August 20-21 FWHLC BWROG

Dresden
2015 FWLC Scrams &
2014 Turbine Trip due to MSDT LT failure

Dave Kijowski
Feedwater Heater System Engineer
Dresden Station

Exelon

2015 FWLC Scrams

Dresden Unit 2 Scrammed two times in one month due to a malfunction of the digital feedwater level control (FWLC) system.

2015 FWLC Scrams

System Description

The Feedwater Level Control (FWLC) is a digital system designed to control, either manual or automatically, the flow of feedwater into the reactor vessel to maintain vessel water level. The FWLC system is designed and provided by ABB/Bailey and most commonly referred to at Dresden as the “Bailey” FWLC system. This digital system is comprised of two Human-Machine Interfaces- the Operator Interface Station (OIS) and Engineering Work Station (EWS), several input/output (I/O) cards, and dual-redundant Multi-Function Processors (MFPs)

The MFPs are digital cards located in a control room panel. The MFP is the main processing component of the Bailey, receiving input from Feed Flow, Steam Flow, and Reactor Water Level. It then processes these inputs with necessary algorithms and configurations to provide output signals to:

- Feedwater Regulating Valves
- Reactor Recirc Pump Runback Control Logic (ASD)
- Alarms and System Indicators
- Reactor Feed Pump Automatic Start and Trip Logic

2015 FWLC Scrams

System Description

Upon FWLC system initialization the normal primary MFP is setup with dipswitch settings on the cards to be MFP 2-0640-32, and the normal backup on initialization MFP 2-0640-33. For our discussion MFP 2-0640-32 card is referred to as MFP32 and MFP 2-0640-33 is referred to as MFP33. Although these cards assume labels such as primary and backup they are redundant and will swap roles to maintain control without affect to the feed water loop.

To further support redundant operation of the MFP's as well as the other cards in the Bailey FWLC system, panel power is supplied by four redundant power supplies. All four power supplies provide power to the DC bus in a parallel connection as an auctioneered system. If any one of the power supplies has a failure the other three will supply power to the DC bus without interruption.

2015 FWLC Scrams

System Description

Power supplies, 2-0640-2063C and 2-0640-63D, receive input power from the Instrument bus and provide output power of +5V, -15V, +15V, & 25.5V to a DC power bus in the control room FWLC System panel. The other two power supplies, 2-640-63E and 2-0640-63F, receive input power from the essential service system (ESS) and provide the same voltage outputs to the DC power bus in the control room panel. All four power supplies provide power to the DC bus in a parallel connection as an auctioneered system. If any one of the power supplies has a failure the other three will supply the power to the DC bus without interruption.

2015 FWLC Scrams

Timeline

1988
EC 2741 - Unit 2 Bailey Net90 Digital FWLC installed. Bailey replaced the GE analog FWLC.

1996
Unit 2 scrams due to FWLC System Engineer making online configuration changes to the FWLC system. This incident made the station especially sensitive to online work performed on the FWLC system. A system modification was initiated to improve system performance.

1997
ECs 3723 and 6791, WO 97102835 - The currently existing Bailey Infi-90 Digital FWLC System was installed on Unit 2, replacing the Bailey Net90 Digital FWLC system. This modification retrofitted the existing panel to support installation. The +5V DC to MMU ribbon cable was disconnected/ reconnected when the Digital I/O slave module was installed. WO had no documented verifications of card positional components

2015 FWLC Scrams

Timeline

01/30/2006
IR# 447627 –Control Room Alarm 902-6 H-3, FW CONTROL SYSTEM TROUBLE, received due to loss of the backup processor 2-640-33 MADR2 card. The #7 LED indicating light was off on MFP 33.

02/19/2006
WO# 887887-01 - The MFP33 card was replaced without incident, and no attempt was made to re-initialize the card. No further analysis performed on the failed MFP card or the FWLC system.

09/04/2014
IR 1699697 - “Backup MFP Bad Status” alarm displayed on the Operator Interface Station (OIS) for the Unit 2 FWLC system. There were no LED indication issues on the cards as the Bailey system reset itself and the system redundancy returned. This was believed to be a spurious malfunction with the digital FWLC system. The vendor manuals were reviewed and provided no additional detail in regards to the malfunction. No additional actions were taken.

2015 FWLC Scrams

Timeline

10/10/2014

IR 2394030 - “Backup MFP Bad Status” alarm displayed on the Operator Interface Station (OIS) for the Unit 2 FWLC system and the FWLC system did not reset itself. System redundancy was lost. The Unit 2 MFP 32 displayed LED Error Code “2, 5, 6”. At the time of the failure MFP 32 was the Primary MFP, and MFP 33 then took over as Primary as a result of the failure. After the MFP 32 failure issue, MFP 33 had a green status LED and LEDs 7 and 8 were lit indicating it as the Primary card with no errors which was the expected condition. The Vendor technical information was reviewed which indicated the fault was “address or bus error” and the “corrective action” was to “reset MFP module. If error recurs, call Bailey field service.” The Bailey field service vendor was contacted to assist in resetting the MFP on 10/11/14.

2015 FWLC Scrams

Timeline

10/11/2014

WO # 01776124 - The ABB/Bailey vendor representative came on site and performed a “soft reset” of MFP32. After the reset, MFP 32 had a green status LED and LED 8 was lit indicating it was successfully reset and in backup status. MFP 33 had a green status LED and LEDs 7 and 8 lit indicating it remained as the primary. During conversations with the Bailey representative, the need to perform “soft reset” was not an abnormal occurrence. There was no deeper analysis on the failed MFP or the FWLC system, despite this being the second MFP issue in a little over a month, after 9 years of good performance.

10/28/2014

Engineering Review: Per Bailey Controls VTIP: The FWLC card is acceptable for continued use if the card resets on the second attempt. If it does not reset on the second attempt, the direction is to replace the card and send failed card out for failure analysis. No further analysis was performed.

2015 FWLC Scrams

Timeline

01/12/2015 11:01
IR 2436166 - “Backup MFP Bad Status” alarm displayed on the Operator Interface Station (OIS) for the Unit 2 FWLC system and the FWLC system did not reset itself. System redundancy was lost. At the time of the failure MFP 33 was the Primary MFP, and no transfer to the backup was needed. The Unit 2 MFP 32 displayed LED Error Code “1”. MFP 33 had a green status LED and LEDs 7 and 8 were lit indicating it as the Primary card with no errors which was the expected condition. The Vendor manual was reviewed which indicated Error Code 1 was “NVRAM memory checksum error” and the “corrective action” was to “Initialize NVRAM. If error recurs, replace MFP Module. If error recurs call Bailey field service”. Initializing NVRAM requires a “Hard Reset”, which requires removal of the MFP to re-initialize it. The ABB/Bailey technical support representative identified they would normally recommend a hard reset, but due to the age of the card (almost 10 years old) and risk of another MFP 33 failure, the card should be replaced.

2015 FWLC Scrams

Timeline

01/12/2015 Days
Operations Training start to perform Just In Time Training (JITT) on a loss of FWLC transient. The operator on Unit 2 during the 01/13/15 scram attended the training on this date.

01/12/2015
Replacement of the MFP32 card was scheduled for 1/15/15. This date was chosen as the Bailey field support representative was not available until 1/14/15, and the CMO “FWLC Expert” was off site on other business and could not be on site until 1/15/15.

01/13/2015 18:35
Unit 2 received control room alarm 902-6 H-3 FW Control System Trouble.

01/13/2015 19:03
With Unit 2 at 100% Power, MFP 33 Failed resulting in a loss of the FWLC system and 2A Reactor Recirc Pump Runback.

