to improve reliability of power supply.

Why We Need Transmission Interconnections
These interconnection because,apart from delivery,the purpose of thepurpose of the transmission network is to poll power plants and load centers in order to minimize the total power generation capacity and fuel cost.Transmission interconnections enable taking advantage of diversity of loads,availability of sources,and fuel price in order to supply electricity to the loads at minimum cost with a required reliability.In general,if a power delivery system was made up of radial line from individual local generators without being part of a grid system, many more generation resources would be needed to serve the load with the same reliability,and the cost of electricity would be much higher.Less transmission capability means that more generation resources would be required regardless of whether the system is made up of large or small power plant .In a deregulated electric service environment,an effective elective electric grid is vital to the competitive environment of reliable electricservice.

On the other hand,as power transfear grow,the power system become increasingly more complex to operate and the system can become less secure for riding through the major outages.It may lead to large power flows with inadequate contral,excessive reactive power in various parts of the system,large dynamic swings between different parts of the system and bottlenecks,and full potential of transmission interconnections cannot be utilized.

In react year,greater demands have been placed on the transmission network,and these demands will continue to increase because of the increasing number of nonutility generators and heightened competition among utilities themselves.Added to this is the problem that it is very difficult to acquire new rights of way rights of way.Incrresed demands on transmission,absence of long tearmplanning,and the need to prvide open access to generating companies and customers,all together have created tendencies toward less security and reduced quality of supply.The FACTS technology is essentiai to alleviate some but not all of these difficulties by enabling utilities to get the most service from their transmission facilities an enhance grid reliability.It must be stressed,however,that for many of the capacity expansion needs,building of new lines or upgrading current and voltage capability of existing lines and corridoes will be necessary.

APPLICTION OF DC TRANSMISSION:
The detailed comparison of AC and DC transmission in terms of economics and technical performance, leads to the following areas of application for DC transmission:

1. Long distance bulk power transmission.
2. Underground or underwatercables.
3. Asynchronous interconnection of AC system operating at different frequencies or where independent control of systems is desired.
4. Control and stabilization of power flows in an integrated power system.

The first two application are dictated primarily by the economic adavantages of DC transmission,where the concept of break-even distance is important.to be realistic,one must also assign a monetary value for the technical advantages of DC.The problem of evaluation of the economic benefits,is further complicated by the various alternatives that may be considered in solving problems of AC transmission phase shifters,staticvarsystems,seriescapacitors,single pole switching etc.

The technical superiority of DC transmission dictates its use for asynchronous inter connections,even when the transmission distances are negligible.Actually there are 'back to back' (BTB) DC links in existence where the rectification and inversion are carried out in the same converter station with no DC lines.The advantage of such DC links links lies in the reduction of the overall conversion costs and improving the reliability of DC system.

The alternative to DC ties may require strengthening of exsting AC network near the boundary of the two systems.This cost can be prohibitive if the capacity of the tie required is moderate compared to the size of the systems interconnected.

In Large interconnected systems,power flows in AC ties can be uncontrolled and lead to overloads and stability problems,thus endangering system security.Strategically placed DC lines can overcome this problems due to the controllability of power.the planning of DC transmission in such application requires detailed study to evaluate the benefits.

Presently the number of Dc lines in a power gride is very small compared to the number of AC lines.This indicates that DC transmission is justified only for specific applictions.Although advances in technology and introduction of multi-terminal DC system are expected to increase the scope of application of DC transmission,it is not anticipated that AC grid will be replaced by DC power grid in future.There are two majar reasons for this.Firstly ,the control and protection of MTDC systems is very complex and the inability of voltage transformation in dc networks imposes economic performance of AC transmission ,through introduction of FACTS controllers.

The rate of growth of DC transmission was slow in the beginning.In over 16 years,only 6000MW of DC systems were installed using mercury arc valves.The introduction of thyristor valves overcame some of the problems of growth of DC transmission capacity has reached an average of 2500 MW/year.

There are more than 92 HVDC projects worldwibe with a total capacity exceeding 75000 MW.Initial application of HVDC transmission was for submarine transmission or frequency distance bulk power transmission and for asynchronous BTB links.
A compilation of the worldwide HVDC projects titled "HVDC Projects List" is available at the website maintained by HVDC and FACTS subcommittee of IEEE/PES Transmission and Distribution committee.

DESCRIPTION OF DC TRANSMISSION SYSTEM:
The Dc links are classified into three types which are defined below:

1. Monopolar link(see fig 1.(a)) has one conductor usually of negative polarity and use ground or sea return. Sometimes metallic return is also used.
2. Bipolar link (see fig 1.(b)) has two conductors,one positive and the other negative.Each may be a bundled conductor in EHV lines.Each terminal has two sets of converters of identical ratings,connected in series on the DC side.The junction between the two sets of converters is grounded at one or both ends.Normally,both poles operate at equal currents and hence there is zero ground current flowing under these conditions.
3. Homopolar link has (see fig 1.(c)) has two or more conductors all having the same polarity and always operated with ground or metallic return.

Because of the desirability of operating a DC link without ground return,bipolar links are most commonly used.Homopolar link has the advantages.Incidentally,the corona effects in a DC line are substantially less with negative polarity of the conductor as compared to the positive polarity.
The monopolar operation is used in the first stage of the development of a bipolar line,as the investments on converters can be deferred until the growth of load which requires bipolar operation at double the capacity of a monopolar link.

