OPTIMISATION OF ELECTRICAL AND INSTRUMENTATION DESIGN FOR THE DIAMOND LIGHT SOURCE DDBA UPGRADE

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Abstract

In planning the upgrade of one cell of the Diamond Storage Ring, the DDBA upgrade, it was evident that the electrical installation and commissioning would contribute a significant component of the overall installation time. Given the pressures to minimise the shutdown length, the electrical and instrumentation design was optimised for time effective installation and commissioning. This paper outlines the electrical and instrumentation design for DDBA; explores the installation time determining issues and how these were addressed; and reports on the lessons learnt from the actual installation and commissioning process.

INTRODUCTION

The concept of converting one cell of the Diamond light source storage ring from a double bend achromat (DBA) structure to a double-DBA or "DDBA" structure has been described previously [1]. The motivation for the DDBA project was to create a new straight section where an in-vacuum insertion device can be located, since all other straights in the Storage Ring are occupied. See Fig. 1.

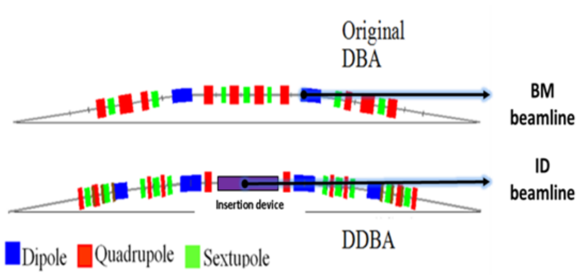

Figure 1: Schematic diagram of the existing DBA cell and the modified DDBA cell.

Diamond light source delivers 5000 hour of operations a year, with many beamline stations heavily oversubscribed. As a result in planning for the DDBA installation, minimising the required shutdown length was a key requirement. The installation shutdown length was largely a function of mechanical and electrical installation tasks. The former, involving by the removal of the three DBA arc girders and the replacement with two new DDBA arc girders and a new straight section, is dealt with in [2]. The latter, in terms of electrical design, and installation, is considered in this paper.

The lessons learnt from the electrical aspects of the DDBA project potentially have relevance for light sources, including Diamond [3], that are planning a major upgrade involving replacement of the storage ring.

DDBA ELECTRICAL REQUIREMENTS

The DDBA installation involved removing three DBA girders consisting of 2 dipoles, 10 quadrupoles and 7 sextupoles, 14 steerers 4 skew quadrupoles, 7 electron BPMs, 42 vacuum instruments, 15 axes of girder alignment and thermal monitoring and machine protection. They were replaced with two DDBA girders consisting of 4 dipoles, 10 quadrupoles and 10 sextupoles and 24 steerers 6 skew quadrupoles, 8 electron BPMs, 26 vacuum instruments, 10 axis girder alignment and thermal monitoring and machine protection. All electrical circuits, except dipole, were cabled via four layers of cable tray and three trenches to the instrumentation (power supplies, vacuum gauge controllers, ion pump supplies, PLCs, etc.) located in a Control Instrumentation Area (CIA) dedicated to that cell. While the total number of circuits did not change significantly the location of components within the cell did change and the cable routes also had to change because the original three cable trenches were reduced to two as part of providing floor space for the new insertion device. In addition, the cabling associated with the already installed insertion device and the photon front-end traversed the same cable routes. So while in terms of the number of circuits, the old and new installations were very comparable, it was not practical to reuse the existing cables for reasons of installation time and logistics. Initially we proposed to retain a minimum number of the existing cables and rerun a majority of new cables but the estimate of 16 weeks for this work, during the DDBA installation shutdown, was rejected as being too long and another solution had to be found.

To minimise the shutdown installation time it was proposed to install temporary new cables, via a different route, to the equipment on the existing DBA cell. This then meant that the existing cables and cable routes could then be reorganised, and new permanent cables installed prior to the DDBA shutdown. To speed up the DDBA girder installation it was decided to fit plugs and sockets on the girder so that electrical connections could be made rapidly, leaving the space around the DDBA cell available for other work during the DDBA installation shutdown. The result of this was that the electrical contribution the DDBA shutdown was reduced to 4 weeks, mostly in the CIA outside the tunnel with less than 1 week working in the Storage Ring tunnel.

Figure 2: Temporary cables connected to existing DBA cell.

ELECTRICAL DESIGN FOR INSTALLATION

In undertaking the electrical design it was decided to apply connectors to all circuits, except the dipoles and electron BPMs as part of minimising installation time. The plugs and sockets were grouped together on connector panels, Fig 2., attached to the girder, with trays to manage the cables to devices also mounted on the girders. The connector panels used HARTING high current connectors [4] for magnet connections and junction boxes for Machine Protection System (MPS) and other instrumentation signals – temperature sensors and water flow switch contacts. To help cable installation, of the in-tunnel-cables, copies of the on girder connector panels were used to accurately terminate the large cables.

