THYCON

Est.1968

DCM

Double Conversion Module
Technical Considerations

THYCON

Overview

The parallel operation of converters for increased output power or redundancy is commonplace but poses problems for larger systems. The Thycon DCM is a new approach which minimises component count, simplifies start and fault -recovery procedures while maintaining a high degree of redundancy and reliability.
There are a number of specialised features and technologies in the DCM providing long term advantages for both the client and system installer.

Transformers

These may be supplied by the System Installer and sourced locally to avoid transportation costs and increase local content, (though Thycon may also manufacture them if required).
Thycon will provide a transformer specification to achieve optimal performance in conjunction with the DCM modules.

Input Power Factor and THD

The rectifiers in each DCM are 12- pulse and operate at a high power factor. Improvement in input power factor to unity and THD may be achieved by inclusion of an optional Thycon APR module. Single or multiple APR modules may be supplied depending on the availability and performance requirements of the DCM system.

Overload Capability and Crest Factor

Transformers and motors draw large inrush currents on magnetization. The DCM system must provide this current which will be several times the nominal current, depending on the load characteristics.

It is important for the total DCM inverter output to be able to provide this inrush current. As the current exists for only a short period, it is not necessary for Thycon to fully rate the DCM modules for this current. Instead we rely on our “Static Flywheel” technology to ride through these current surges. This reduces equipment cost and physical size.

Other manufacturers, without this capability must design them for 3 or 4 p.u. to cope with these occasional transient conditions; this would be tantamount to installing a 4MW inverter for a 1MW application.

Thycon DCMs have two unique features which circumvent these problems:

- They use thyristors which do not fail on cycle- long overloads.
- They are fitted with “Static Flywheels” which provide vast amounts of transient commutation power to the inverters and can directly supply the asymmetric magnetisation energy to the transformers (or starting current for motors). In fact, the static flywheels can provide 2 p.u. reactive power indefinitely (3 p.u. recommended for SFCs).

The superior thermal overload capability of thyristors compared to IGBTs is partly due to the lower conduction losses but principally to the fact that thyristors do not de-saturate whereas transistors do, which means that beyond a certain current level (approx. 4 x rated) the transistor will limit the current for a few tens of microsecond and then shut down via the gate circuit or fail.

A typical IGBT can conduct a maximum of 7200A for 1ms whereas the thyristors fitted in each DCM can conduct 26kA for 10ms. Conventional VSIs (Voltage Source Inverters) rely on PWM (pulse-width modulation) to control output voltage and hence the current. Thus the magnetization of a transformer can be done progressively in the form of a ramped “soft-start”.

However, if additional loads are added to an energised system, the existing loads will be required to be disconnected and the PWM controls will again ramp control the output voltage to limit the inrush current to the newly connected transformer. This is a likely scenario in SFCs for dock-side ship-supplies when a new arrival connects to the SFC bus or ring-main.

Thycon DCMs rely on their unique Static Flywheels to provide asymmetric inrush currents irrespective of the state-of-load of the inverters thus avoiding problems related to ramping, voltage dips and under-voltage protection systems.

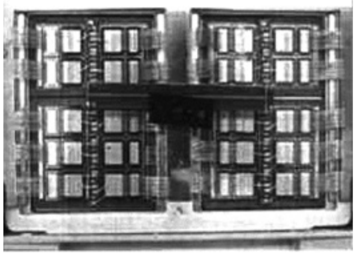

Fig. 1. Wired IGBT substrate prior to encapsulation
(Courtesy ABB Switzerland)

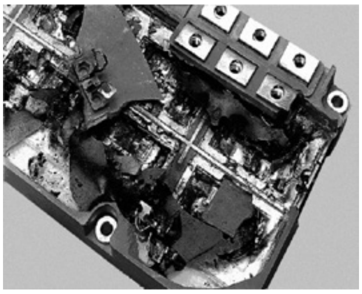

Fig. 2. Failed IGBT module
(Courtesy ABB Switzerland)

Efficiency

All Thycon converters use thyristors in a two-level current source configuration which means that current flows through only two semiconductors with low on-state voltages; about half the conduction losses of an IGBT. More importantly, the thyristors switch at line frequency whereas IGBTs in LV (Low Voltage) VSIs switch typically at >3kHz in order to synthesize a sine- wave of acceptable THD. This adds at least 30% to already significant conduction losses with further increases due to filters needed to attenuate the high switching flanks of the output waveforms.