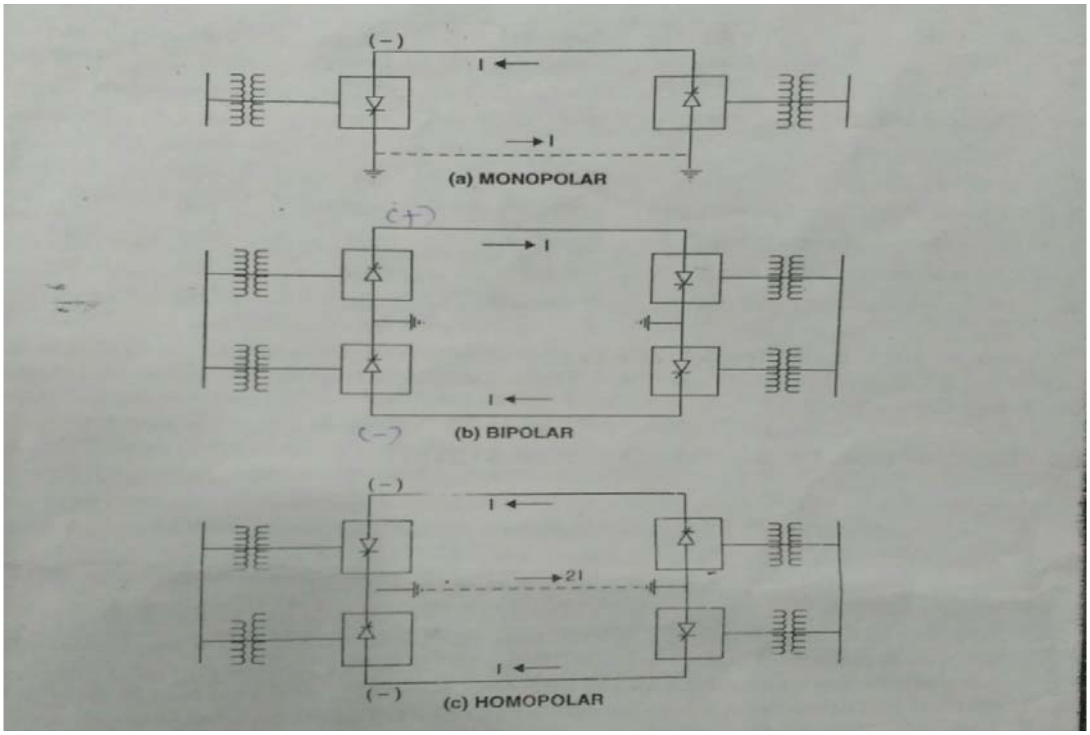


FIG (1) DC link configurations

Converter Station:
The major components of a HVDC transmission system are converter station where conversions from AC to DC and from DC to AC are performed.A point to point transmission requires two converter stations.The role of rectifier and inverter stations can be reversed by suitable converter control.