2015 FWLC Scrams

Timeline

01/13/2015 19:04
Operations initiated a Manual Reactor Scram because of Rx Water Hi Level ~+45 inches. The Reactor high level was caused by 2A RR pump runback and the failure of the FWLC system.

01/14/2015 02:30
An Exelon technical call. The conclusion of the call was to replace both MFP cards and continue with the troubleshooting.

01/14/2015 11:00
ABB/Bailey field services representative arrived at Dresden to support troubleshooting and repair of the FWLC system.

01/14/2015 16:00
ABB/Bailey field services representative, CMO, and engineering performed a brief walkdown of the Bailey FWLC system.

2015 FWLC Scrams

Timeline

01/14/2015 17:04
Day shift provided completed complex troubleshooting plan (Support/Refute Matrix). This document identified the failed MFPs as the cause of the FWLC issue and supported plant restart. No documented troubleshooting was completed for the 2A Reactor Recirc Pump runback. The matrix stated that all power connections had been verified sound, which subsequently was shown to be inaccurate.

01/14/2015 17:20
WO 1799123 - With Unit 2 in hot shutdown, IMD (with vendor support) performed a “soft reset” of MFP33, and MFP33 reset normally. Both MFP cards were also replaced based on Support/Refute Matrix.

01/14/2015 ~17:20
The FWLC Power Supplies 2-0640-63D & 63E were replaced. Note: The decision was made not to replace all four power supplies at the same time to avoid any infant mortality risk with the new power supplies.

2015 FWLC Scrams

Timeline

01/14/2015 21:18
Startup Plant Operations Review Committee (PORC) was complete with no Nuclear Safely Issues Identified. PORC decision to start up was based on the troubleshooting Support/Refute Matrix.

01/15/2015
Post transient review completed and approved by station management. Unit 2 was placed in Mode 2 to support Unit start up & then synchronized to the grid the next day.

01/16/2015
MFP Cards were sent to ABB/Bailey for failure analysis.

2015 FWLC Scrams

Timeline

01/18/2015
ABB/Bailey failure analysis concluded that the MFPs passed all tests and no issues were identified. See Attachments 10 and 11 for ABB correspondence on MFP analysis at ABB.
Note- There is a FWLC simulator system at Dresden, but the MFPs could not be tested at Dresden because of firmware compatibility issues between the simulator and the MFP's.

01/19/2015 10:04
IR 2439302 – "Backup MFP Bad Status" alarm received on the OIS in Main Control Room. There were no LED indication issues on the cards and the bailey reset itself. A WO was issued to troubleshoot and the Outage Control Center (OCC) was staffed.

01/19/2015
Restarted Complex Troubleshooting to determine failure of MFP cards.

2015 FWLC Scrams

Timeline

01/19/2015
A conference call was held with the ABB vendor “expert” who stated that the following were possible causes for the MFP failures:
1.) Loose connections in the FWLC cabinet
2.) External Environmental Electronic noise
3.) Corrosion on circuit board surfaces
4.) Age of the cards
5.) Grounding plane issue
6.) Power surges from the Main Power Transformer (MPT) failure (U2 MPT failed on 04/12/14)
7.) Power Supply Issue - Perform power and ground exercise (special test equipment for checking power supplies and ground)

01/20/2015
Several legs of the complex troubleshooting plan identified the need to hook up a recorder to the FWLC panel to monitor the electrical noise and ground issue.

2015 FWLC Scrams

Timeline

01/23/2015
The Plant decided to perform Single Loop operations on 2/7/2015 to reset the Adjustable Speed Drive (ASD) system to regain system redundancy. During this load drop, replacement of one of the MFP cards and the other two power supplies would be completed.

01/27/2015
The Complex troubleshooting plan was sent out for corporate review and challenge. Minor Comments were received and incorporated. A WO was created to install a recorder to monitor noise on the 5VDC power supply. The planner performed an initial risk screening. Package screened as potential Operational Risk and potential reactivity risk.

2015 FWLC Scrams

Timeline

02/04/2015
Design Engineering Electrical identifies to members of the troubleshooting team and root cause team that the previously observed spurious 2A RR pump runback could be due to an incorrect DIP switch configuration on the Bailey I/O circuit cards. (Actions to check the DIP switch positions were to be included in the original root cause report, but Unit 2 scrammed two days later on 02/06/15 before the root cause report was complete and any actions were initiated).

02/05/2015
A walk-through/test was performed of the recorder configuration in the IMD lab on the Bailey simulator. This walk-through/test was performed with the Instrument Maintenance Department individuals that would be hooking up the recorder to practice the recorder hookup and validate the connection points.

2015 FWLC Scrams

Timeline

02/05/2015
SRO completed review of the WO. This review determined that Operational Risk was not applicable. Elevated risk and reactivity risk is applicable and verification of DVM and recorder settings and proper Human Performance tools are required.

02/05/2015
A Management challenge meeting was conducted to challenge hooking up recorder to FWLC Panel at 100% power, and assess the risk involved with this activity. Installation at 100% power was approved

02/05/2015
WO #1801088-04 - Recorder installation on FWLC Panel at 100% power was challenged by the Duty Team. The WO task screened as elevated risk, but it was conservatively challenged as if it was classified as Operational Risk.

2015 FWLC Scrams

Timeline

02/06/2015 ~12:20
WO 1801088-04 - IMD and CMO started installing the test recorder. One connection was made successfully. During the placement of the second connection IMD expected to see 5.2V, but observed an unstable voltage around 4.8V. IMD did not believe the connection was fully seated and utilizing plastic pliers attempted to seat the test lead harder. This activity interrupted power to the cards due to a loose connection on the opposite end of the five-ribbon cable, which caused both MFP cards to reset and a FWLC transient to occur (not considered a likely fault due to Support Refute Matrix utilized in the first scram).

02/06/2015 12:25:39
The control room received the FW REG VLV LOCK UP alarm and a loss of FWLC occurred as evidenced by loss of indication of FWRV position, reactor narrow range level, and total feed flow rates. The FWRVs and the Condensate Booster Recirc Valve locked up as designed.

2015 FWLC Scrams

Timeline

02/06/2015 12:25:39
A signal was provided to the ASD system to runback the 2A Reactor Recirc Pump to a minimum speed of 30%. No signal was provided to the ASD system to runback the 2B Reactor Recirc Pump. The 2A Reactor Recirc Pump power decreased from 3.82 MW to 0.138 MW. The RFP discharge and suction pressures remain constant, which is evidence that the RFPs continued running and the FWRVs locked up.

02/06/2015 12:25:41
Reactor Water Level begins increasing due to the 2A Reactor Recirc Pump runback and associated swell in reactor core with no automatic FWRV adjustments.

02/06/2015 12:26:59
An automatic reactor scram occurs from the Reactor Protection System on RPV LVL LO (+8”) following Operator attempts to stabilize the plant from the transient conditions.

