AN UNINTERRUPTIBLE POWER SUPPLY FOR THE SRS

S A Griffiths, D E Poole,
CLRC Daresbury Laboratory, Warrington, WA4 4AD, UK

Abstract

The deterioration in the commercial electricity supply to the SRS in recent years has led to the recovery time from short mains interruptions becoming the major cause of beam loss. Two uninterruptible power supplies, operating in conjunction with diesel generator sets, have been introduced to reduce the downtime. This paper describes the design, installation and early operating experience of the system.

1 INTRODUCTION

The Synchrotron Radiation Source (SRS) is the UK's only dedicated source of high energy synchrotron radiation. It is required to run 24 hours a day and deliver approximately 7000 hours of beam time every year. To maintain this stringent duty cycle and achieve operating efficiencies of over 90%, it is important to identify potential causes of problems. The SRS performance figures for the period April 95 to March 96 recorded the fault analysis figures shown in Table.1, and highlighted the major cause of beam loss.

Table 1: Fault Analysis Figures.

Category	Hours Lost	% Hours lost
Mains dips	128	38
Magnet Power	35	10.4
RF system	29	8.6
Others (15)	145	43
Total	**337**	**100**

The reliability of the site electricity supply has decreased in recent years and mains interruptions typically 0.1 to 2 seconds have become the major cause of down-time. The 128 hours of lost beam time equates to an average down-time per mains interruption of 10 hours. These fault analysis statistics prove conclusively that the facility would benefit from uninterruptible power.

The overall SRS power consumption is approximately 3MW, so for financial and practical reasons it is not feasible to support the entire facility. To obtain the best improvement in recovery time for the minimum capital cost, uninterruptible power is provided to everything except the magnet power converters, RF system and helium refrigeration. This will not retain the stored beam, but allows the SRS hardware and instrumentation to be reset in a controlled manner, thus reducing down-time to that of a normal refill, approximately 45 minutes.

At the heart of the system are two 300kVA Uninterruptible Power Supplies (UPS) of the continuous on-line type. A basic connection diagram of one UPS is shown in Figure 1. If a total mains failure occurs the load is supplied by the UPS from banks of lead acid batteries for a minimum of six minutes. The scheme also includes two diesel generator sets, which have been on site for many years but rarely used. Their function is to operate after a mains interruption longer than 30 seconds and to prevent further discharging of the batteries.

The switching between the commercial mains supply and the diesel generator set is provided by a changeover contactor. The overall system is controlled by a Programmable Logic Controller (PLC).

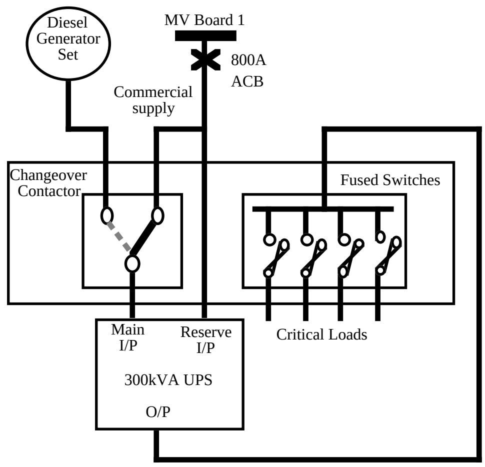

Figure 1: UPS Connection Diagram

To enable the UPS to feed the critical loads the medium voltage site distribution network was re-organised. These changes meant that one UPS could support the SRS Storage Ring and Beamlines, while the other supplies the Linac, Booster and Computer Hall. The entire air conditioning associated with the Computer Hall could not be maintained and prolonged mains interruption may have caused the computers to trip on over temperature. To avoid this a monitoring facility was provided enabling a controlled shutdown in case of over temperature or diesel start faults.

2 UPS SYSTEM

2.1 General

An Uninterruptible Power Supply should provide clean and stable power irrespective of the condition of the commercial mains. There are two main types of UPS system, a Static Inverter system or Rotary system. Rotary systems provide some advantages such as high efficiency and full isolation. On the negative side is their cost and they are only available for high kVA ratings. The Static Inverter offers much lower cost, a greater kVA range and is much smaller and easier to install.