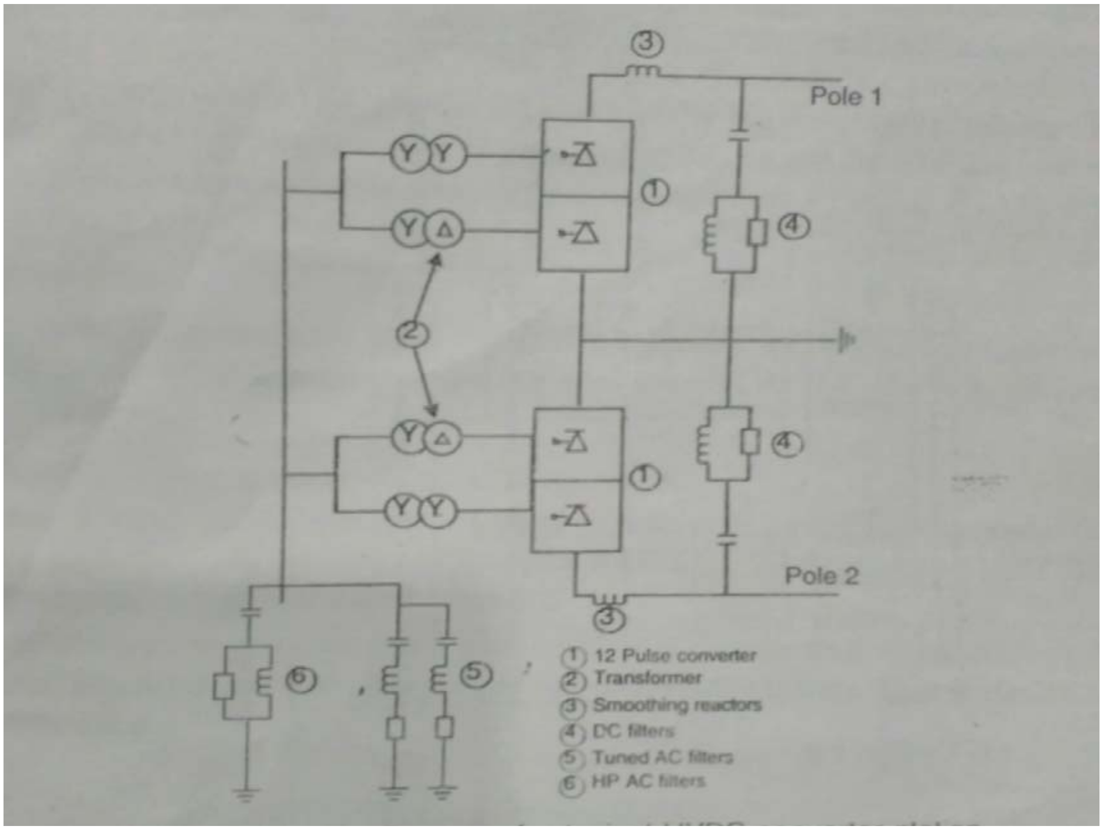


Fig (2) Schematic digram of a typical HVDC station

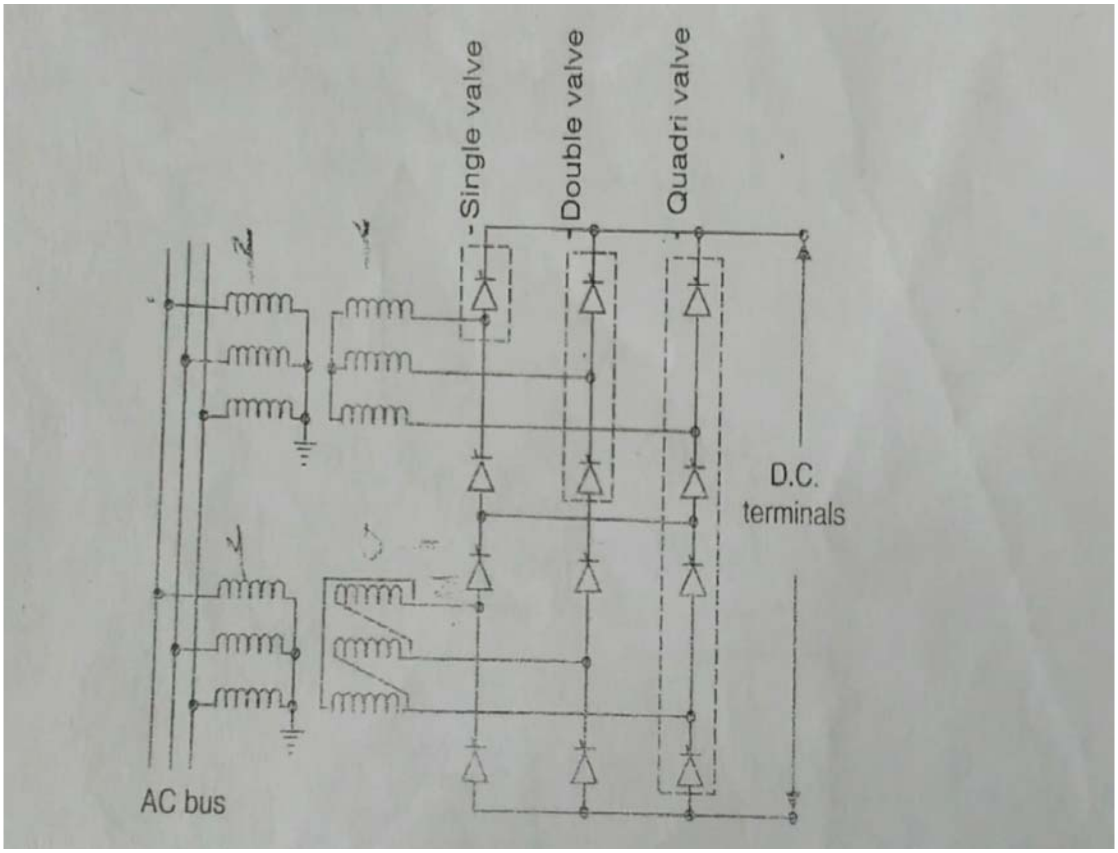
A typical converter station with one 12 pulse converter unit per pole is shown in fig (2).The various components of a converter station are discussed below.

Converter unit:

This usually consists of two three phase converter bridges connected in series to from a 12 pulse converter unit as shows fig(3). The total number of valves in such a unit are twelve. The valves can be packaged as a singal value can be packaged as a single valve, double valve or quadrivalvearrangments.Thedesing of valves is based on the modular concept where each module contains a limited number of series connected thyristor levels.

Valves firing signals are generated in the converter control at ground potential and are transmitted to each of the thyristor in the valve through o fiber optic light guide system.The light signal received thyristor levels is converted to an electrical signal using gate drive amplifiers with pulse transformers.

The valves are protected using snubber circuits, protective firing and gapless surge arrestors.Some of the details of the operation,control and protection of thyristor valves are given in Appendix A.



Fig(3) A twelve pulse converter unit

Converter transform:-

The converter transformer can have different configuration:

1. Three phase ,two winding,
2. Single phase,three winding,
3. Single phase two winding.

The valve side winding are connected in stare and delta with neutral point unground.on the AC side,the transformers are connected in parallel with neutral grounded.The leakage reactance of the transformer is hosen to limit the short circuit currents through any valve.

The converter transformers are designed to withstand DC voltage stresses and increased eddy current losses due to harmonic currents.One problem that can arise is caused by the DC oragnetization of the core due to unsymmetric firing of valves.

