Regulatory Conference Related to Davis-Besse EDG FFSS Finding

February 1, 2022

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Purpose of Meeting

- Provide information and perspective on the uncertainties with significance determination related to the 5 areas outlined in the Inspection Report Preliminary Greater Than Green Finding Dated Dec 16, 2021
- Provide information and perspective on the failure analysis performed on the Field Flash Selector Switch (FFSS) after the inspection team was on site.

Agenda

- Apparent Violation and Performance Deficiency
- Licensee Perspective
- Summary of FFSS Failure
- PRA Considerations
- Independent Failure Analysis
- Conclusions
- Questions and Wrap-up

Apparent Violation & Performance Deficiency

- “On May 27, 2021, a self-revealed finding with its safety significance as yet to be determined (TBD) and an associated Apparent Violation (AV) of TS 5.4.1.a were identified for the licensee’s apparent failure to develop a preventive maintenance schedule for the inspection of emergency diesel generator (EDG) field flash selector switches (FFSSs)”
- “The Team concluded that the failure to develop a preventive maintenance schedule for the inspection of the FFSS, was contrary to Technical Specification 5.4.1 and Section 9.b of Regulatory Guide 1.33, Revision 2, February 1978, and constituted a performance deficiency”
- Preliminary Greater Than Green Finding – “The failure to inspect the switch contributed to the long-term degradation of the switch electrical contacts and ultimately contributed to an EDG failure during fast start testing”

Licensee Perspective

- Energy Harbor staff determined the significance of the May 27th event could be characterized as Low to Moderate (White) based on PRA considerations
- Independent failure analysis of the FFSS performed after the on-site portion of the NRC inspection ruled out silver sulfidation and determined foreign material (FM) as the most likely cause
- The results of the failure analysis led Davis-Besse to change our perspective from the initial investigation:
  - Davis-Besse staff has determined that a PM to inspect the contacts of the FFSS would likely have not prevented the May 27th event
  - Davis-Besse staff perspective is that the significance of the performance deficiency associated with the FFSS should not be based on the May 27th event

Summary of EDG#1 FFSS Failure

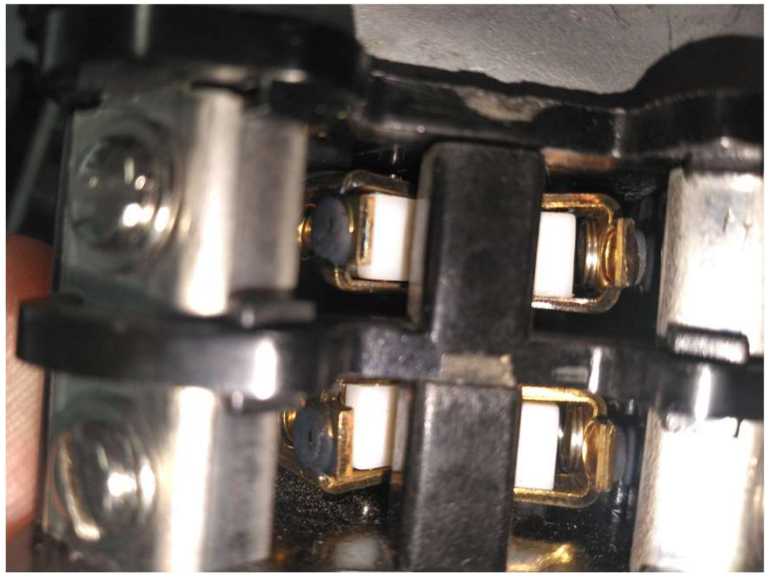
5/27/21 Fast-Start Surveillance Test – EDG 1 184 Day Test