2015 FWLC Scrams

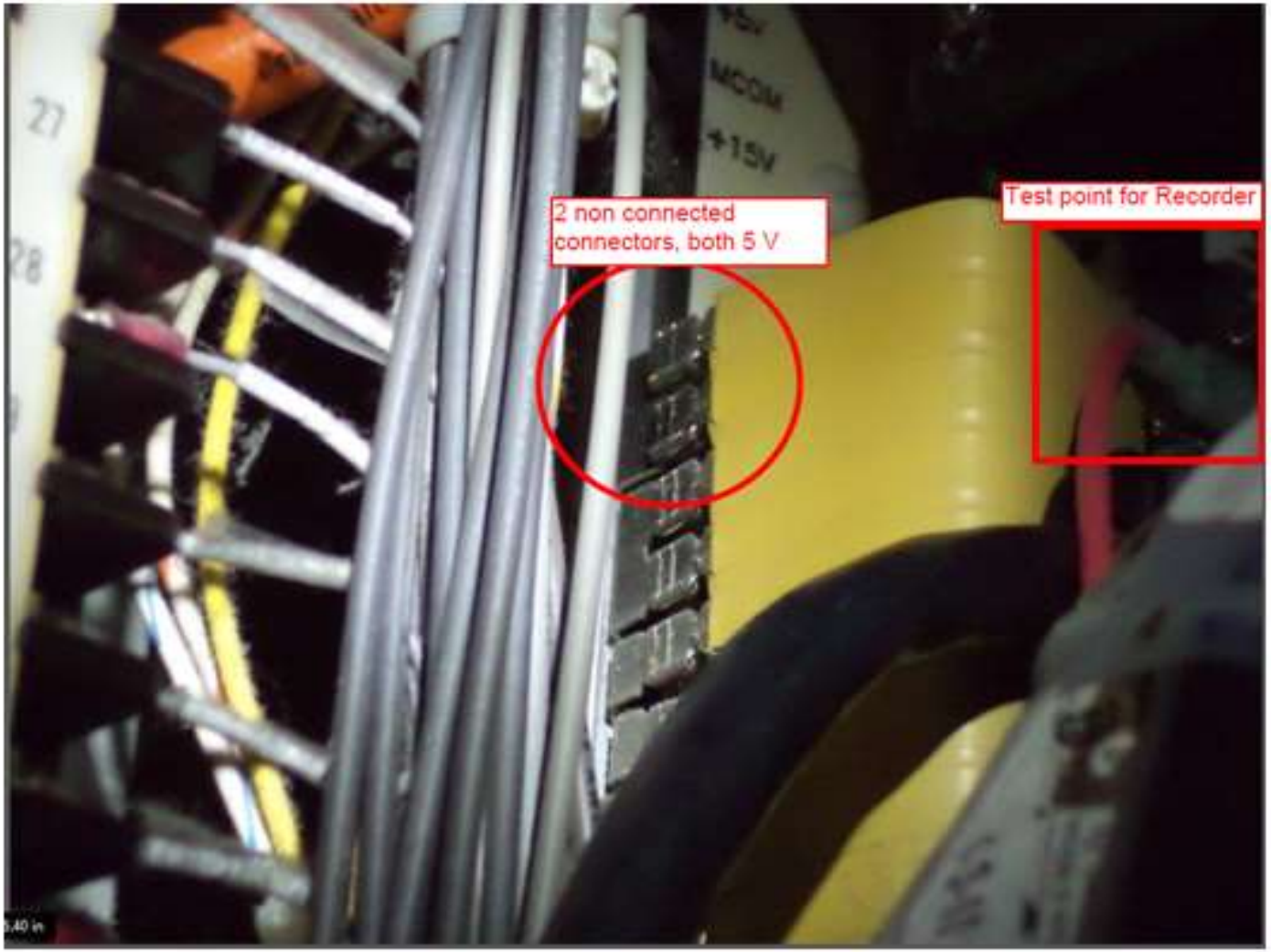
Root Cause 1:
A root cause of both the manual scram initiated on Unit 2 on 01/13/15 and the scram on 02/06/15, is a spurious power interruption on a historically **improperly landed power supply ribbon cable** connection for the digital FWLC system, which caused a momentary 5Vdc power supply loss to the FWLC Multi-Function Processors (MFP).

Root Cause 2:
A second root cause for the scram on 02/06/15 was **less than rigorous organizational challenge of troubleshooting.**

- Inadequate Troubleshooting was performed after the first scram on 01/13/15 in D2F55 due to a pre-disposition that the cards were at their end-of-life and experiencing intermittent failures as supported by the vendor.
- The troubleshooting was not rigorous and did not identify the root cause of the first scram on 01/13/15, thereby not preventing the second scram on 02/06/15.
- Potential causes were rationalized, assumptions were not adequately challenged, and less than rigorous organizational challenges were performed because of over-reliance on vendor and expert disposition.
- The troubleshooting team and station had the mindset that the only issue with the FWLC system failures was the MFP circuit cards and did not rigorously challenge the issues further.

2015 FWLC Scrams

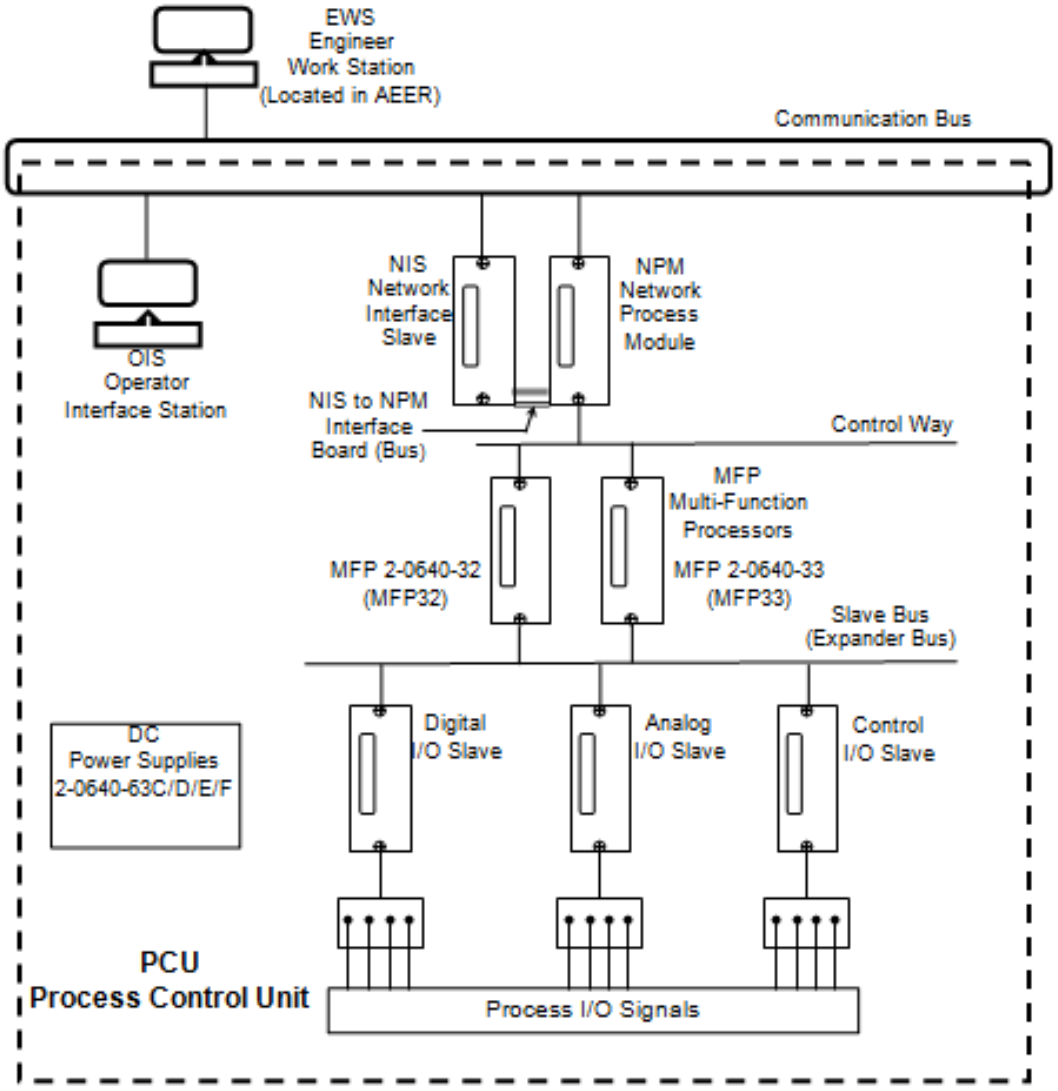
Unit 2 FWLC System Power Supply Ribbon Cable with faulty connection:



Exelon

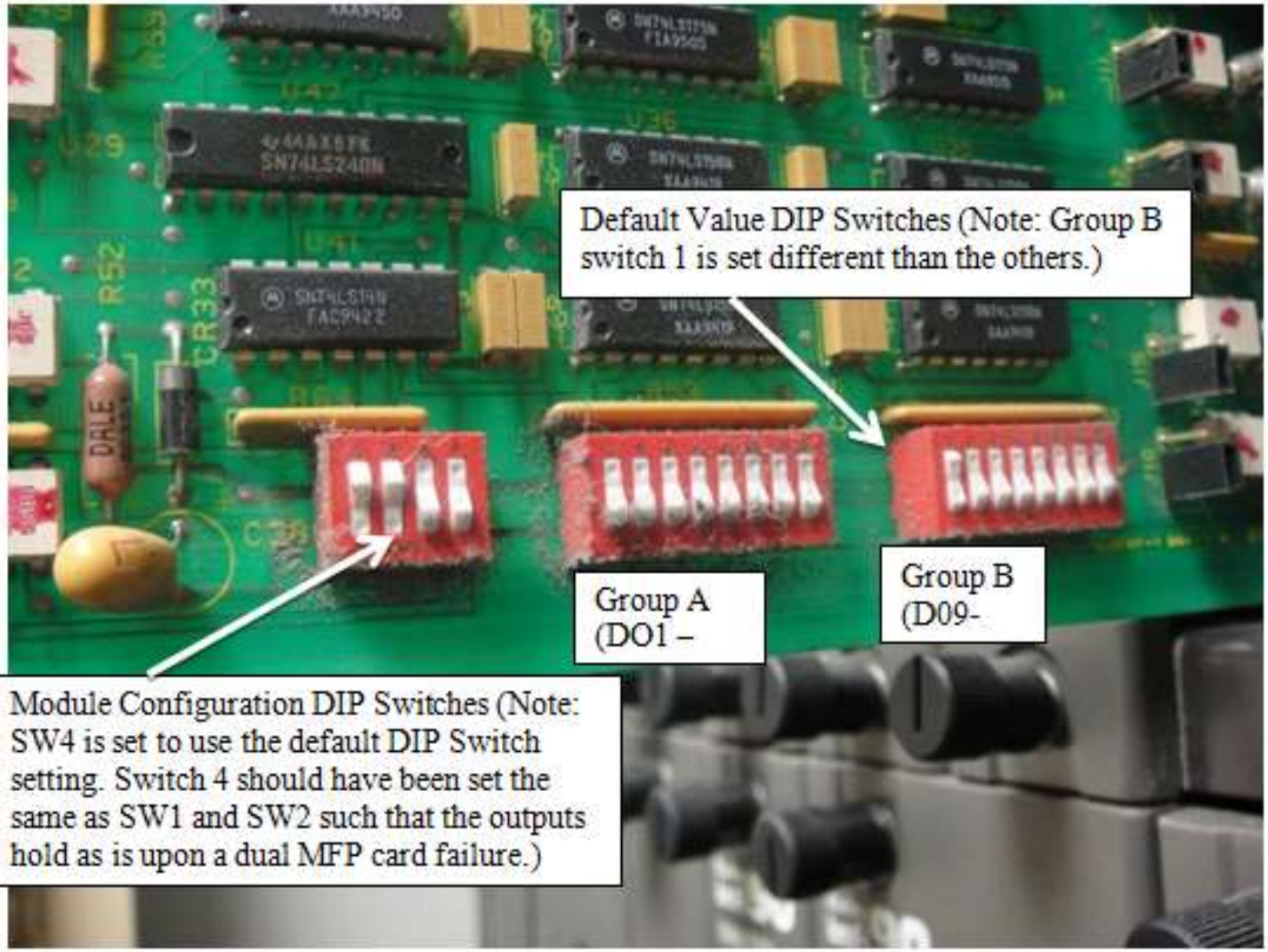
2015 FWLC Scrams

ABB/Bailey Diagram (Simplified)



2015 FWLC Scrams

Digital I/O Slave Module (IMDSM05) DIP Switches:



Exelon.

2014 Turbine Trip due to failed MSDT LT

While Dresden Unit 2 was shutting down for a planned maintenance outage in October 2014, a failed Moisture Separator Drain Tank (MSDT) Level Transmitter (LT) led to an automatic turbine trip.

2014 Turbine Trip due to failed MSDT LT

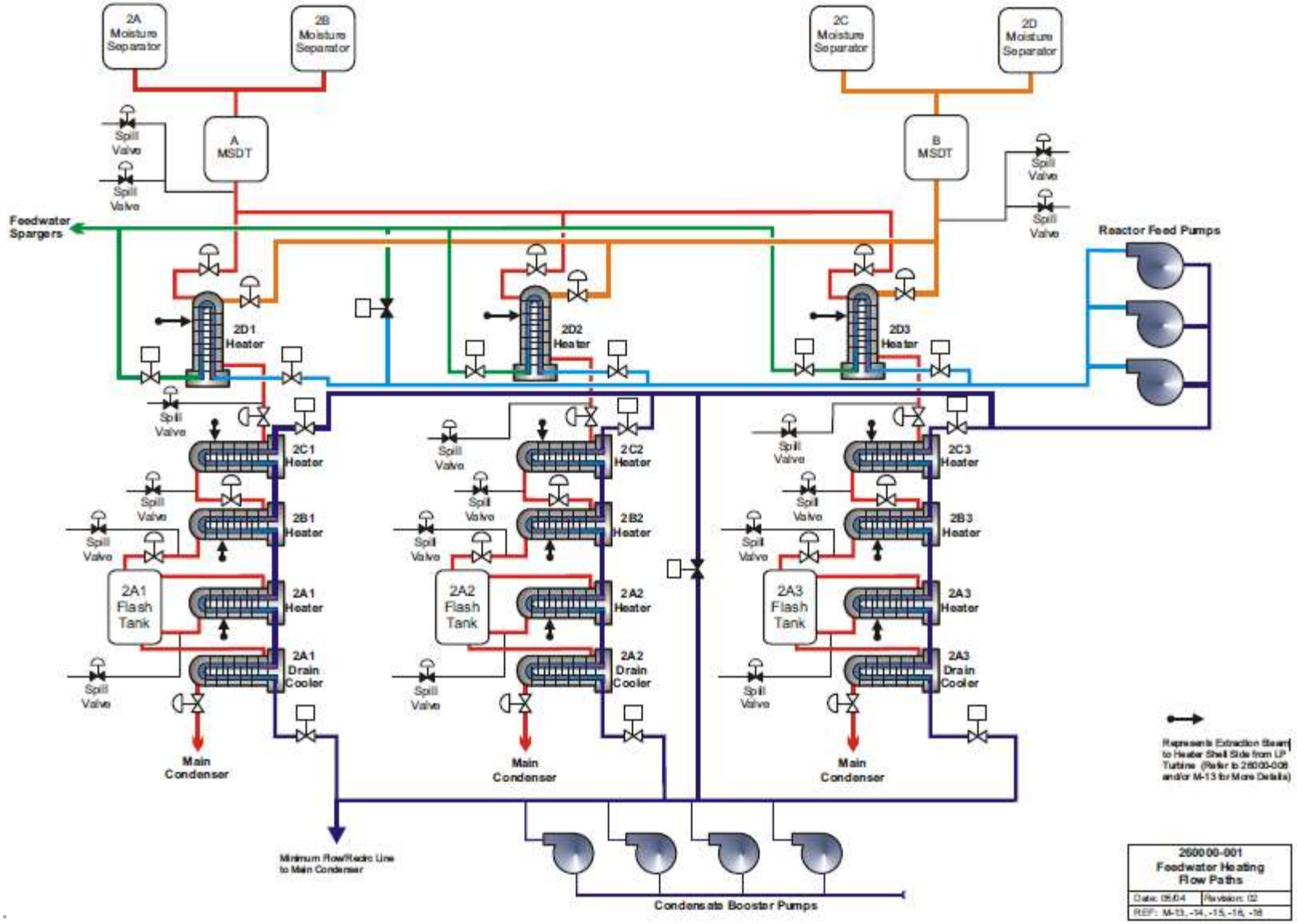
System Description

The high-pressure turbine steam exhausts to four corrugated plate moisture separators. The steam passing through the moisture separators gives up this moisture and is discharged to the low pressure sections of the turbine.

