Implementation of a Device Circuit and Conductor Routing Analysis Database at Point Lepreau Generating Station

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Abstract

As a result of the Fire Probabilistic Safety Assessment performed in support of the refurbishment of the Point Lepreau Generating Station, all room locations for cables and conductors connected to safety significant devices were required to be identified. It was originally estimated that manual identification of these cable locations could take up to 100 man-years. Using a device circuit and routing analysis program, the room locations of these safety significant cables and conductors were determined in a fraction of that time. This paper describes the methodologies used, and the difficulties encountered, during the design and implementation of this program.

1. Introduction

The primary objective of this project was to define all cable and conductor routings from the power source, control or instrumentation device to each end device. This was required for all devices of importance to the fire Probabilistic Safety Assessment (PSA[1]) conducted at the Point Lepreau Generating Station (PLGS) in support of refurbishment. In particular, the locations of all devices, trays, cables and conductors in each cable route of a device circuit were defined through the use of a cable and conductor routing analysis program developed by Atlantic Nuclear Services Limited (ANSL). This analysis program was used in conjunction with the Device Installation and CONnection (DICON) and Atomic Energy of Canada Ltd. (AECL) Integrated Electrical and Control (IntEC) databases in use at PLGS, fire hazard assessment data, and various other sources of information such as general arrangement diagrams and walkdown reports.

2. Background

Prior to March of 2004, electrical wiring records at the Point Lepreau Generating Station were stored in the Fuel Handling department's DICON database. DICON is a non-relational legacy database used to store cable, device and wiring information. Printed reports, and later digital reports, were transmitted to users to allow them to manually trace device and cable location and routing information throughout the plant. It was a carefully planned and managed database that served PLGS throughout the construction and commissioning phases, on into 2004, at which point the DICON database was retired and replaced by the AECL IntEC relational database. The

[1] Appendix A contains a list of acronyms used in the report.

DICON data was subsequently normalized and imported into IntEC, which now maintains the PLGS equipment and wiring records.

Each device at the PLGS plant falls under a Basic Subject Index (BSI) category. Identifiers embedded in the device's name tag determine the category. A list of BSI's that have an impact on safety was compiled as a component of a preliminary fire PSA report conducted at PLGS. As a result of this preliminary report, it was determined that the circuits, and cable and conductor routing for all end devices belonging to those BSI categories needed to be analysed to ascertain the cable room locations, for use as input to the final Fire PSA report. However, only the cable endpoints were known, as the main electrical wiring database, DICON, had not been designed to track each room through which a cable was routed.

In 2004, a device circuit and conductor routing analysis program was designed by ANSL to determine the cable and conductor room locations using data extracted from the DICON database. This would allow the device circuit routing to be traced for all those devices with a BSI having an impact on fire safety. At this time, the data was extracted from the DICON database and imported into the newly developed analysis program.

Importing the legacy data into a relational database created several issues which needed to be resolved before the cable routing could be performed reliably using the analysis program. One major issue was that many of the routes compiled by the program were found to terminate prematurely at intermediary devices such as Junction Boxes, Distribution Frameworks and Panels due to formatting inconsistencies in the naming conventions of the data stored in DICON. During the initial construction phase at PLGS, DICON had been used to track records inputted by a number of different groups. Although each group followed their own set of design guides in accordance with stringent Quality Assurance (QA) requirements, there existed differences in the naming conventions used by each group. These differences had been inconsequential to users tracing the circuits manually; however, the differences were significant from a relational database development point of view.

After the PLGS DICON data had been moved to the IntEC database, a project was undertaken by ANSL to compare circuit and route analysis results based on the data stored in the IntEC database to those circuits and routes previously determined using the DICON data, and to assess any reduction in work that could be achieved using the IntEC data. As a result of the IntEC upgrade there were several improvements made to the quality of the data that had been stored in DICON. In particular:

- During the process of normalizing the DICON data to fit into the IntEC database structure, data from the various input groups had been merged into single records, removing or rectifying many of the formatting issues which had caused the device circuit and cable route analysis process to fail. Data that had been duplicated between the various construction groups had been merged into a single common set of data. This allowed the code to be simplified, resulting in an improvement in the analysis program's execution time.

- Dummy data records created either during the initial implementation of the database, or while training new users, had been removed from the database. PLGS users typically did not see this data as it was filtered out from the available DICON reports, so a number of these records had accumulated in the database over the past 25 years.

- All inactive or historical data had been removed from IntEC. Although this had been useful to plant personnel, the many extra tens of thousands of records slowed the cable routing analysis process. Removal of these records reduced the analysis time significantly.