In back to back links,which are desingned to withstand DC voltage levels,an extended delta configuration can result in identical transformer being used in twelve pulse converter units.This result in identical tranformers being used in twelve pulse converter units.However,the application of extended delta transformear is limited.

Filters:

There are three types of filters used:

1. AC filters:- These are passive circuits used to provide low impedance,shunt paths for AC harmonic currents.Both tuned and damped filter arrangrment are used.

2. DC filters:- These are similar to AC filter and are used for the filtering of DC harmonics.
3. High frequency (RF/PLC)filters:- These are connected between the converter transformer and the ststion AC bus to suppress any high frequency currents.sometime such filters are provided on high-voltage DC bus connected between the dc filter and dc line and also on the neutral side.

Reactive power source:
Onverter stations reactive power supply that is dependent on the power loding.This is due to the fact that current drawn by a line commutated converter can only lag the supply voltage.Fortunately,part of this reactive power requirement is provided by AC filters.In addition,shunt capacitirs,synchronous condensers and static var systems are used depending on the speed of control desired.

Smoothing reactor:
A sufficiently large series is used on DC side to smooth DC current and also for protection.The reactor is designed as a linear reactor and is connected on the line side, neutral side or at intermediate loction.

DC Switchgear:-
This is usually a modified AC equipement used to interrupt small DC currents.DC breakers or metallic return transfer brekers are used,if required for interruption of rated load currents.
In addition to the equipment described above, AC switchgear and associated equipment for protection and measurement are also part of the converter station.This includes dc current and voltage transducers.

Experiment No: 09

AIM: - To study Power Electronic Applications for Aerospace applications.

Theory: -

The insertion of power electronics in aerospace technologies is becoming widespread. The application of semiconductor devices and electronic converters, as summarized in this paper, includes the International Space Station, satellite power system, and motor drives in 'more electric ' technology applied to aircraft, starter/generators and reusable launch vehicles. Flywheels, servo systems embodying electromechanical actuation, and spacecraft on-board electric propulsion are discussed. Continued inroad by power electronics depends on resolving incompatibility of using variable frequency for 400Hzoperated aircraft equipment. Dual-use electronic modules should reduce system development cost.

1. AEROSPACE POWER SYSTEMS

The advent of MET for aerospace systems has focused attention on AC-, and hybrid DC- and AC-based power management and distribution (PMAD) systems. There are many commonality used electronic converters, photovoltaic (PY) solar arrays and batteries are available. In aerospace systems, PEBB-related integration issues are the level of power and frequency range, application- and mission-dependent extreme temperature range, weight and size, electromagnetic interference and performance. Resolution of these issues is expected to promote expeditious insertion of electronic modules in aerospace technologies.

1.1 POWER ELECTRONICS APPLICATION IN AEROSPACE TECHNOLOGIES

The International Space Station (ISS), satellite power systems, MET, starter/generator system, reusable launch vehjc1es, flywheel technology and onboard electric propulsion are discussed to highlight the important role of power electronics in these systems.

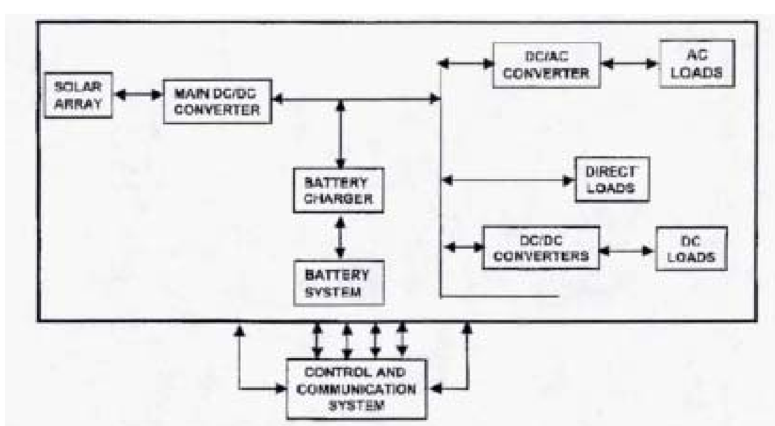


Fig: - 1 DC-PMAD-Based Electric Power System.

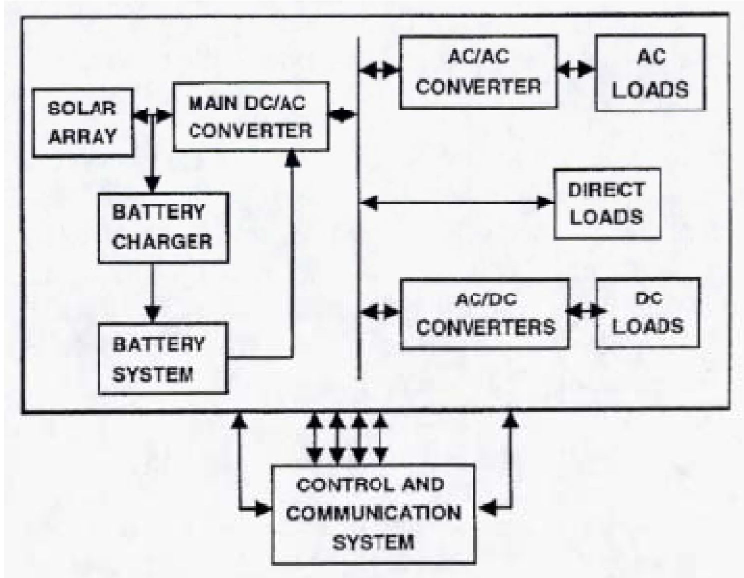


Fig: - 2 AC-PMAD-Based Electric Power System.