There are three categories of static inverter each designed for a particular applications. The continuous on-line model was chosen for this project as it provides full isolation from the source and can account for all mains disturbances.

2.2 Specification

When specifying the UPS it was important to ascertain the actual three phase currents drawn by the load and their power factor. It is normal for the rating of a UPS to be given in kVA with a 0.8 power factor (p.f). A 300kVA UPS allows a maximum output current of 417 Amps. If however the load had a unity power factor, this would have de-rated the UPS to a maximum current of 334 Amps. To optimise the size of UPS it was necessary to balance the load wherever possible and to use the highest phase current measured.

A record of the harmonics in the load current were provided in the specification as UPS have restrictions on the permitted levels. Most UPS designs have a facility to measure the harmonic content of the load. The Crest Factor is one method used, which is determined by the peak output current divided by the rms value. If this exceeds a value of three, the UPS is protected by de-rating the output.

When the original specification was issued the only constraint imposed on the batteries was that the hold-up time be the shortest standard rating because of the inclusion of the diesel generator. Inevitably a considerable variety in the size and quality of battery was offered.

To allow a fair comparison tenderers were asked to offer a battery conforming to BS6290 Part 4 with a specific hold-up time. The British Standard specifies the material, design and performance requirements for stationery cells and batteries comprising lead-acid units of the valve regulated type, having an intended design life of at least 10 years. The valve regulated type is a unit which under normal operating conditions reconstitutes the products of electrolysis and is fitted with a pressure release valve. This type of battery can apparently expect a 10 year design life to last 7 to 8 years because they do not operate under normal laboratory test conditions in a UPS.

Care must be taken when a battery is offered as to BS6290 Part 4; this does not necessarily mean it is tested and certified to conform to the British Standard. During this tender exercise companies offered batteries to the British Standard but they had not been certified and were a cheaper alternative.

To allow a fair evaluation of the tenders the expected outlay over an defined operating period (e.g. over 10 years) was calculated. This included servicing, battery replacement and power to feed the internal losses. The higher the system efficiency the lower the premium paid in electricity costs. A 5% difference in efficiency on a 300 kVA UPS amounts to 105 MWhr per year.

Some companies offered a remote monitoring service which meant they maintain responsibility for the UPS system; the cost varied with the response time required and this was included in the evaluation.

2.3 Operation

The uninterruptible power supply chosen for this project was EDP 90 from Chloride Power Electronics, shown in Figure 2. This continuous on-line UPS converts the commercial AC source into DC power by a 12 pulse rectifier configuration, composed of 2 six pulse rectifiers phase shifted by 30 degrees. The DC output from the rectifier is used to maintain the batteries in a fully charged condition and supply power to the inverter. The inverter then converts the DC source into clean and regulated AC power, which is supplied to the critical load through the static transfer switch.

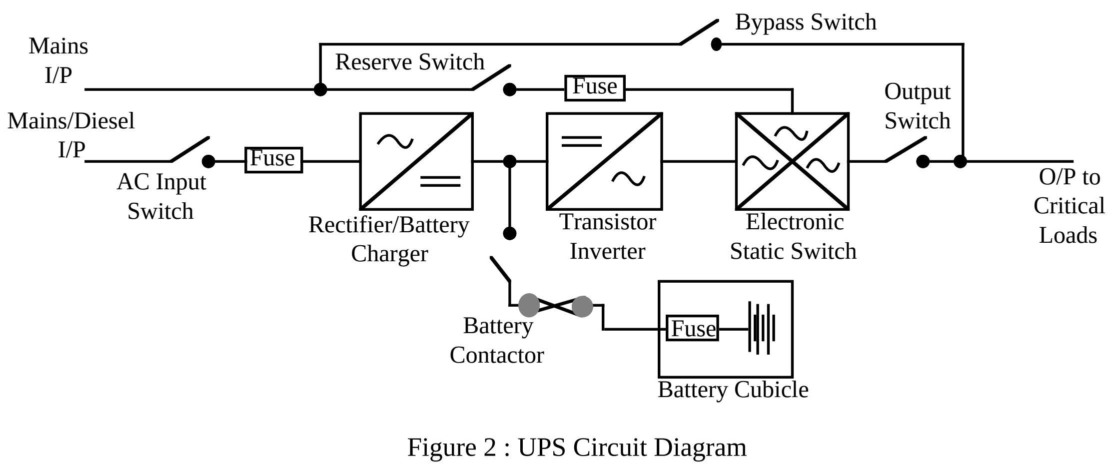

Figure 2 : UPS Circuit Diagram

The static switch monitors and ensures that the inverter tracks the reserve supply frequency. This means the output will be synchronised to the mains in steady-state conditions.