- Many fields in DICON were not ‘required’ fields with the result that for some records, information had been stored as text in the record’s description field instead of in the appropriate field location in the record. These empty or incomplete fields were now required fields in IntEC, and had to be filled in prior to the data transfer.

- Device BSI’s and device types had been extracted from the device names or tags into separate fields. Originally, when working with the data stored in DICON, the device type and BSI data had to be extracted through code, which was time consuming and not 100% accurate due to the data inconsistencies. Having this data error checked and the results stored in a separate field in IntEC helped to standardize and facilitate the building of relationships, and the analysis of the device circuits and cable routes.

- IntEC has available a separate “signal type” field that defines whether a cable carries a power or a control signal. This information was often not available in DICON and when it was, it had to be extracted through code from the channel information fields.

Despite the improvements to the data now stored in IntEC, the IntEC program had not been designed to programmatically trace all of the cable room locations for each device circuit, and the ANSL device circuit and conductor routing database was still required to trace the device circuit information now stored in IntEC.

It was decided at this point to undertake a new project to address the remaining routing issues using a current copy of IntEC data to take advantage of these data improvements.

3. Overview of device circuit and cable route analysis process

PLGS design services staff currently use a combination of IntEC records and drawing analysis to determine device and cable routing in the plant. Originally, DICON records had been distributed to PLGS staff as paper reports, and later in a .pdf file format viewed using Acrobat Reader. Connections were traced manually by searching through DICON reports for the device currently being scrutinised. When the device was found, it listed each cable, conductor, or individual wire attached to that device, and the cable route, if any, that those cables and conductors followed to their destination. Using reports based on the route information, the user could then determine the applicable trays report which would then give details such as General Arrangement (GA) and Elementary Drawing (ED) numbers which would allow the users to determine the room location of the trays, cables and conductors in the circuit.

This manual iteration to trace a circuit for a particular component can be extremely time consuming. Each cable route between any two devices can take up to 15 minutes for an experienced person to trace. Considering a device circuit can have any number of cable routes, it can take over an hour or more to manually trace all of the cable routes associated with a single device circuit. There are several thousand devices defined for the BSI's and rooms required by the Fire PSA project, and each device has on average approximately three terminals which could in turn branch multiple times into several different routes. PLGS staff had originally estimated that finalizing the device circuit and cable routing analysis for this list of devices could take up to 100 man-years to accomplish. It was therefore decided that the only practical methodology for this analysis would involve determining the circuits programmatically through database analysis.

The IntEC database allows users to electronically view cable, conductor, device, and tray connection data. Limitations exist with this system however, since, if the circuit data in IntEC is formatted inconsistently from one device to the next as is often the case with the data transferred from DICON, the users must still manually trace the circuit using diagrams. The device circuit and cable routing analysis program was therefore used to programmatically determine the device circuit and cable and conductor routing for all devices having a BSI in the lists provided from the fire probability safety assessment. This analysis provides the entire device and cable routing for the circuit from the power source and any control or instrumentation devices to the end device for each of the devices in the list. The program will also determine the rooms and tray locations for each of the cables in the routes.

The device circuits and cable routes in the analysis program were determined using the process described below:

- Device "tags" consist of a System BSI, device type acronym, and user assigned qualifier merged together into one field. Those devices having a BSI from the AECL BSI list in their tag were identified and filtered.

- These devices were then filtered again to remove devices not considered to be of importance to the fire PSA. This included non-functional or intermediate devices such as Junction Boxes, Sockets and Plugs.

- The program logic in the analysis database examines each device in the filtered device list individually, then copies the analysed information into a new database table. Connection points on those devices are then stepped through one by one, and the cables, conductors and wires attached to those points are listed. Any devices connected to the opposite end of those cables are then copied into the new table in sequence along with their attached cables, conductors and wires. This process is then repeated sequentially for each device that is connected to the previous devices. The analysis is terminated whenever a functional terminal device, or 'not connected', spare, ground, or shield cable, conductor or wire is reached.

- The cable routes found in the step above are then analysed and the route-tray sequence plotted. For each route, the sequence of trays in the route is then copied to a new table in order of occurrence.

- Based on the sequence of trays, the location of the cables within the tray, and the tray locations within every room, as taken from the available Fire Hazard Assessment data, walkdown information, and analysed tray diagrams, it is now possible for the program to determine the rooms that each cable route passes through. This room information is then saved in sequence in the order of occurrence.

- Reports are then used to merge all of the information compiled in the previous steps (The report example in Appendix B illustrates a single conductor route from motor 2165-M1 to main control centre 5430-MCC01).

This analysis report also provides an explanation of the data issues and inconsistencies encountered in the creation of this program, and how these issues were rectified.