MV (Medium Voltage) VSIs have devices switching at <1kHz but these tend to be used in the more complex 3-level configuration which improves the waveform and makes the lower switching frequency possible.

However HV semiconductors produce much higher switching losses and the current also flows over four devices instead of two. Some attempts at making two level VSIs with series connected LV devices are made but the net result is always the same.

The high switching frequency also provokes losses in output transformers or motors of about 1.5%. It has been shown that thyristor-based load commutated inverters (LCIs) offer the highest efficiencies, of up to 1.5 %, excluding transformer losses. Thus, used in typical configurations, Thycon DCMs can result in power savings of around 300kW in a 10 MVA system.

Reliability

Reliability is a measure and prediction of failure rates. Failure mechanisms are various but they fall into three well-defined categories: infant mortality, useful life and wear-out. Some components (such as ordinary incandescent light bulbs) have a low failure rate during a short (500hrs) useful life and a rapidly increasing rate thereafter.

Solid-state devices (semiconductors) such as thyristors, have extremely long useful lives of 20 to 30 years due to a very low random failure rate. Though semiconductors may be amongst the most critical, they are not the only components in a power electronic system: control and gating circuits also use many components and the higher the number of components, the lower the reliability.

A further consideration is the manner in which a piece of equipment fails.

Component	FIT
IGBT chip @ 50A / chip	6
Diode chip @ 100A / chip	3
IGBT module (4.5kV / 1200A)	180
Thyristor (4.5kV / 2000A)	20
Diode (4”)	15
IGBT gate-drive	150
Thyristor gate-drive	100
Resistor	10
Capacitor	20
Choke	10
Transformer	20

Fig. 3. Typical component failure rates

When a thyristor junction overheats, it will fail to block and as a result, the equipment will shut down. The failure is not necessarily destructive and the device may recover; in any event, no collateral damage occurs.

This is not the case with IGBTs which generally explode on failure producing a short across the supply. Fuses are sometimes used to limit the energy of the explosion but IGBTs, in module form, contain fine aluminium bonding wires (Fig. 2) which rupture faster than fuses. Fig. 2 shows an example of a failed IGBT module: the resulting plasma invariably causes arcing within the equipment and may cause arcs to strike outside, depending on the design of the enclosure.

Reliability Calculations

The method for calculation of equipment reliability is based on the addition of failure rates of all the components and the result is dependent on the number of components and their individual FIT (Failures In Time) rates. Typical failure rates are shown in Fig. 3.

A striking difference in reliability between the thyristor and the IGBT module can be seen from the table of Fig. 3. Thyristors are monolithic devices meaning that one housing contains one chip whereas IGBTs are multi-chip devices meaning that one device contains many chips, as illustrated in Fig. 4 and Fig. 5. Of all the components listed in Fig. 3, inductors and resistors have the lowest FIT rates of all components and capacitors used in the static flywheel are also amongst the most reliable devices.

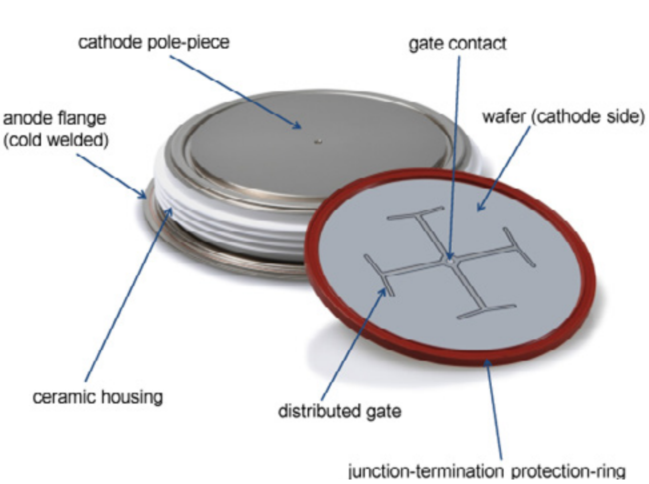

Fig. 4. Wafer and complete press-pack thyristor
(Courtesy ABB Switzerland Ltd)

