A Paradigm Shift

Time to break the shackles of conventional DC power technologies

Most of the utilities are transforming their Operations and Equipment, both Electrical and Transmission, however the adoption of new DC Power System technologies are yet to find their place in India barring few. Enter any power utility site and you will come across bulky and highly Conventional battery charger systems, which supply DC power to mission critical equipment. These are Thyristor-based DC Power Systems (DCPS).

- Nitin Sikri

Since their introduction in the early 1970's, Thyristor-based DCPS have been conceived as highly reliable. But this reliability has come with lower power factor and huge space requirements. A typical Thyristor based DCPS utilizes Ferro-resonant techniques, a primary reason for massive size, large weight and lower efficiency. Further, these systems do not have the scope for modular expansion, due to which, frequent changing of the DCPS with each expansion of the switching/ transmission system becomes a concern.

The advent of newer technologies such as SMPS, allowed for much improved inherent reliability over Thyristor, but did this at half the floor space, and an added advantage of communicable. As compared to conventional Thyristor controlled DCPS the operating characteristics such as Transient Response, Power Factor, Efficiency, Total Current Harmonic Distortion and Ripple Noise markedly improved in SMPS (Switch Mode Power Supply) based DCPS. Moreover, these systems have been widely adopted for various critical sectors like Signalling in Railways, Mobile Switching Centre

(MSC) in telecom services for serving mission critical equipment, which require far greater reliability than a power plant equipment.

Although the advantages are evident, SMPS based DCPS are yet to see traction in the Indian utility circles. This article talks about the technical merits and most importantly, shows how it exceeds the requirements on this industry, without any added risks.

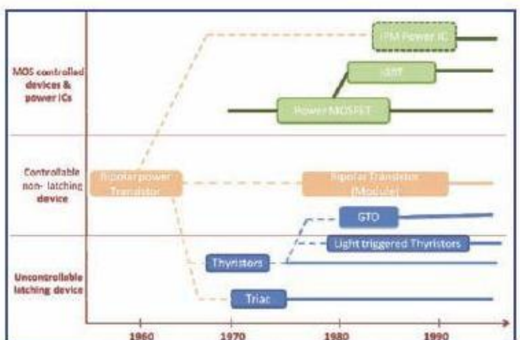
Power Semiconductor device - history

Power electronics devices made headway in the converter application with the advent of Silicon controlled rectifiers proposed by Bell labs and subsequent commercial production by GE in 1950s. These compact and robust devices replaced bulky Mercury arc rectifiers to a great extent, though without suitable turn-off capabilities these devices were found to be inadequate for high power applications. Soon, Bipolar Transistors arrived as a competition to SCR with superior turn-off capabilities than SCRs. Higher operating frequencies obtainable with a discrete Bipolar compared to the 'fast' inverter-grade SCRs permitted reduction of filter components. However, these devices had their own drawbacks such as high base current requirements for switching and incapability to block reverse voltages; restricting their application in convertor systems.

Power MOSFET, modern integrated circuit & discrete power semiconductor manufacturing technologies, burst into the scene commercially near the end seventies. With higher gain, courtesy voltage drive capability, parallel operation and much higher operating frequencies upto a few MHz made these devices formidable competition to Bipolar mainly for SMPS type of applications. Further, with VLSI manufacturing facilities for the MOSFET, prices fell sharply to enable mass adoption in convertor applications.

While improvements were being tried out on the SCR regarding its turn-off capability mostly by reducing the turn-on gain, the Gate turn-off Thyristor (GTO), were proposed by various manufacturers. Restrictive costs and requirement for an extremely high turn-off control current via the gate prevented the adoption of these devices, except for high power applications above few hundred kVA.

The lookout for a more efficient, cheap, fast and robust turn-off-able device, proceeded in different directions with MOS drives for both the basic Thyristor and the Bipolar. The Insulated Gate Bipolar Transistor (IGBT, basically a MOSFET driven Bipolar from its terminal characteristics has been a successful proposition with devices being made available at about 4 KV and 4 KA. Its switching frequency of about 25 KHz and ease of connection and drive saw it totally removing the Bipolar from practically all applications. Presently, there are few hybrid devices and Intelligent Power Modules (IPM), which are being marketed by some manufacturers. However, these new devices must prove themselves before they are accepted by the industry at large.