4. Data sources

The information used in the device circuit and cable routing analysis was compiled from multiple data sources documented as follows:

- The original BSI category list was generated during the PLGS fire hazard assessment and probabilistic safety assessments. It was also determined that some BSI's were stored in multiple formats within the database (i.e.: BSI 5750 is equivalent to 57500, and the instrumentation BSI would be 65750), and code was written into the database to add any equivalent BSI numbers missing from the BSI lists.

- For the initial device circuit and cable and conductor routing analysis performed in 2004, a flat-file copy of the DICON data was provided. For subsequent analyses, the data stored in IntEC was exported to flat files by ANSL staff for importing into the routing analysis database.

- The Point Lepreau Refurbishment Probability Safety Assessment group at AECL provided the list of devices to be used as starting devices for the device circuit and cable and conductor route analysis.

- Numerous analyses of tray locations within a room had been performed over the course of the project. These included a tray by tray analysis using the PLGS cable tray general arrangement and routing drawings to locate and confirm the routes. The cable tray routes that could not be confirmed using the drawings were subsequently walked down during plant outages and incorporated into the ANSL cable routing analysis database.

5. Methodology

ANSL staff had recognised from the start of the project that coupling the DICON/IntEC database data with the available fire hazard assessment data that identifies cable trays and the rooms in which they are located, would provide them with the ability to list the room locations of cables and trays. This coupling was necessary since neither DICON nor IntEC track cable data in terms of their room locations; they only identify cable endpoint rooms and the cable tray locations.

All of the data sources listed in Section 4 above were tracked in different file and database formats by their originators. Upon receipt, all data sources were converted and imported into a common database to enable advanced querying and data linking methods.

Table and field names in the new database analysis program were changed to reflect the names in use in DICON, for comparison purposes. Data field types were set, and relationships created among the various tables. Further modifications were performed to allow the IntEC data to be imported, as the data format was significantly different than what was used in DICON. The data was checked extensively for errors and old test or 'dummy' records throughout the course of the development of the program.

The program was written recursively, using multiple database queries to determine the device circuits and routes by looping through and identifying each cable connection to each device defined in the BSI list. The analysis continues from device to device until the signal terminates, similar to the manual process. As branches in the circuit are found, the cable routing of each branch is processed and saved until the end device is reached, then the next branch is followed, and the process repeated. This sequence would continue until all cable routing branches in the circuit had been followed. The program effectively accounts for and returns every branch as a new device cable routing.

The following three subsections summarize the procedures used in the database to determine the device circuit and conductor routing.

5.1 Routing procedure - step 1

a) Device, cable, routing and tray data were extracted from the DICON legacy database, and subsequently, the IntEC SQL server system. This, and other data such as the fire hazard assessment tables, was imported into the device circuit and conductor routing database, fields were trimmed of empty spaces and renamed to match existing field names in the database, and relationships and queries were created.

b) All of the archaic DICON hierarchical system of records and the majority of the dummy and test records and fields with null data were removed during the transfer of data from DICON to IntEC, enabling several steps of data cleanup to be skipped in the final versions of the database.

c) Device lists were created based on the BSI category list supplied by the Probability Safety Assessment group at AECL.

d) A starting device list was created based on the list of device types pertinent to the fire PSA. The device circuit and cable routing analysis was executed on a group of ANSL computers over a period of several days. Analysis continues from device to device and all of the particulars such as cable, route, wire, conductors, and any branches off of the main circuit are all saved, until one of the following criteria are met:

    1) The first functional device is reached, this includes among others:

i) A panel with a BSI category of 54**, 56**, 53** is considered a power panel and the route can be considered to be terminating correctly at a functional device.

ii) Panels with a fuse as a terminal (FU**) can also be considered to be terminating correctly.

iii) Panels with BSI 58** are ground or shielding panels

2) The first spare, ground, float, or shield conductor, terminal, or wire is reached; this includes:

i) If a connection is only connected at one end, analysis is halted.

ii) If a connection has a wire number denoted spare, shield, ground or float, then all devices and connections with that wire number are considered to be the same, and route analysis is halted

iii) “JT” type devices are considered to be a BUS by PLGS staff and are always Ground, Shield or Power type connections.

iv) According to PLGS staff there should be no internal conductors in the Distribution Framework not tracked in DICON/IntEC, so if the route ends at a DF type device it is always a spare.

v) Routing is terminated when an “NC” or “Not Connected” type terminal is reached for Main Control Centre, Junction Box, Junction Socket, or other types of devices. If the “NC” terminal is connected to a switch type device, routing is allowed to continue as the “NC” in this instance refers to “Normally Closed”.