Water extracted by the corrugated separator plates drains to the bottom of each moisture separator. Two moisture separator drain tanks (MSDTs) are installed to control the moisture separator condensate. Level controllers in these drain tanks maintain the level within the correct operating limits. High and low level alarms are provided on a control room panel to alert the operator in the event of malfunction in the moisture separator drain system.

Drainage from two moisture separators goes to one drain tank. From the moisture separator drain tank, the condensate is drained to the shell side of the D heaters. MSDT Emergency Drain lines are routed to the Main Condenser.

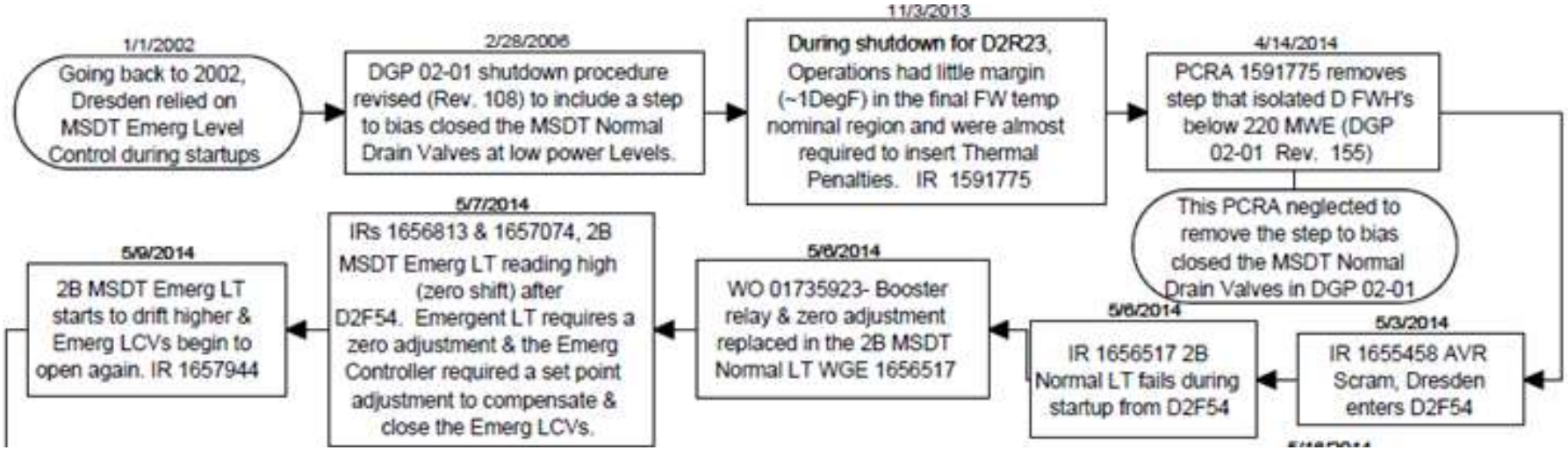
2014 Turbine Trip due to failed MSDT LT



Exelon

2014 Turbine Trip due to failed MSDT LT

Timeline



Exelon.