Advancement of Power Electronics devices

SMPS Design

Two Stage Conversion SMPS

In these SMPS systems, the conversion of AC to DC is accomplished in two stages as given below:

- First Stage conversion:

  The input AC voltage is directly rectified & converter in high voltage DC.
- Second Stage Conversion:
  - Rectified high voltage DC is stored in capacitors.
  - High voltage DC is then converted into a very high frequency AC (20 KHz and higher).
  - Conversion of high voltage DC to high frequency AC is achieved by means of very powerful and fast semi-conductor switching devices.
  - High frequency AC is stepped down to the required level by means of a small high frequency transformer.
  - Stepped down AC is rectified to DC of desired voltage and filtered by means of high frequency filters.

Salient Features of SMPS Technology

SMPS based DCPS use very high frequency switching due to which size of the transformers and chokes is reduced considerably. This makes the power plant compact due to which a lot of saving in floor area is achieved. Further, these systems are small and light in weight, and hence fit perfectly in modular concept. Up-gradation of the capacity in modular system is easy, simply plugging-in the additional modules adds to the capacity, with the limit of ultimate capacity and does not require the scrapping of existing power plant as in case conventional power plants.

These DCPS have very high conversion efficiency and consume less power resulting in low operational cost. Conversion efficiency of these DCPS is

S.No	Description	Thyristor based Charger	SMR based charger
1	Efficiency	85 to 90% at full load and nominal input voltage	> 95% at full load & nominal input voltage
2	Power factor	0.7 to 0.8 at nominal input voltage	0.98 to unity
3.	Regulation	Min 1% of set value	< 0.5%
4.	Ripple	450 MV peek to peek using external filter circuit	100 MV peek to peek without using external filter circuit
5.	Monitoring	Discrete panel meters / LED	Single CSU with alpha numeric display
6.	Settings	Manually adjustable using potentiometers	Digitally controlled and adjustable using push buttons.
7.	Total current harmonic distortion	< 25 – 30%	< 10 %
8.	Technology	Thyristor based phase controlled version	IGBT or MOSFETs based systems of Pulse width modulation using micro controllers,
9.	Magnetics	Heavy due to low frequency (50Hz) of operation. Approximately ten times more than that of SMPS.	Light weight due to high frequency of operation (70-100KHz)
10.	Construction	Big Size (components are panel mount type)	Modular design.
11.	Floor area	Twice that of SMPS	Very less foot print
12.	Images		

Advantages of SMPS based DCPS over Thyristor based DCPS

more than 89% for single phase systems and better than 90% for three phase systems.

SMPS offer a very improved power factor (near unity) making the system more efficient and make easy to comply with state electricity boards P.F. norms. These power plants have a very high reliability and therefore are less prone to faults which results in low operational costs. Additionally, the systems are solid-state systems which require much less routine maintenance and their compatibility with microprocessor based control systems enables remote supervision and control. Further, all these power plants are provided with Auto float/charge operation to recoup the battery lost capacity faster.

Float Rectifiers-cum- Float Chargers (FR/FCs) or Float Rectifier-cum Battery Charger (FR/BC) modules: These are modular, plug-in type, rack mountable normally supplied with rack enclosures, which are fully pre-wired for the ultimate capacity of DCPS. The modules supplied are hot swappable and designed to over N+N redundancy to ensure reliable & quality power always.