A) Space Station Power System

A single channel diagram, Fig. 3, of the ISS electric power system (EPS) shows a DC network of PY solar arrays, batteries, power converters, switches and user loads. The networks of 120V American and 28V Russian can exchange bi-directional power flow via American-to-Russian Converter (ARCU) and Russian-to-American Converter (RACU) units. The primary distribution system (PDS) comprises the PV arrays, batteries and the network up to the DC-DC converter units (DDCU's), for 160V to 120V step down to the secondary distribution system (SDS). The sequential shunt unit (SSU) regulates the voltage output of the PV array. The DDCU's isolate the PDS and SDS from each other, and condition the source power for the SDS. The batteries store energy during isolation periods, and supply load power during orbital eclipse. The battery charge/discharge units (BCDU's) isolate the battery from the primary bus. Remote power controller modules (RPCM's), or Switch gears, distribute power to the load converters. The BCDU's, DDCU s and the load converter contain semiconductor switches in their circuitry, thus underscoring the importance of power electronics in the ISS EPS.

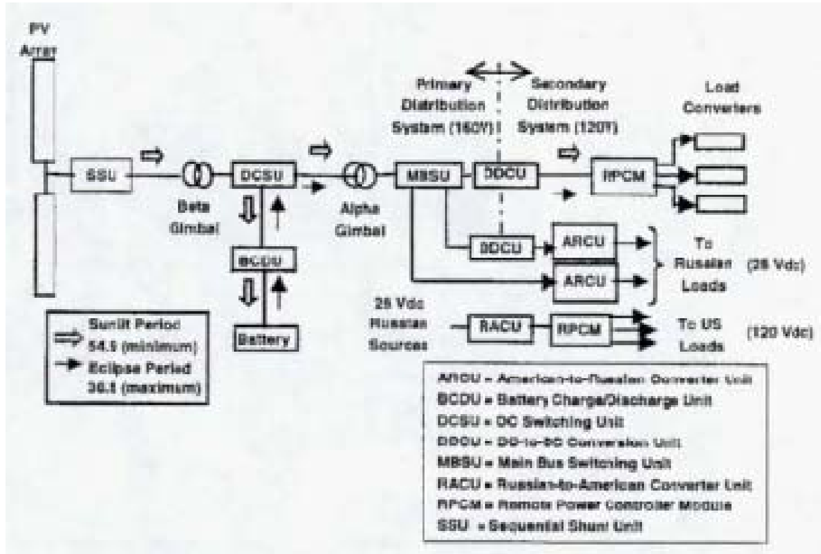


Fig: - 3 Single Channel Diagram of ISS Power System.

In their modular form, power electronics are expected to facilitate the control of PMAD and diagnosis of system malfunctions, to yield reliability improvement. Some level of electronic modularity has already been built into some Seattleite EPS, to permit adaptability of the EPS to various and future programs, with minimal re-design.

B) Satellite Power Systems

A partial block diagram of a satellite modular EPS is shown in Fig. 4. It depicts only the north portion of a 'Dual Bus ' power system for a geosynchronous satellite.

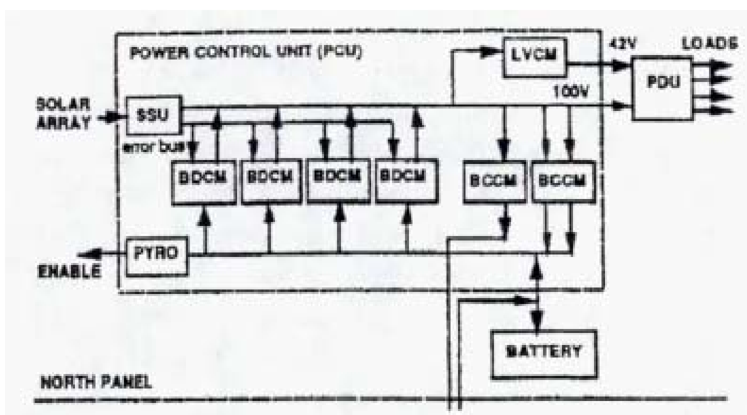


Fig: - 4 Block Diagram of Satellite Power System.

The primary-side elements of the EPS are the PV arrays, battery and power control unit (PCU). On the secondary side, the PCU embodies the SSU, battery charge and discharge converter modules (BCCM, BDCM), and low voltage converter module (LVCM) of redundant, main bus-connected DDCUs which feed the spacecraft loads via the power distribution unit (PDU). The operation of the satellite EPS is similar to that of the ISS regarding sunlight and eclipse portions of a mission. The built-in modularity makes it possible to vary battery voltage and output power levels, by adding and removing converter module(s).

This feature renders the EPS configurable for future mission. Al 0, the modularity facilitates power electronic packaging, equipment deployment into space, and needed on-orbit EPS modifications.

The use of power electronics-based motion control systems in selected aerospace systems is discussed next.