2014 Turbine Trip due to failed MSDT LT

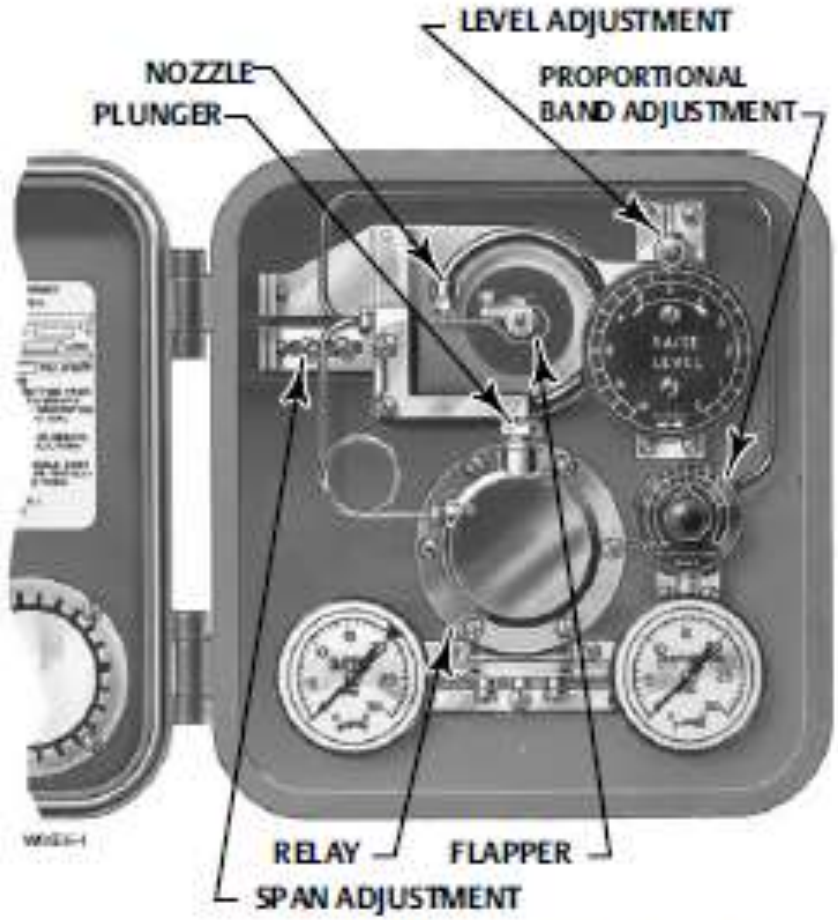
Fisher 2500T Level Transmitters

Figure 1. Fisher 2500 or 2503 Controller/Transmitter on 249 Caged Sensor

Exelon

2014 Turbine Trip due to failed MSDT LT

Fisher 2500T Level Transmitters



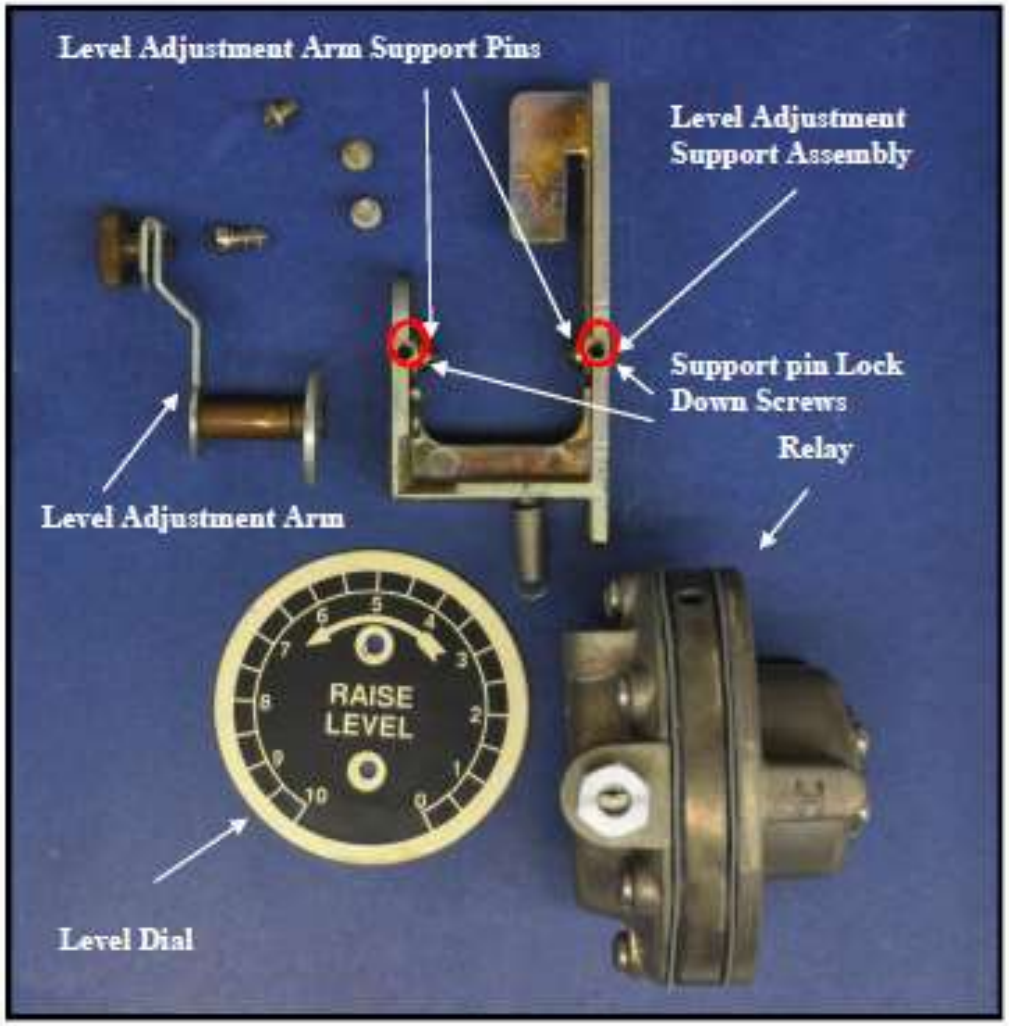
RIGHT-HAND MOUNTED 2500
PROPORTIONAL CONTROLLER

2014 Turbine Trip due to failed MSDT LT

Failed Zero Adjustment on the 2B Normal LT discovered in May 2014

Photograph 1
Field Photograph of the Actual Controller/Transmitter
Note: Level Set Adjustment Handle was Out of Place (Found Behind Dial)

2014 Turbine Trip due to failed MSDT LT



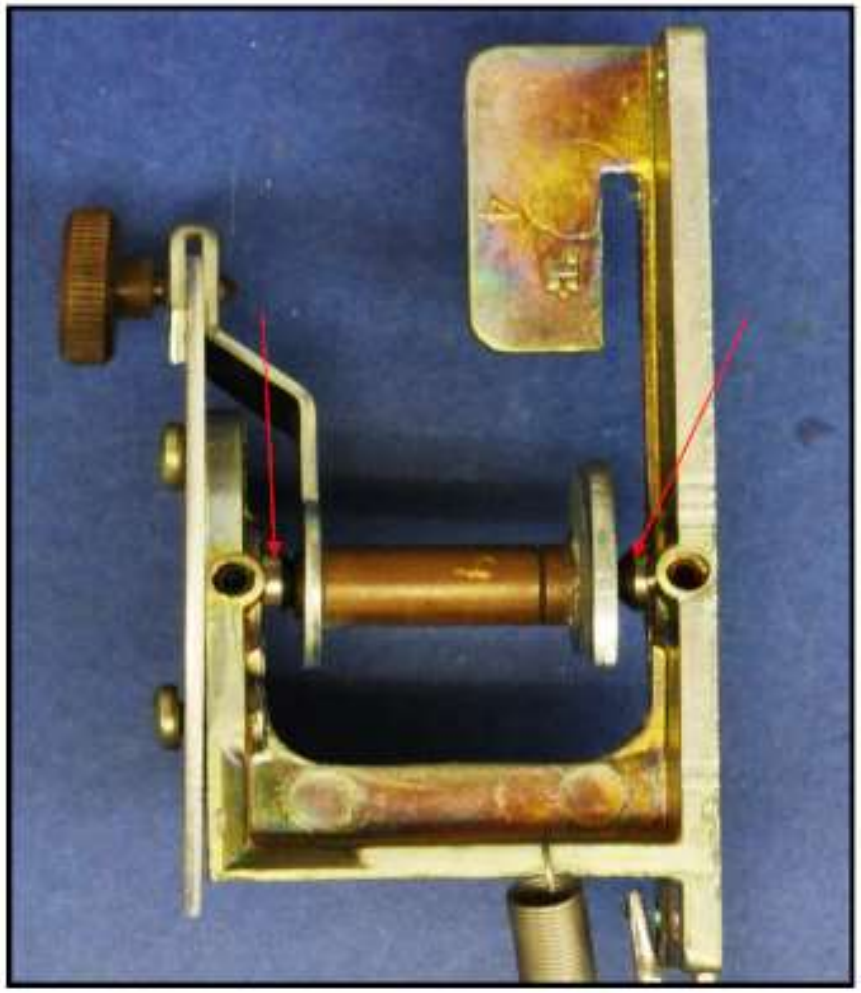
Photograph 2
Components Submitted for Analysis

Failed Zero Adjustment & Pneumatic Relay from the 2B Normal LT, replaced in May 2014

2014 Turbine Trip due to failed MSDT LT

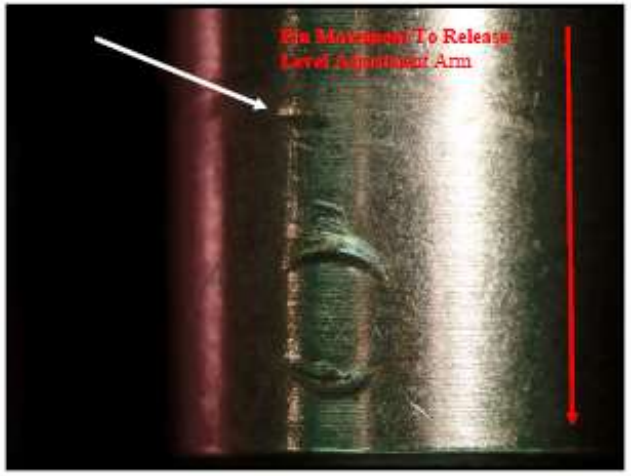
Failed Zero Adjustment on the 2B Normal LT discovered in May 2014

In order to determine how the level adjustment lever became dislodged from the level adjustment support assembly, the support screws were tested for tightness. It was noticed that both of the support pins that hold the adjustment lever in place could be moved by hand pressure, which would explain why the lever fell out during service. When pins were moved back to their original positions, the set screws were found to be loose.

