UPGRADE OF THE ISIS PRE-INJECTOR EHT GENERATOR

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Abstract

The thermionic driver stage for the 665kV Cockcroft-Walton EHT generator for the ISIS pre-injector has been replaced with a solid-state 10kVA frequency converter. Control and monitoring are via a Controls Group Standard STEbus microprocessor crate operating under the new ISIS control system based on Alpha workstations running Vsystem. The converter, its associated electronics and control system are described.

1 INTRODUCTION

The -665kV EHT generator for the ISIS pre-injector was supplied by *Emil Haefely & Cie AG* in 1967 and had been in almost continuous use ever since. Although it gave little trouble, its age, and concern about the continued availability of its thermionic tubes and other spares prompted the decision to replace its power electronics with a solid-state 10kVA frequency converter supplied by the U.K. company, *Magnus Power Ltd.*[1]

Its control and monitoring were implemented using an example of the recently-developed Controls Standard STEbus (CSS) [2] embedded microprocessor system which is now being used to interface ISIS accelerator equipment to the Alpha workstations of the new control system via Ethernet.

2 FREQUENCY CONVERTER

Fig. 1 shows the frequency converter as supplied and Fig. 2 shows the controller with its associated STEbus crate. The converter's incoming 400V 3-φ a.c. supply is rectified to 230V dc. This dc supply is fed to three paralleled output Power Modules consisting of four-element bridge circuits, two diagonally-opposite arms of which are switched fully on at any instant, depending on the state of four 56kHz control signals. The mark-space ratio of these control signals determine the output voltage of the Power Modules.

The resonant frequency of the output load on the converter is about 5.5kHz and exhibits some long-term variation. For this reason, the output frequency is programmable from 5 to 6kHz with a resolution of 1Hz. To produce the required output frequency, sinusoidal modulation of the mark-space ratio of the 56kHz control signals is used to produce a sinusoidal output waveform from the Power Modules of up to 120V rms. This voltage is stepped up to 5kV-0-5kV rms, by an external transformer, replicating the push-pull anode outputs of the pentodes of the original Haefely equipment. This output is used to drive the 3400-0-3400 turn primary of the original Haefely transformer. The 66000 turn secondary of this transformer gives the input voltage for the associated five-stage Cockcroft-Walton multiplier to generate the required -665kV.

With full beam intensity, the current required at -665kV is 2.2mA. The actual load on the frequency converter at full beam intensity is 61A at 69V rms giving 4.21kW which can easily be met by only two output Power Modules. Although no failure has yet occurred, a faulty output module could be removed for repairs while allowing continued operation of the converter.

Fig. 1: Frequency Converter

Fig. 2: Controller and STEbus Crate

3 CONTROLLER

A block diagram of the controller and STEbus crate is shown in Fig. 3. Four independent dividers monitor the EHT. Their outputs are filtered to remove remanent converter-frequency ripple, sampled to exclude the perturbation in EHT caused by pulses of beam current, and digitised in the ADC. One output is selected for comparison with the EHT demand level from the DAC. The difference error signal is amplified and integrated to set the required output power from the converter. The necessary drive level is monitored as a useful diagnostic of the condition of the rectifiers, etc, of the Cockcroft-Walton multiplier and of the tuning. The reading of the EHT return current to the Cockcroft-Walton multiplier is also digitised. Transient reductions in EHT voltage, caused by voltage breakdowns, are detected for logging.

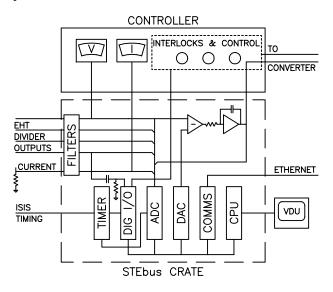The controller also provides the usual machine and personnel interlocks.

Fig. 3: Block diagram of Controller and CSS crate.

4 CONTROL SYSTEM AND CSS CRATE

4.1 New ISIS control system

The new control system comprises a network of seven Digital Alpha workstations running the Open VMS operating system and a commercial control system package, Vsystem. Interface to the user is via X-windows multi-window displays (control screens), keyboards, mice and programmable knobs or tracker-balls.

Using the Vsystem [3] Draw package, control screen displays can be generated interactively using a mouse, not only selecting fixed symbols and boxes etc. for display but also linking the screen display through the distributed database to the equipment so as to give continuously updating displays and to allow interactive operator control of equipment.

4.2 CSS Hardware

Interface to the accelerator equipment is via Ethernet to the CSS system employing the IEEE-1000 STEbus standard. It uses *ARCOM CONTROL SYSTEMS Ltd* hardware, driven by software developed in the ISIS Controls Group.

STEbus is an 8-bit bus which uses a master-slave concept in which a master, having gained control of the bus, may address and command slave modules on the bus. The masters and slaves communicate by using an asynchronous interlocked handshake protocol.