C) Motor Drive Applications

The key elements in electric actuation (EA) for MET are the electric motor, its power electronics, the control system and the actuator load(s). Lower costs and advances in power electronics and high speed electric machines have fuelled the interest of technologists, developers and researchers in industry, Government Agencies, and academia, in aerospace motion control systems. A key premise of the MET is to replace the traditionally mounted auxiliary drives and bleed air extraction with integral engine starter/generators (S/G's), electrical driven actuators and engine-gearbox-driven fuel pumps. The replacement eliminates hydraulic, pneumatic and mechanical power, and minimizes and/or eliminates their associated costs, as well as high pre-flight operation, maintenance and refurbishment of hydrazine-driven auxiliary power units (APU's).

i) More Electric Technology for Aircraft

Figure 5 shows a conceptual diagram of the Air Force's 'more electric aircraft ' (MEA) subsystems. The hydraulic-driven flight control actuators, the engine-gearbox driven fuel pump and air-driven environmental control system (ECS) are electrically powered by electric motor drives. A S/G supplies electric power to a fault-tolerant PMAD subsystem which feeds power to the EA, engine starting, braking, ECS, fuel pump and anti-icing. Uninterrupted power from an integrated APU and battery system provides redundancy and engine start-up.

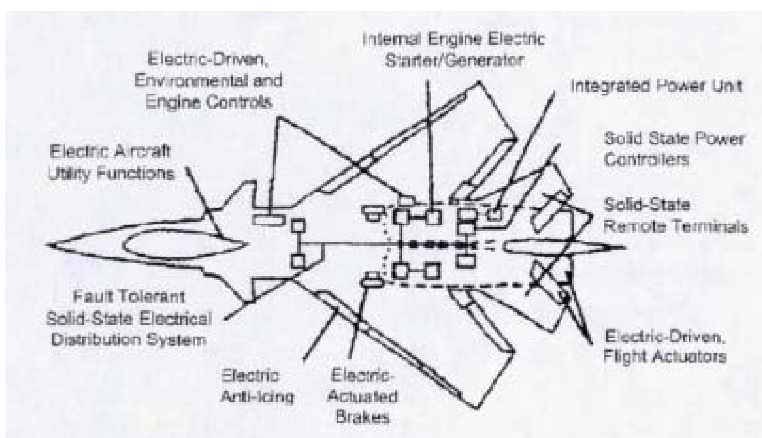


Fig: - 5 Concept of More Electric Aircraft.

The candidate electric motor drives for the MET are the IM, BLDCM and SRM drives. For each selected drive in the MET, depending on the application, the EA and its electronic controller must suitably match the safety and reliability of hydraulic actuation. This may require motor drive redundancy, for assured flight and landing. Thus, the built-in redundancy in its independent motor windings due to magnetic isolation, and in power switching circuits by electrical isolation, makes the SRM an attractive choice for fault-tolerant EA. This 'limp home' ability of the SRM has been one of the key factors in its selection by the Air Force in their MEA development.

ii) Starter/Generators

A general variable speed constant frequency (VSCF) S/G system is shown in Fig. 6. The machine may be any of the three candidates in next section. During motoring, constant frequency (CF) electrical power from the main AC bus is converted to VF by the bi-directional power converter, and fed to the machine to start the load such as an aircraft engine. In the generating mode, the variable speed load provides mechanical power to run the machine the variable frequency of which is converted to a constant frequency for the main bus. The control system receives inputs from the VSCF sources, and provides gating signals for the converter to maintain proper interface between VF and CF requirements.

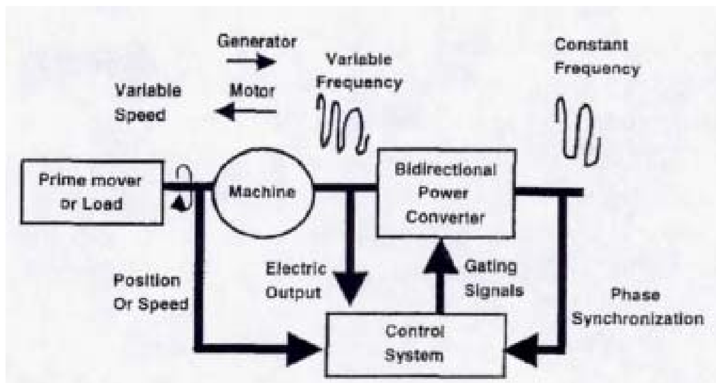


Fig: - 6 Typical VSCF Starter/Generator System.

iii) Servo System Applications

The MET proposes the use of VF motor drives to operate hydraulic and fuel pumps on aircraft. Using high-density motor drives can eliminate the usual size and weight limitations of drives. However, issues of VF incompatibility with 400Hz-operated aircraft equipment such as fuel and hydraulic pumps, attendant increase in motor weight to achieve the required torque at high frequencies, and potentially high upgrade cost must be resolved.