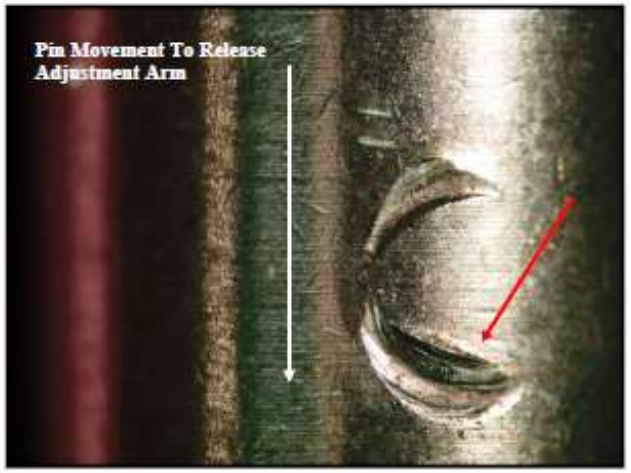


Photograph 3
Level Adjustment Assembly Shown Assembled
Note: Pins that Support the Adjustment Arm

2014 Turbine Trip due to failed MSDT LT



Photograph 4
Front Support Pin Showing Initial Indent from Screw being Tightened Down and Score Mark from Screw Moving, Arrow Indicates Where Screw May Have Settled After the pin Moved



Photograph 5
Rear Support Pin Showing Indent Mark from Screw
Note: Rolled up Material At Edge Possible Indicating that When Screw was Loose the Pin was Forced Backward Upsetting the Metal

Failed Zero Adjustment on the 2B Normal LT discovered in May 2014

The set screws were fully loosened and the pins were extracted and examined further under light microscopy. Both of the pins showed deep indents where the set screws were originally tightened down. However, both pins also contained additional set screw marks which indicated that the pins had slightly moved from their original positions. The small axial movements of the pins would have allowed the adjustment lever to fall out. The front support pin also contained a shallow scratch/score mark which confirmed that the pin had moved during service.

2014 Turbine Trip due to failed MSDT LT

Photograph 6
Orifice Fitting Removed from Relay

Photograph 7
Orifice Hole After the Piece of Foreign Material had been Dislodged

Failed Relay

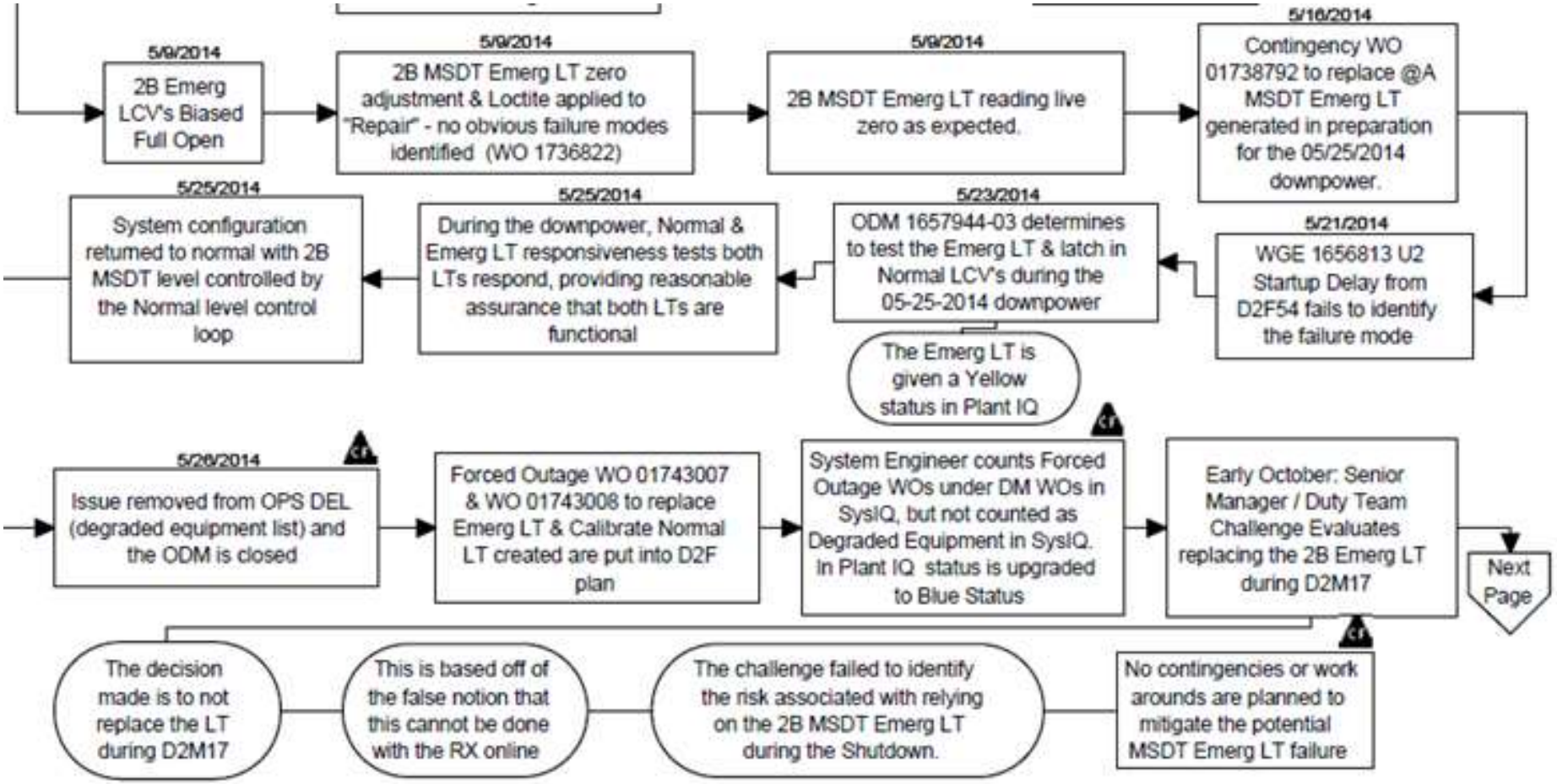
- Orifice found blocked
- However when the piece blocking the orifice was attempted to be recovered, the piece was dislodged and lost so no additional evaluations could be performed.
- Further examination of the relay was performed by dismantling and inspecting the different chambers.
- When the chamber dead space was examined, there appeared to be small cast material flakes that could easily be dislodged.
- It is possible that one of these flakes was the source of the blockage.

2014 Turbine Trip due to failed MSDT LT

Photograph 8
Dead Space on one of the End Plates Showing Small Cast Material Flakes that Could Easily be Dislodged

