POWER CONVERTERS FOR THE ISIS SECOND TARGET STATION PROJECT (TS-2)

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Abstract

The Extract Proton Beamline to the ISIS second target station will require magnets to be powered by ac/dc power converters. A total of 56 magnets, quadrupole and dipole, require high stability dc current converters over a large dynamic range from 1.5kW to 680kW. There is also a requirement for two 10Hz pulsed magnets to extract the proton beam from the present 50Hz target beamline and hence specially designed power supplies are necessary. This paper describes the power converter requirements, types of topology considerations and evaluation criteria.

INTRODUCTION

ISIS, Figure 1, sited at the Rutherford Appleton Laboratory (RAL) is the world's most intense pulsed neutron source. Intense bursts of neutrons are produced at 20mS (50Hz) intervals when a heavy metal target is bombarded by a high-energy (800MeV) proton beam from a synchrotron accelerator releasing neutrons by the process of spallation. A second target station (TS-2) is under construction and when completed will receive a 10Hz proton beam to provide neutrons for a further 18 neutron instruments. The 10Hz proton beam is achieved by operating two slow pulsed magnets and a septum magnet to direct the proton beam to TS-2 Extract Proton Beam line (EPB). The TS-2 EPB, approximately 150 metres long, will require 56 magnets and their associated power supplies to produce magnetic fields for the beam optics. The power supply ratings will range from 1.5kW to 160kW with one 680kW DC septum power supply and two 10Hz pulsed power supplies.

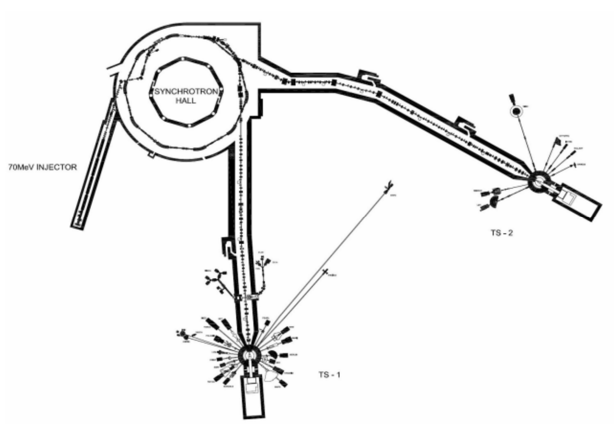

Figure 1: ISIS Layout.

DC POWER CONVERTERS

Table 1. Shows a list of the dc power converter ratings, voltages, currents, and converter topologies.

Table 1: Power Converter Ratings

Magnet Type	DC Power (kW)	DC Voltage (V)	DC Current (A)	Qty.	Topology
Q11/M21	7.5	29	260	25	SMPS
Q13	18	45	400	1	Thyristor
Q12	23	72	325	7	Thyristor
M21	40	110	365	2	Thyristor
M22	65	116	560	4	Thyristor
Q13	72	90	800	4	Thyristor
Q13	156	130	1200	1	Thyristor

The 7.5kW power converters are water cooled Danfysik Series 9000 modular type, mounted into 19" racks in groups of six or seven converters per rack.

Figure 2. shows a block diagram of the power converter, which is a full bridge phase modulated, zero voltage-switching converter.

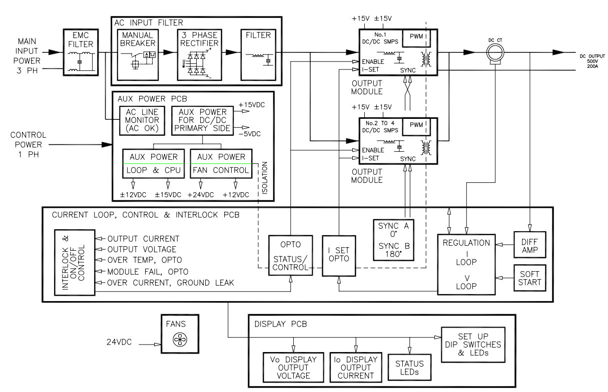

Figure 2: Danfysik Series 9000 Converter.

The remaining dc power converters (18kW, 23kW, 40kW, 65kW, 72kW and 156kW) are water cooled Danfysik Series 8500 converters, which use thyristor power regulation technology (see figure 3).