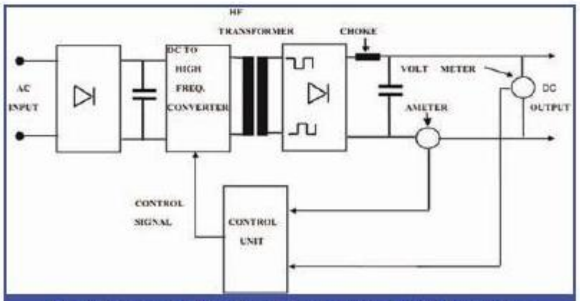
Auto Float/Charge Operation: Normally the power plant voltage remains at 54V for VRLA Batteries and 52.8V for flooded lead acid conventional batteries. The float voltage is settable in the range -48V to -56V. When the power plant is restored after any interruption, master controller steps up the DCPS voltage to 55.2V for fast recoup of the battery. When the battery is fully charged controller reverts the DCPS voltage to 54V for in case of VRLA batteries & 52.8V in case of conventional flooded batteries respectively. These two modes of operation are called auto float/charge operation.

Deep discharge Prevention: Deeper the battery is discharged, lesser the life of the battery becomes. Discharge of the battery beyond 80% of its rated capacity, drastically reduces the life of the battery. This can be understood by the fact that an exchange battery when discharged to Depth of discharge (DOD) of 20%, may give up to 3000 such cycles. Same battery at 50% DOD may give about 2000 such cycles & will give only 1400 cycles to 80% DOD. The same battery if discharged to its full rated capacity may give about 600 such cycles only. DOD of the battery can be easily controlled in SMPS based DCPS.

Battery Under voltage protection: In SMPS based systems the voltage during charging of the battery is continuously monitored. When the battery reaches the pre-set voltage, the battery is isolated from the load thus preventing further discharge of the battery. When the DCPS starts to deliver output, the battery gets automatically reconnected to the float bus to get recharged from the power plant and be ready to take load in the case of any interruption in the AC power supply. The voltage corresponding to 80% shall be set to prevent the discharge of battery beyond 80% DOD.

Battery health Check: Master controllers in DCPS monitor each cell of the battery for voltage and temperature. It is also possible to monitor the current, trickle current and battery voltage at set periodicity (programmable). The same parameter can also be monitored using centralized control and monitoring system through RS 485.

Control of the battery temperature: The importance of temperature control in VRLA batteries can be very well understood by the well known fact that the life of the battery is reduced to half when working temperature increases by 10°C above the specified ambient. The two major reasons for rise in battery temperatures are increase in ambient temperature and increase in battery chemical reaction. Both these factors can be controlled by SMPS



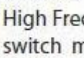
Block Schematic-Two Stage Conversion SMPS Technique

power plants by Limiting the battery path & current temp. compensation for Battery specified at 27°.

Redundant operation of modules: SMPS FR/FC modules are designed to operate in parallel with one or more modules of similar type, make & rating, other output conditions remaining within specified limits. The load sharing by these modules is within +/- 10% of the average current per FR/FC, FR/BC module in the system (mounted in the same or different racks) when loaded between 50 to 100% of its rated capacity for all working conditions.

Conclusion

SMPS based DCPS systems provide benefits like modularity, scalability, higher efficiency and higher reliability. The DCPS systems based on SMPS are designed specifically to reduce the mean time between failures (MTBF) and hence increase the lifecycle costs of maintaining such critical systems. With power utilities expanding their operating base to meet the growing demand in an energy deficit nation, the need for scalable yet reliable solutions becomes far more evident. The primary concern of module failures in SMPS based systems, emerging due to harsh environmental conditions in Power plants, has been largely addressed with use of effective heat transfer mechanisms & deployment of industrial grade dust prevention filter systems. Additionally, VMC systems in collaboration with its technology partners has developed high efficiency systems with use of IGBT/MOSFET combination, Lossless Snubber for High Frequency Switching Power Converters and True 3-phase switch mode rectifier technology. Extending the benefits of primary SMPS technologies, the new range of DCPS systems are aptly designed to meet the requirement of robust DC power systems Indian Power Utilities. ■



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Nitin Sikri, Product Manager, VMC Systems Ltd, is responsible for Product Line Management of High-Wattage Power-supplies portfolio. He has experience with Reliance Energy, BSES Delhi and has been instrumental in deployment of India's first Power distribution SCADA-DMS system. He worked with Wylie Indicators Ltd and was looking after production of Overload warning systems for Cranes. An Electrical Engineer from Kurukshetra University he completed MBA from IIM, Calcutta.