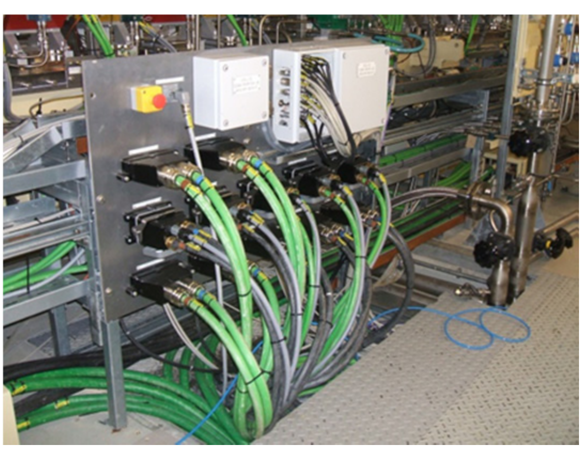

Figure 3: DDBA girder connector panels.

To minimise the number of individual MPS circuits cabled out of the tunnel, they were divided into two types: those which could trip the synchrotron, which were wired directly back to the MPS rack outside the Storage Ring in the CIA and those that were non-tripping signals which were connected to PLC Remote I/O modules located in the tunnel on the girders. To find out if radiation from the Storage Ring would affect the in tunnel Remote I/O module, they were tested for a year before the DDBA shutdown with no recorded faults.

The dipoles are connected in series round the Storage Ring using eight single core cables of 400mm^2 cross sectional area. Given the constraints on handling such cables in confined spaces and to introduce two new dipoles to the circuit, and connect them quickly while other work was going on around them, a high current connector block was designed. The dipole current of 1400A is not uncommon in distribution systems and so bus bar of this rating was easily obtainable. Short lengths of bus bar were spaced apart using custom made insulators and a cover provided. Four connector blocks were installed months before the DDBA shutdown; two used for DBA dipoles the other two fitted with links until needed. Smaller cables, 240mm^2 were used for the links from the connector blocks to the dipoles. They were made to the correct length as part of the girder build programme.

CABLE INSTALLATIONS PROCESS

Based on the accepted benefits of using temporary cables to minimise the shutdown length the installation plan became:

1. Install temporary cables.

2. Disconnect the original cables and connect temporary cables.
3. Re-commission on temporary cables.
4. Remove the original cables.
5. Install temporary connector panels and new cables and test.
6. Build a cable assembly onto each new DDBA Girder and test.
7. Remove original girders.
8. Place DDBA girders connect and test.

As Diamond is an operational facility the activities 1 to 5 above had to be fitted into pre-programmed shutdown periods which meant that to achieve an October 2016 DDBA shutdown date, temporary cabling work had to commence in February 2014. Twelve shutdown periods were used for the work with preparatory work being done during running periods.

The temporary cabling turned out to be a major piece of work with 40km of cable, two cable bridges across the walkway inside the storage ring and specially made cable supports above the girders being called for. See Fig. 3. Once installed, operation of the exiting DBA cell was transferred to the temporary cables and removal of the original cable started. It then took a team of 12 people 15 weeks to the remove the old cables and replace them with cable for the new DDBA cell. In doing so, they were terminated to temporary connector panels that mimicked the final location of the connector panels for the new DDBA girders. Cables were prepared for termination to the instrument electronics at the CIA end.

INSTRUMENTATION SPACE

As a consequence of DDBA cell an additional insertion device would be inserted into the Storage Ring and the DBBA cell required additional magnet power supplies (Trim winding on Dipoles, Sextupoles, and Steerers) necessitating space for additional instrumentation racks in the CIA. In addition to the space requirement for new equipment there was also a requirement to maintain operation of the existing system while introducing new equipment thereby allowing the possibility of reverting back to the DBA cell if the DDBA upgrade failed for any reason. To accommodate the space constraints the follow changes were undertaken:

- Replaced control racks for the existing photon front-end and insertion device with updated technology, so reducing the space required from four racks to two.
- Extended the CIA, to provide space for four new racks.
- Rebuilt the vacuum control racks, thereby reducing the space from three racks to two.
- Built new Machine Protection System sub-rack to swap with the existing unit.
- Temporarily located photon front-end and insertion device racks outside the CIA.

CONCLUSIONS

By carefully designing cable routes and the sequence of operations, using temporary cables and a lengthy preparatory phase, it was possible to achieve the stated objective of reducing the DDBA shutdown length to eight weeks overall; with electrical aspects contributing four weeks. In doing so, the cost associated with the temporary cable and their installation were significantly less the value of the additional beam time from being able to run the facility for an additional 12 weeks. Most importantly it supported the needs of Diamond's user community in terms of access to synchrotron radiation.

Nevertheless the work on installing and switching over to temporary cable was non-trivial and ran for a period of more than two years before the actual DDBA installation. In doing so it did not have any detrimental effects on operational reliability of the facility.

REFERENCES

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