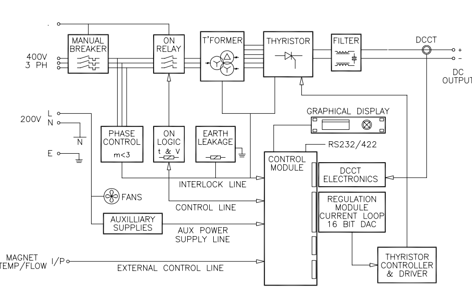

Figure 3: Danfysik Series 8500 Converter.

SEPTUM POWER CONVERTER

The septum power converter is a modular type, designed and manufactured by Kempower OY. The converter will consist of twenty-four identical sub-converters each rated at 68V @ 420A connected in parallel. The topology of each sub-converter is IGBT technology (see figure 4). There are 8 power cabinets each containing 3 sub-converters, 1 cabinet for the DCCT, 1 cabinet for the common control, 1 cabinet for the mains switch and 4 cabinets for the EMC filters. Cooling of the sub-converter is a combination of water cooling and forced air cooling.

Table 2. Septum Power Converter Rating

Magnet Type	DC Power (kW)	DC Voltage (V)	DC Current (A)	Qty.	Topology
Septum	680	68	10000	1	IGBT

The septum power converter is designed with n+1 redundancy. In the event of a sub-converter failure, the remaining converters will take up and share the extra current within 50mS thus enabling the extracted proton beam continuous operation.

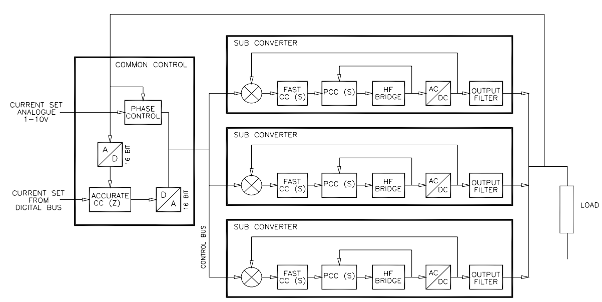

Figure 4: Septum Converter (one power cabinet).

BIPOLAR POWER CONVERTERS

The Danfysik System 7000 sub-converter is designed with a high efficiency 100 kHz push-pull bipolar power converter/amplifier together with a linear bipolar transistor output stage. The converter is air cooled by internal fans, which are speed controlled depending on ambient temperature.

Table 3: Bipolar Converter Ratings

Magnet Type	DC Power (kW)	DC Voltage (V)	DC Current (A)	Qty.	Topology
M24	1.5	±75	±20	9	SMPS

The bipolar power converters will be used for powering the steering magnets.

10HZ PULSED POWER CONVERTERS

The pulsed power converters are designed and manufactured by Danfysik and are based on a high voltage capacitor bank to drive up the current to the required level (450A Kicker 1 and 2800A Kicker 2) and a low voltage capacitor bank to achieve the flat top requirement for a minimum of 600µS. The stored energy in the magnet is recovered back into the high voltage capacitor bank to reduce the power requirements.

Table 4: Pulsed Power Converter Ratings

PSU Type	Power (kW)	Voltage (V)	Current (A)	Qty.	Topology
K1 12.1mrad	2	235	450	1	IGBT
K2 90mrad	30	1355	2800	1	IGBT

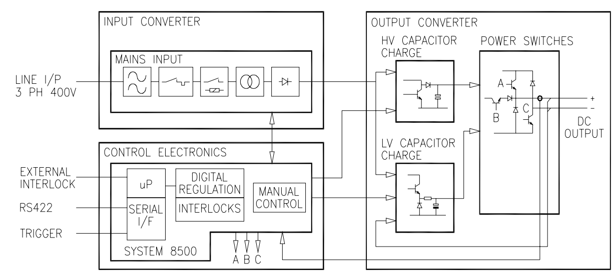

Figure 5: Danfysik 10Hz Pulsed Power Converter.

Input Converter

The AC main input supply is EMI filtered and over current protected with a manually operated circuit breaker. There is two stage switching to minimise the inrush current. A transformer converts the mains voltage to a lower level and provides galvanic isolation.

The transformer output voltage is rectified in a twelve pulse rectifier and filtered with a L-C low pass filter to produce a dc link voltage for the output converter.

Output Converter

The output converter consists of three major blocks. A high voltage capacitor pre-charger, a low voltage capacitor pre-charger and the power output switches.

Switch Control Principle

When the capacitor voltages are charged to their specific value, a ready signal will be generated to the regulation loop. A trigger signal from ISIS or a test push button will then start the 10Hz pulse sequence.