When the commercial supply is interrupted, the internal batteries sustain the power to the inverter until either the mains returns or the Diesel generator operates. If the Diesel fails to start then the mains must return within 6 minutes on maximum load before UPS shutdown occurs. In the event of this happening the battery contactor will be opened and a clean break achieved.

Monitoring of the two UPS is provided by remote alarm units situated in the SRS control room; additional information is supplied to the SRS control system from the PLC, giving the overall system condition.

When reorganising the medium voltage distribution network a useful feature included was the ability to transfer the load from the UPS to a direct mains feed. This allows complete isolation of the UPS and associated switchgear for maintenance and repair.

3 DIESEL GENERATOR SETS

The purpose of a diesel generator set is to prevent prolonged periods where essential equipment is left without mains. They cannot provide a continuous no-break supply, as a delay of approximately 15 seconds is necessary for the alternator to achieve normal operating speed and output voltage levels. To include the two diesel generators currently on site, extensive modifications were required to the circuit design to enable PLC control.

The alternator ratings for the diesel generator sets are 416kVA and 400kVA at 0.8 p.f. The maximum permitted input demand for the UPS is 322kVA float and 402kVA with battery recharge. With the ratings of the alternator output and the UPS input so close, the PLC disables the battery charger while the generator sets are operational.

It is a significant factor that many UPS systems cause mains pollution, generally due to the use of thyristor controlled rectifiers in the AC/DC conversion stage. To avoid de-rating of the alternator, a UPS with a 12 pulse rectifier and an input resonance filter was chosen. This reduced the total harmonic distortion to only 5.8%.

The UPS also has a facility which loads the AC source gradually over a period of 10 seconds after the input is applied. This feature enables the governor to maintain the frequency of the generator to within the required ±5% tolerance.

4 SWITCHGEAR

The two switchboards consist of a changeover contactor, output fused switches and selected controls. The changeover contactor is mechanically and electrically interlocked to prevent closure of both contactors. The switchboard contains a phase failure relay to indicate the mains status to the PLC and input contacts to allow closure of the main and secondary contactors .

5 PROGRAMMABLE CONTROLLERS

A 16 I/O relay type PLC was the most suitable for this application. In developing the PLC program it was an advantage to use a state flow diagram. This provided a simple method of identifying all states (conditions) the system could adopt; any states not accounted for would have failed the system.

A brief explanation of the circuit operation (Figure 1) is as follows:

1. In normal operating conditions the main contactor is closed and the commercial mains feeds the UPS.
2. If a mains interruption longer than 30 seconds occurs the PLC produces a diesel start signal and opens the main contactor.
3. When the alternator achieves the required voltage level the output is applied to the changeover switch. A secondary contactor will close automatically when volts are supplied to its input terminals.
4. Once the generator is running it is operated for a minimum of 5 min before checking whether the mains is healthy again. This allows the generator to reach its normal operating temperature as recommended by the manufacturer.
5. When the mains supply has been stable for 1 minute the PLC stops the generator automatically and returns the system to its normal operating condition.

Designed into the PLC program were some special features. These included a controller disable function, which holds the outputs in a designated state to allow maintenance on the diesel generator sets. There is also a facility for simulating a mains failure, enabling the load to be transferred from the mains to the UPS and then to the diesel generator.

6 CONCLUSION

The UPS system has now been operational since February 1996; during this time there has been one mains interruption. The UPS operated successfully with the batteries sustaining the load.

It is anticipated that the down-time of the SRS will be reduced by a factor of between 5 and 10, but a true representation of the benefits gained can only be gauged over a much longer period.

7 ACKNOWLEDGEMENTS

We would like to thank the following people for their help in the installation and commissioning of the project: J. Towers, S. Hands and M. Heron.