3) Otherwise:

i) If a route ends at a panel that is not electrical (BSI 5****) then the wiring is as supplied by vendor and should be checked manually to confirm

ii) Terminal Blocks in a panel can be considered to be terminating as per design since the wiring of the panel was done by an external company and the connections are not available in DICON/IntEC.

iii) Terminal Blocks found to be connected to an end device such as a pump means that the pump was supplied on a skid attached to several other devices, which were all wired internally by the manufacturer.

e) Upon completion of the database analysis, comparisons were made between the circuits and routes generated by the database, and a number of manual verification results performed for the purposes of verification, and no significant differences were found.

5.2 Routing procedure - step 2

Step 2 of the circuit and route analysis procedure examined each of the cable routes found in the previous step. Based on the route data, the procedure determines what trays encompass that particular route and the sequence in which they occur.

5.3 Routing procedure - step 3

Step 3 determines what rooms that the trays, cables and conductors pass through. To accurately gauge cable location within a room, the analysis database must compare the cable-tray information from step two to the tray-room analysis data available from the fire hazard assessment, diagram analysis and subsequent walkdowns. That is to say we need to know at what section the tray enters the room and at what section it leaves the room. For example, if a room XXX contains a tray going from position '20' to position '40', and a cable in the circuit being analysed is in the same tray from position '0' to '30', then we can determine that the cable begins outside of our room, passes approximately 10 feet into room XXX, and either goes on to another tray, is run-to-suit (short runs of cable not in a tray), or it terminates in room XXX.

6. Program verification

To verify the analysis program code and to ensure there were no errors made in the writing of the code, a number of random devices were selected upon which a manual analysis was performed. Two ANSL employees were trained to perform a manual device circuit and routing analysis using the same methods as those used by staff at Point Lepreau. The manual analysis method uses a different approach than the database method, involving a combination of plant elementary diagrams and DICON data reports.

The device circuits verified were a combination of fuel handling equipment, and instrumentation and control devices such as solenoid valves, limit switches, temperature transmitters, hand switches and pump motors. The manually generated circuits and routes were compared to the circuits and routes generated using the routing analysis database code.

These verification circuits were instrumental in determining many of the data formatting inconsistencies that had accumulated in DICON over the past 25 years of usage. These inconsistencies, in some cases, initially prevented the completion of the device circuit and routing analysis using the analysis database methods. There was also little or no internal error checking built into the DICON database to check for those formatting inconsistencies or for human errors such as typographical errors. For example, a user from one project group could do a search for a device record in the format they expected. If the record wasn't found, they could then add a new record that may have a slightly different format (i.e.: an extra dash) from a record for the same device that had been input by a user from a different project group. Given that there did exist some consistency between what the different project groups used for terminology, it was often possible to determine what record to expect when such an issue was encountered during the device circuit and routing analysis. For example, equivalency tables were created in the database to account for instances where a record pertaining to a device connection point of 1B1 may have a corresponding connection point 1B-A for the same device. The link between connection point 1B1 point 1B-A may be obvious to the eye (especially if the format continues where 1B2 = 1B-B, and 1C1 = 1C-A), but this logic needed to be replicated in the database to enable it to search and account for all instances where this occurred. Building this function into the program code allowed the analysis to continue even if the connection record formats were different or inconsistent. An example of this is available in the report in Appendix B. Logic was also incorporated into the database to link associated devices, so that if a cable route terminated at a Junction Plug (JP), for example, the database would search for a corresponding Junction Socket (JS) to allow the routing analysis to continue (i.e.: Device 57500-JP1 is understood to be connected to 57500-JS1).

These differences found during the initial comparisons made between the manual verification circuits and the circuits created by the analysis database enabled ANSL to modify and enhance the program to account for many of the data formatting discrepancies that had been transferred over to IntEC from DICON. Subsequent cable analysis reports created using the data stored in IntEC were compared back to the manual circuit and routing analysis with the result that all of the verification circuits for the devices selected were determined to be complete and correct. Further verification of the device circuits and cable routing was also performed by comparing the circuits and cable routes generated to General Arrangement (GA) routing drawings available at PLGS.

It was found that the code produced correct results where data was actually available and/or consistent within DICON and IntEC, and the verification circuits were determined to be complete from start to finish. Thus, within the limitations of the verification runs, the device circuit database code has been proven to produce nearly identical results, with the only differences occurring where changes to the data had been made when the DICON data was imported into the IntEC database.