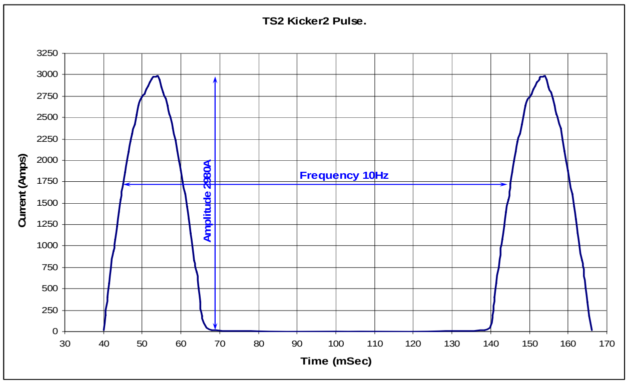

Figure 6: Simulated 10Hz pulse.

IGBT A and IGBT B (see figure 5) are turned on. The flat top period begins after the digitally controlled output current reaches the desired set value (approximately 2800A). IGBT A is then turned off and IGBT B will continue to carry the output current. Figure 6 shows two 2.8kA half sine wave pulses.

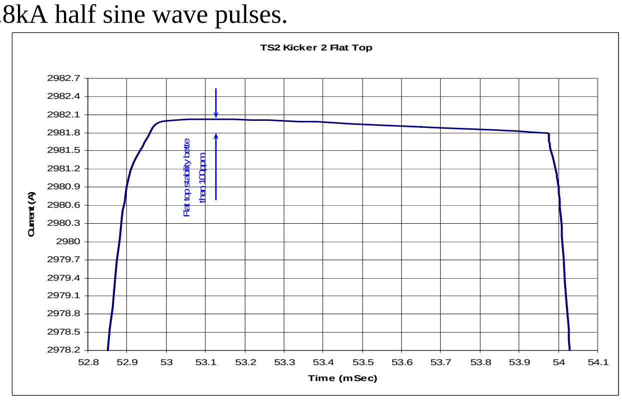

Figure 7: Simulated 10Hz pulse flat top.

The flat top is digitally loop controlled and has a duration of a minimum of 600µS (see figure 7). IGBT C will then open starting the recovery period. In the recovery period the current will flow back to the HV capacitor through its top diode. After this recovery period the capacitor will be re-charged ready for the next pulse.

A measure of the flat top accuracy is achieved from the following principle:

If the dc flat top voltage = resistive load x current, then the voltage across the load inductor will be zero. No voltage across the inductor is an indication of no change of current.

High Voltage Capacitor Charger

The high voltage capacitor charger is a boost converter boosting the dc link voltage to a value between 20 and 100% of nominal value set by the regulation module. The boost converter is constructed using Danfysik 859 type building blocks. The 859 converter is a current mode switch regulator suitable for charging larger capacitor loads. The voltage regulation must be within an accuracy of 0.25% to ensure a flat top jitter of ±60µS. The control module has light guides for input and output. The input light guide is a PWM modulated signal with a fixed frequency noting the charge voltage level. A missing pulse disables the charging converter.

The output light guide has three indication states:

- Continuous off. (module fault, IGBT fault or over load)
- Pulses. (charging in progress)
- Continuous on. (capacitor voltage within specification and ready to be fired)

Low Voltage Capacitor Charger

The low voltage capacitor charger is a buck converter controlling the dc link voltage to a value equal to the required voltage at flat top. This is a level voltage given by the regulation module. This voltage is constantly adjusted by the digital loop to an accuracy of 1%. This equals a flat top deviation on 50ppm.

The control module for the LV capacitor charger works on the same principle as the HV capacitor charger.

Control Electronics

The control electronics has to perform the following tasks:

- Control of the input converter block.
- Control of the output converter block
- Communication. Remote & Local
- Current measurement and regulation control
- Status and monitoring.
- Interlock (fault) supervision. Internal & external.

EVALUATION PROCESS

There are eight sections within the evaluation document. They are:

- General Requirements.
- Ratings.
- Power Circuit Topology.
- Cooling.
- Material.
- Design, Project Reviews & Planning.
- Training and Product Support.
- Cost.

The first seven sections cover all of the power supply design, engineering and documentation requirements. This accounted for 60% of the total points towards the final selection score. The cost of the tender accounted for 40% of the final selection score.

ACKNOWLEDGMENTS

We would like to thank P A Elkjær of Danfysik AS. Jyllinge, Denmark for providing information on the design and manufacture of the pulsed power converters.

We would also like to thank P Korhonen of Kempower OY. Lahti, Finland for providing information on the design and manufacture of the 680kW septum power converter.