By comparison with CF power, VF motor controllers can reduce transient inrush current at motor start. Furthermore, a variable speed motor-driven fuel pump can provide only the required amount of fuel. Also, such a fuel pump can improve aircraft performance by reducing engine gearbox weight and enabling direct integration with the aircraft electronic propulsion and flight control

Additionally to their use in aerospace power systems, electronic converters play an important function in the on-board electric propulsion of spacecraft.

iv) On-Board Electric Propulsion

Power electronics are constituent parts of the power processing unit (PPU) of spacecraft electric propulsion which is credited with reducing launch vehicle requirements, notably for north-south station keeping of commercial geosynchronous satellites. A PPU comprises one or more electronic converters.
It provides electric power for the spacecraft thruster, and commands and telemetry interface to the electric propulsion system, as shown in Fig. 7. The converters may be current-controlled and voltage-fed, to rapidly supply constant current to offset thruster voltage variations, typically during a start-up period.

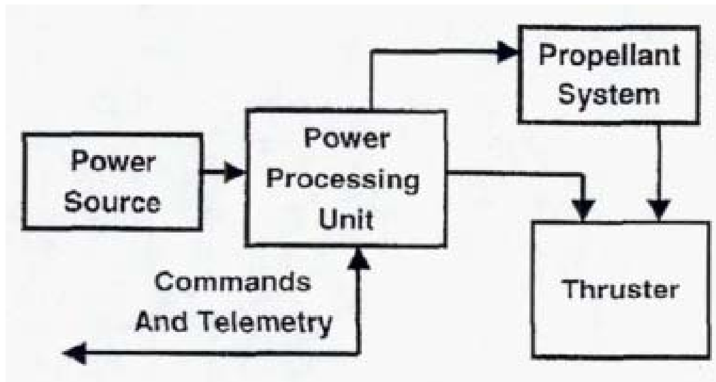


Fig: - 7 Electric Propulsion System.

Several challenges must be overcome for continued penetration of power electronics into aerospace systems.

2. FUTURE TRENDS

VF is currently used in turbo-prop and business jets. The cost and savings attractions of VF are tempered by the potential high cost of VF-upgrade for conventional, 400Hz-operating equipment on aircraft.

Continued improvements in power electronic devices and their switching schemes, advances in magnetic materials and capacitors, and better design of motors and electronic controls are expected to ameliorate weight, size and reliability issues of MET application to aerospace systems.
The need for bi-directional converters for battery charge/discharge functions and fixed frequency power and voltage, and expected varying requirements of multiple loads in aerospace systems suggest future use of hybrid AC and DC multi-converters with multi-voltage levels

Increasing use of power electronic modules will require consideration of device ratings, bi-directionality or otherwise of power flow, power density requirements and degree of integration, when developing aerospace systems. Hardware commonality will promote dual-use application of the modules, and decrease system development cost. For instance,
We planned development of 2 to 3kW power processor/thruster is expected to provide modular elements for various mission requirements.

This experiment presents a survey of power electronics applications in aerospace technologies. It encompasses the International Space Station, satellite and aircraft power systems, flywheel technology, spacecraft onboard propulsion, and the 'more electric' technology (MET) insertion in spacecraft, aircraft and launch vehicles.

Power electronic converters are central to the perfom1ance of aerospace power systems and spacecraft on-board electric propulsion. Resolution of incompatibility between conventional, 400Hz operating equipment and the variable frequency of MET should promote increased penetration of power electronics into aerospace systems. Future multi-voltage needs and varied load requirements will necessitate the use of multi-voltage level converters. The use of electronic modules with dual-use options and hardware commonality for aircraft and spacecraft should reduce development cost and maximize system re-use, while improving system reliability and performance.

Experiment No: 10

Aim : To Study The Power Electronics Application In High Voltage Dc Transmission Line

Theory :

In an AC system, voltage conversion is simple. An AC transformer allows high power levels and high insulation levels within one unit, and has low losses. It is a relatively simple device, which requires little maintenance. Further, a three-phase synchronous generator is superior to a DC generator in every respect. For these reasons, AC technology was introduced at a very early stage in the development of electrical power systems. It was soon accepted as the only feasible technology for generation, transmission and distribution of electrical energy.

The Principle Arrangement of an HVDC Transmission Project is reflected on the Moyle Interconnector project. The HVDC stations between Northern Ireland and Scotland are operating with the following highlights:

• Direct light triggered thyristor valves for the complete HVDC system, with 1872 thyristors in total, with 20% better reliability and all valve components free from oil.

• Triple tuned AC filter in both stations.

• Unmanned stations, fully automatic remote operation and automatic load schedule operation.

• Hybrid optical ohmic shunt for DC current measuring unit.

• Low noise station design for:

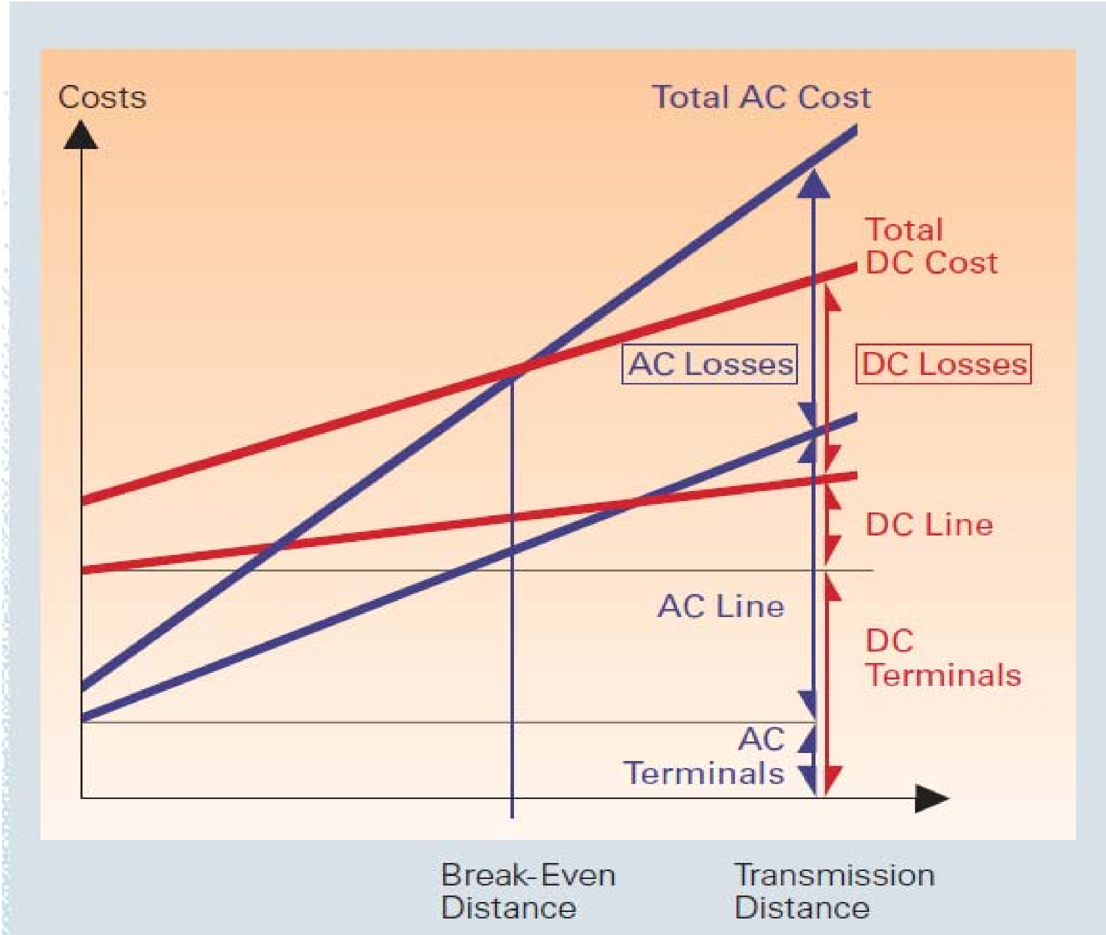
– AC filter capacitor and reactors

– Converter transformer

– Converter valve water cooling system

– DC hall with smoothing reactor

• Station design for DC see/land cable with integrated return conductor and fibre optic cable for control and communication.



Advantages:-

• A DC link allows power transmission between AC networks with different frequencies or networks, which cannot be synchronized, for other reasons.
• Inductive and capacitive parameters do not limit the transmission capacitor the maximum length of a DC overhead line or cable. The conductor cross section is fully utilized because there is no skin effect.

For a long cable connection, e.g. beyond 40 km, HVDC will in most cases offer the only technical solution because of the high charging current of an AC cable

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This is of particular interest for transmission across open sea or into large cities where a DC cable may provide the only possible solution.

➢ Economical copnsiderations :

For a given transmission task, feasibility studies are carried out before the final decision on implementation of an HVAC or HVDC system can be taken. Fig.1-1 shows a typical cost comparison curve between AC and DC transmission considering:

- AC vs. DC station terminal costs
- AC vs. DC line costs
- AC vs. DC capitalised value of losses

The DC curve is not as steep as the AC curve because of considerably lower line costs per kilometre. For long AC lines the cost of intermediate reactive power compensation has to be taken into account.

The break-even distance is in the range of 500 to 800 km depending on a number of other factors, like country-specific cost elements, interest rates for project financing, loss evaluation, cost of right of way etc.

➢ Environment issues :

An HVDC transmission system is basically environment-friendly because improved energy transmission possibilities contribute to a more efficient utilization of existing power plants.

The land coverage and the associated right-of-way cost for an HVDC overhead transmission line is not as high as that of an AC line. This reduces the visual impact and saves land compensation for new projects. It is also possible to increase the power transmission capacity for existing rights of way. A comparison between a DC and an AC overhead line is shown in Fig. 1-2.

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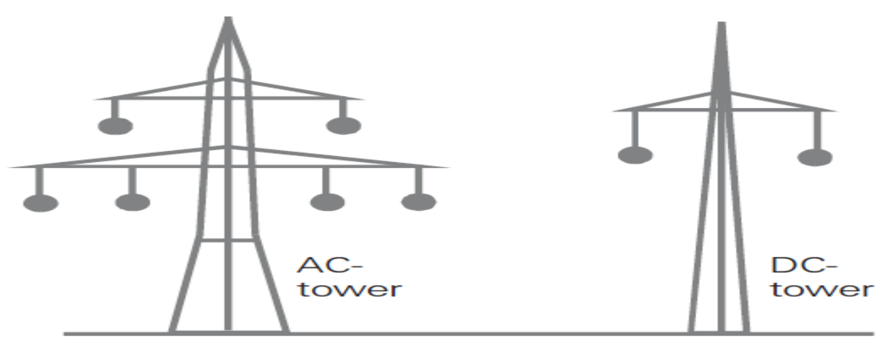

Fig. 1-2: Typical transmission line structures for approx. 1000 MW