With such a system, the speed of data transfer is governed by the slowest participating board, and not by timing figures in the specification. This allows the possibility of performance improvements as and when faster devices become available.

STEbus's protocol does not unduly favour any particular processor family, thereby giving the designer a wide choice of CPUs. The STEbus Control system for the converter uses an *ARCOM* SCIM88-5 CPU card. This forms part of an optimised performance target system based on the Intel 80C188 16MHz microprocessor with 256K bytes static RAM, 256K bytes dynamic RAM and address space of 512K bytes for a FLASH EPROM device (containing the program code). The 80C188 is 100% PC code compatible, which allows code, in our case Borland C, to be developed and compiled on a host PC, downloaded onto the SCIM88 card and then debugged using Arcom's *SourceVIEW* [4], a source-level remote debugger and "ROMing" environment which is powerful and easy to use.

4.3 CSS crate signal processing

A major benefit of the hardware implementation of the *ARCOM* range of Eurocard STEbus cards is the ease with which they can be mixed with other cards made specifically for the application. The signal processing, filtering and sampling of the divider outputs is done on

one non-*ARCOM* eurocard and the converter drive level is generated on another. These additional cards do not share the STEbus but are mounted alongside the *ARCOM* cards and are interconnected with ribbon cables.

4.4 EHT Control CSS Software

This software consists of a "round robin" infinite loop which decodes commands arriving from the main control system and actions them via the local application mapping database and equipment and module handlers (hardware access routines).

The Application Software developed for the converter CSS System can be divided into three sections. The first is the local database containing all the necessary software and hardware parameters required to control each channel, the information for which is created by the ISIS Control System and downloaded into the destination STEbus System. The second is the CSS "kernel" which handles the ISIS Ethernet packet protocol decoding; downloading of the database from the Digital workstations; handling of commands to change channel values; update of read values in the database and the calling of various card and equipment handlers required to control the equipment connected to the system. The third is the STEbus I/O card and equipment handlers called by the main control software.

The main control parameters (corresponding to database channels) which are mapped to the application database for the EHT system are as shown in Table 1.

PARAMETER	CARD
Read EHT divider outputs Read EHT current Read converter drive level Set EHT voltage	14-bit ADC/DAC card
Read number of breakdowns Read converter status Reset number of breakdowns Reset converter status	Digital I/O card
Set ADC read time	ISIS Timing card

Table 1: Control Parameters

When the converter CSS control software is not receiving commands, from a Digital workstation, to change one of the above parameters the local control software performs the supervisory role of continuously updating all of the database READ channels and monitoring the Ethernet for incoming data packets. A piece of code called the reader running on a Digital workstation automatically sends a data packet at two second intervals requesting the return of the STEbus system channel values. The values returned are displayed on a Vsystem GUI (control screen).

A command can be sent, for example, to set the EHT via the Vsystem GUI by typing a new value or moving a slider with the mouse. An Ethernet packet is compiled containing, among other things, the new set value, database channel number and destination Ethernet address. The packet is received and decoded by the CSS software and the database channel containing the EHT value updated with the new value. The database channel contains all the necessary information to select the required software handler, via a software switch, to access the EHT demand DAC.

5 COMMISSIONING

In normal operation, there are several EHT breakdowns each day across the pre-injector accelerating column. The resultant transient electromagnetic disturbances have often caused malfunctions of, and even damage to, adjacent electronic equipment. There were initial concerns about the vulnerability of the solid-state electronics of the STEbus crate, controller and the Power Converter to this interference. The system was therefore installed giving careful consideration to the shielding and routing of cables to minimise the areas of enclosed loops. The converter output transformer, actually positioned in the EHT area, has an effective interwinding screen. Bulkhead co-axial feedthroughs were used for all signal connections through the screen of the EHT area. Transient voltage suppressors and appropriate filtering were used on all system inputs. The system has, at the time of writing, been in continuous use for eight months without damage or significant misbehaviour. The standard deviation of the continuously-monitored EHT voltage is normally less than 100V. The STEbus firmware has required no manual re-initialising despite there being no implementation of a "watchdog" timer facility.

The combination of the new ISIS Controls System, CSS, Arcom's hardware and development software, and an increasing range of card and equipment handlers enables the rapid development of inexpensive, powerful, robust and reliable solutions to SCADA type accelerator controls. The ISIS Controls Group investment in this system is now at least 10 staff-years and the cost of the hardware for a single crate CSS application is typically £2000-3000, depending on the type and number of application cards required.

REFERENCES

[1] Magnus Power Ltd, 29-30 Brunel Rd, St Leonards-on-Sea, East Sussex, TN38 9RT, U.K.

[2] "The Controls Standard STEbus - CSS" Ver 2.0 CLRC 1997. - available from the authors.

[3] http://www.vista-control.com.

[4] Eurocard PC Catalogue. Arcom Controls Systems Ltd, Units 8-10, Clifton Rd, Cambridge, CB1 4WH, U.K.