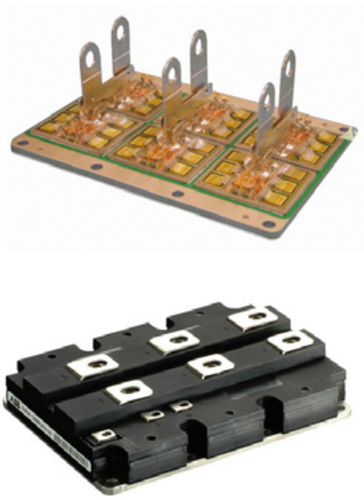

Fig. 5. IGBT module substrate with 36 chips and IGBT module encapsulating substrate (Courtesy ABB Switzerland Ltd)

Thycon DCMs are composed principally of passive components and thyristors. The control cards are few in number so that overall component count is held at an absolute minimum. Furthermore, Thycon manufactured magnetics are wound with VO rated Nomex for the longest possible useful life in harsh environments; the DCMs are air-cooled and require no air-conditioning systems and protection is by circuit breakers (fuse-less design).

Components and particularly semiconductors are, of course, the main drivers of reliability but mechanics and particularly cooling systems also play an important role. By using low-loss power electronic semiconductors and passive components the losses in the DCMs are more distributed thus permitting air cooling up to relatively large powers. In some highly polluted environments or outdoor applications the Thycon DCM can be naturally cooled (with appropriate de-rating).

Most high power IGBT inverters require water cooling with the associated pipes, pumps, hose unions, filters and de-Ionised water systems and these are a further source of failure and increased maintenance costs.

Mechanically, the DCMs are built into cubicles with 2.0mm thick steel panels and components and sub-assemblies are mounted to withstand seismic activity.

Feature	Conventional IGBT	DCM
Overload capability	low	high
Cooling	water	air
Component count	high	low
Controller boards and gate drives	many	few
Inverter losses	high	low
Failure mode	explosive	recoverable
Reliability	low	high
Life expectancy (cycles)	low	high
Repairs	Expensive (replace inverter or buy custom parts)	Inexpensive (replace standard parts)
Load harmonic suppression	extrenal filters needed	inherent
Efficiency	low	high
Installation	by OEM	by local distributor

Redundancy

System availability is enhanced by the use of redundant inverters. The smallest number of inverters in a redundant system is two thus a 1.6 MVA redundant system might be composed of 2 x 1.6MVA modules but this would not be very cost-effective since it requires installing twice the required capacity. A cost and space saving approach would be to use 3 x 0.8MVA.

One unit can then be isolated for repair or exchange while the remaining two DCM modules continue to operate supporting the full 1.6MVA load. A higher number of DCMs may be connected to provide higher levels of redundancy. For instance, a 1.8MVA redundant system could be built from 4 x 0.6MVA modules (N+1) or 5 x 0.6MVA modules (N+2).

The concept, of redundancy can be applied to lower power units using a larger number of inverters but one should nevertheless consider the overall failure rates per the examples of Fig. 3 and maintenance costs resulting from a large number of small units particularly when these contain repeated functions such as controller boards and by-pass switches.

The Thycon DCM approach to UPS and SFC systems introduces a new degree of flexibility in all aspects of power conversion from specification through ordering installation, commissioning, operation, repair and recycling. All these benefits lead to greatly reduced cost-of-ownership for end-users and cost-effective sales and installation processes for local Distributors and Integrators.

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