7. Project analysis results

In the final cable routing analysis, out of a total of almost 80,000 routes analysed, only 11% of these routes were found to terminate at a non-functional end device. Of those 11%, the majority ended at internal or vendor supplied wiring which was never intended to be tracked in DICON or IntEC. A number of these routes were further analysed with the support of PLGS staff, and these cable/conductor routes were often found to terminate at a terminal block or junction socket to which vendor supplied and wired devices were connected. In addition, analysis of the circuits often showed the cable to be a spare, ground or shield conductor. For instance the routes that terminate at the Distribution Framework, an intermediary device, were all found to be spare conductors.

8. Conclusion

It was initially estimated by PLGS staff that it could take up to 100 man-years to perform manual circuit and cable routing analysis for all the devices at PLGS. Extracting circuit and cable routing information using a device circuit and conductor routing analysis database offered substantial improvements over performing the analysis using other methods. Extensive records have been generated providing device, cable, and route location information which is available as a series of reports in a database. Initially, the cable and conductor route analysis program could only analyse the data that existed in IntEC in expected formats. To account for this, the IntEC data was analysed for data inconsistencies and exceptions, and the program logic was modified to account for all data inconsistencies and exceptions encountered in the analysis and in the process of tracing the verification circuits. As a result, the routing analysis is more likely to continue until reaching a functional terminal device.

Analysis of the cable routing data has shown that although it may not be possible to determine all end devices in a device circuit at PLGS strictly by using database methods, the number of man-hours required to perform the manual work required has been reduced to a fraction of the work that would have been required had the device circuit and cable routing analysis database not been available.

Appendix A Acronym list

AECL	Atomic Energy of Canada Ltd.
AECL SJO	AECL Saint John Office
ANSL	Atlantic Nuclear Services Ltd.
BSI	Basic Subject Index
DF	Distribution Framework
DICON	Device Installation and CONnection
FHA	Fire Hazard Assessment
GA	General Arrangement drawing
IntEC	Integrated Electrical and Control database
JB	Junction Box
JP	Junction Plug
JS	Junction Socket
PLGS	Point Lepreau Generating Station
PLR	Point Lepreau Refurbishment
PSA	Probabilistic Safety Assessment
QA	Quality Assurance

Appendix B Device circuit and conductor routing analysis database report sample

PLGS Cable Routing - Complete Cable Routing for all Start Devices having a Cable in Selected Room(s)

RteID	Sequence	DevID	Device Tag	Location	Terminal	Branch / Conductor	Cable	Signal	Channel	Route	Tray Seq	Tray	TType	Tray Fr	Tray To	FHA Fr	FHA To	FHA Room	Confirmed Room
0	0	0	2165-M1	R107	A	RED	QC03	L	AL	40003	1	1	A	0	1				Run-to-suit
											2	4025	TL	3	73	0	13	R1-107	R1-107
											2	4025	TL	3	73	0	14	R1-107	R1-107
											2	4025	TL	3	73	13	29	R1-407	R1-407
											2	4025	TL	3	73	14	30	R1-407	R1-407
											2	4025	TL	3	73	29	73	R1-513	R1-513
											2	4025	TL	3	73	30	56	R1-513	R1-513
											2	4025	TL	3	73	56	73	R1-501	R1-501
											3	4051	TL	0	188	0	188	R1-501	R1-501
											4	1	A	0	4				Run-to-suit
											5	4007	TL	111	34	0	10	R1-010	
											5	4007	TL	111	34	10	51	R1-108	R1-108
											5	4007	TL	111	34	10	52	R1-108	R1-108
											5	4007	TL	111	34	52	68	R1-408	R1-408
											5	4007	TL	111	34	68	94	R1-509	R1-509
											5	4007	TL	111	34	68	111	R1-509	R1-509
											5	4007	TL	111	34	94	111	R1-501	R1-501
											6	4119	C	0	25	0	25	R1-108	R1-108
		1	5750-JB5001	R107	6F1														
																			Junction Box terminal modified to account for data discrepancies
		2	5750-JB5001	R107	6F-A	RD1	PF01	L	AL	50501	1	11	A	0	8				Run-to-suit
											2	10	A	0	9				Run-to-suit
											3	5409	TL	0	9	0	47	T1-501	T1-501
											4	5421	TL	0	7	0	64	T1-501	T1-501
											5	5415	TL	0	41	0	41	T1-501	T1-501
											6	5223	TL	0	70	0	13	S1-148	S1-148
											6	5223	TL	0	70	13	70	S1-146	S1-146
											7	1	A	0	1				Run-to-suit
											8	415	H	10	0				Penetration
											9	20	RS	0	10				Run-to-suit
		3	5430-MCC01/FA12B6	T601	FA1-T1														
																			Functional Device