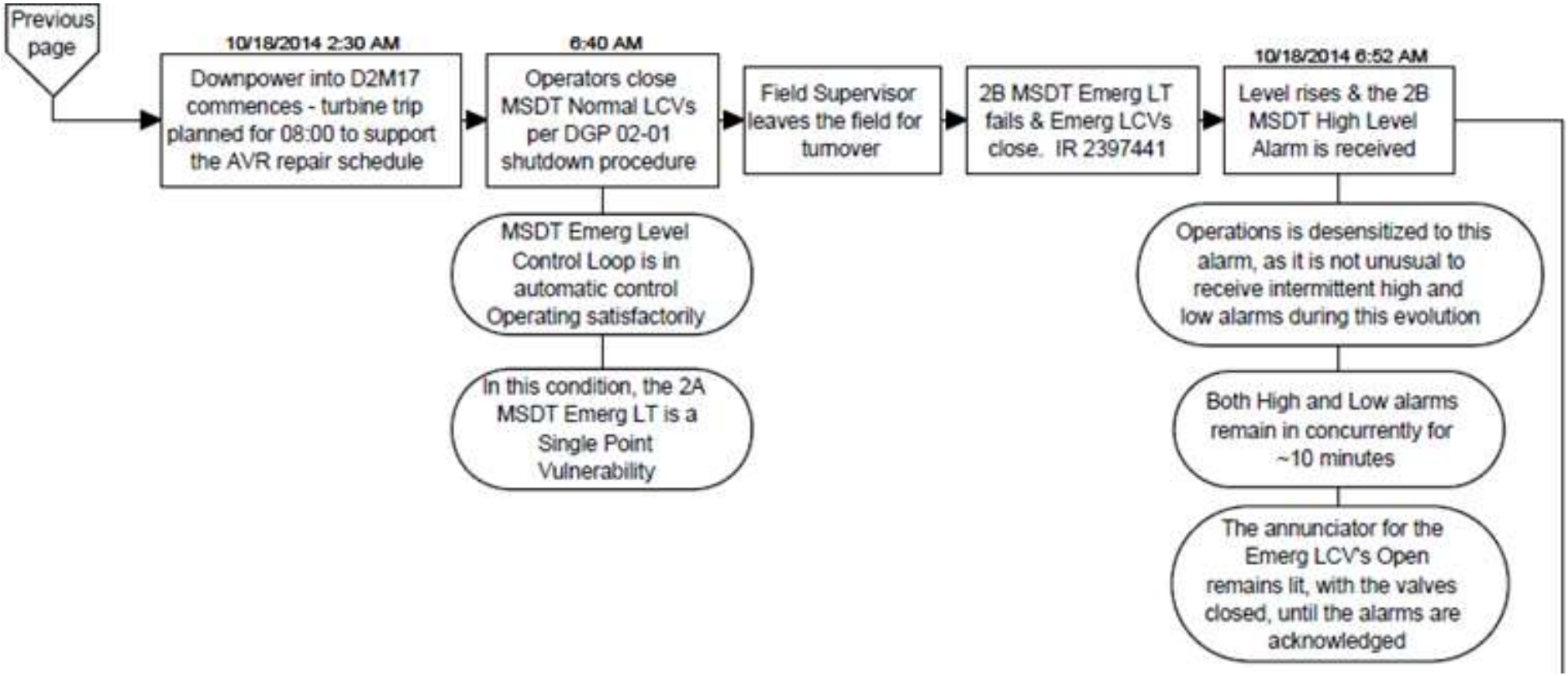
2014 Turbine Trip due to failed MSDT LT

Timeline



2014 Turbine Trip due to failed MSDT LT

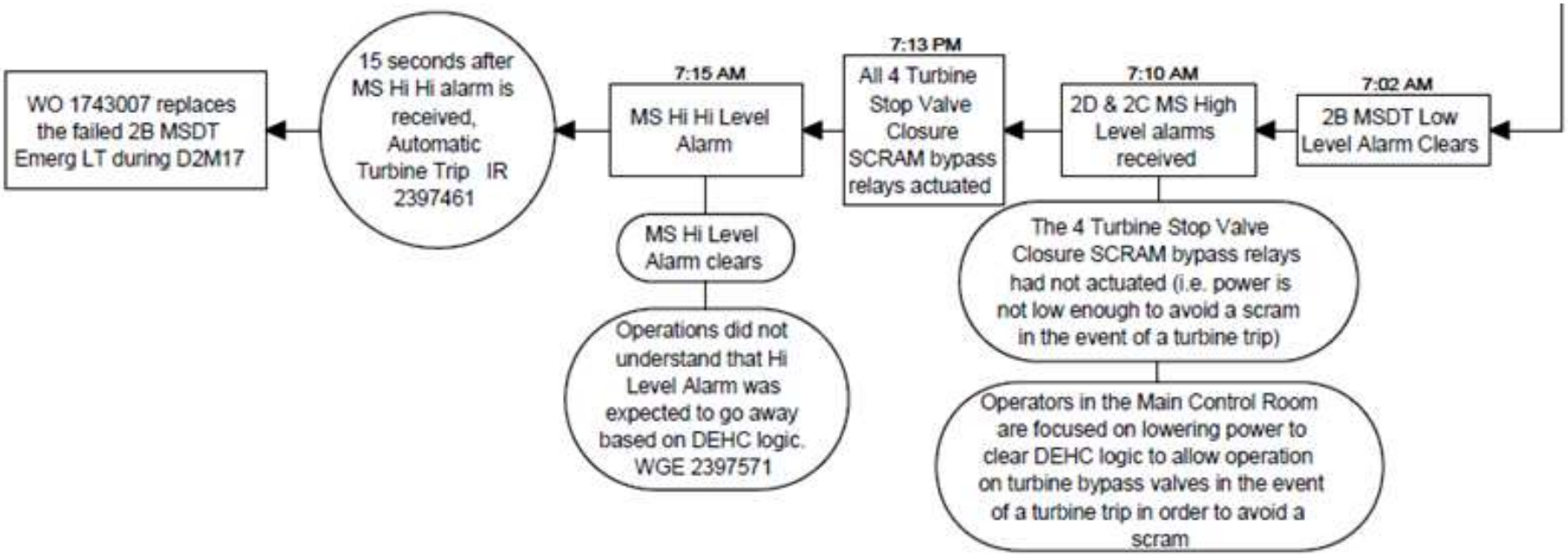
Timeline



Exelon

2014 Turbine Trip due to failed MSDT LT

Timeline



Exelon

2014 Turbine Trip due to failed MSDT LT

More Timeline

During D2M17, it was determined that the 2B MSDT Emergency LT could in fact be replaced with the turbine offline and the reactor online, so WO 1743007 replaced the failed Emergency LT during D2M17. The failed Emergency LT was initially saved for failure analysis, but a miscommunication led to the disposal of the LT before the failure analysis could be completed.

As a learning from D2F54, work instruction steps were added to the Unit 2 Forced Outage WO 1570554-04 to inspect the MSDT LTs during D2F55 (January 2015 FWLC Scram). The inspection was completed SAT. The WO did not include instructions to check sub-components for tightness.

2014 Turbine Trip due to failed MSDT LT

More Timeline

On January 16, 2015, the new 2B MSDT Emergency LT (installed in October 2014) functioned properly initially during startup from D2F55. However, a few hours into startup, the LT began to drift low, causing the 2B MSDT Emergency LCVs to close. The Normal LCVs had not been latched in yet, so level began to rise. Operations recognized that level was rising, and an operator was sent into the field. The operator then biased the Emergency LCVs full open. Troubleshooting under WO 1743008 found the shaft clamp nut that holds the flapper in place inside of the LT to be loose, and this looseness allowed the flapper to move away from the nozzle, which reduced the LT output signal (IR 2438798). Instrument Maintenance tightened the shaft clamp nut and made zero adjustments, and with the LT functioning properly again, Operations returned the 2B MSDT Emergency LIC to service.

2014 Turbine Trip due to failed MSDT LT

Apparent Cause:
The 2B MSDT Emergency LT was not identified as degraded by the **System Manager** prior to the shutdown for D2M17

Contributing Cause:
Shutdown Procedure introduced **Single Point Vulnerabilities** (SPVs) by closing the MSDT Normal LCVs

After the turbine trip on 10/18/14, IR 2402610 identified that the shutdown procedure put Unit 2 in a single point vulnerability configuration when the MSDT Normal LCVs were closed. The shutdown procedure was revised to change the step to bias the MSDT Emergency LCVs 100% open, using the Quad Cities shutdown procedure operating experience as support.

During the extent of condition review, a similar SPV configuration (controlling on the MSDT Emergency LCVs with the Normal LCVs closed) was identified in the startup procedure, so an action was created from the ACE to revise the startup DGP 01-01 procedure to remove this SPV.

Dresden FWLC Scrams & MS Hi-Hi Turbine Trip

Questions?

Dresden FWLC Scrams & MS Hi-Hi Turbine Trip

Question for the audience:

What type of Level Transmitters does your plant use on your MSDTs/ MSRDTs?

Performance?

Other designs considered?