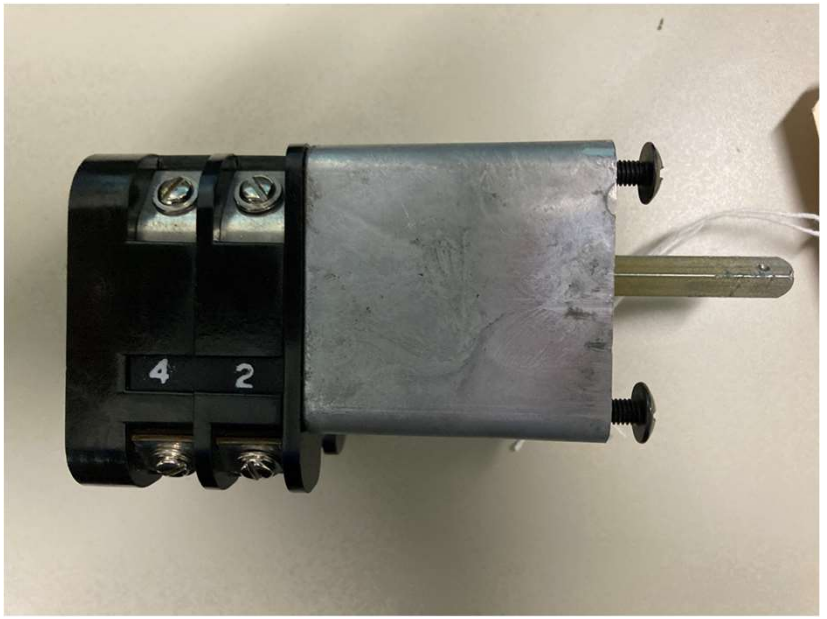
- Performed with the FFSS in the 400 RPM (Emergency Start) position
  - The normal position of the switch is on the 400 RPM position
  - The monthly test for the EDG moves the switch to the 800 RPM (Idle Start) position for the test and then moves it back to the 400 RPM position
- Failed to reach a rated voltage and frequency
  - Engine started as expected and reached 900 RPM
  - No Indications that the field flashed
- Decision made to stop the test and shut down the engine
  - When the FFSS was placed into the 800 RPM position - the field flashed, proper voltage & frequency observed
- The idle shutdown continued, and the engine was stopped to allow troubleshooting

Summary of EDG#1 FFSS Failure

Problem Solving Team

- Discovered intermittent open contact on the FFSS 400 RPM contacts
  - Initial in-situ check showed closed contact
  - The switch was cycled 5 times in-situ, 2 of 5 times open contact observed
- Replaced FFSS and tested satisfactorily on 5/28/21
- Surface contamination is visually observed on the FFSS contacts
- The vendor manual recommended inspection and cleaning to remove sulfide buildup and contact pitting – no periodicity specified
  - No PM existed to inspect/clean the FFSS





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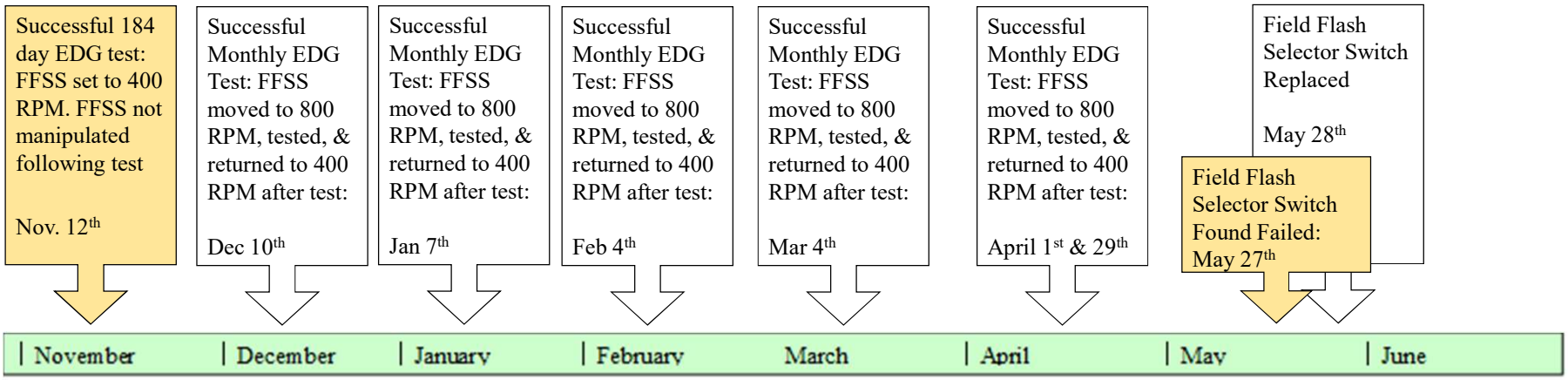
Summary of EDG#1 FFSS Failure

Actions Taken/Planned

- Replaced old FFSS with a new FFSS - complete
- Test procedure enhancement - perform continuity checks following switch manipulation – complete (interim action)
- Procedure enhancement - Field Flash Pushbutton use added to the Emergency Use section of the operating procedure - complete
- Initiated enhancement PMs to Inspect/Replace FFSS – complete
- EDG Reliability Assessment - complete
- Modifications being considered:
  - Install an indicating light for the switch contacts when returned to the 400 RPM position to provide positive indication of circuity integrity.
  - Redesign of the field flash circuit to remove the dependence on the 400 RPM contact functioning and eliminate the vulnerability.

Summary of EDG#1 FFSS Failure

Timeline of Events

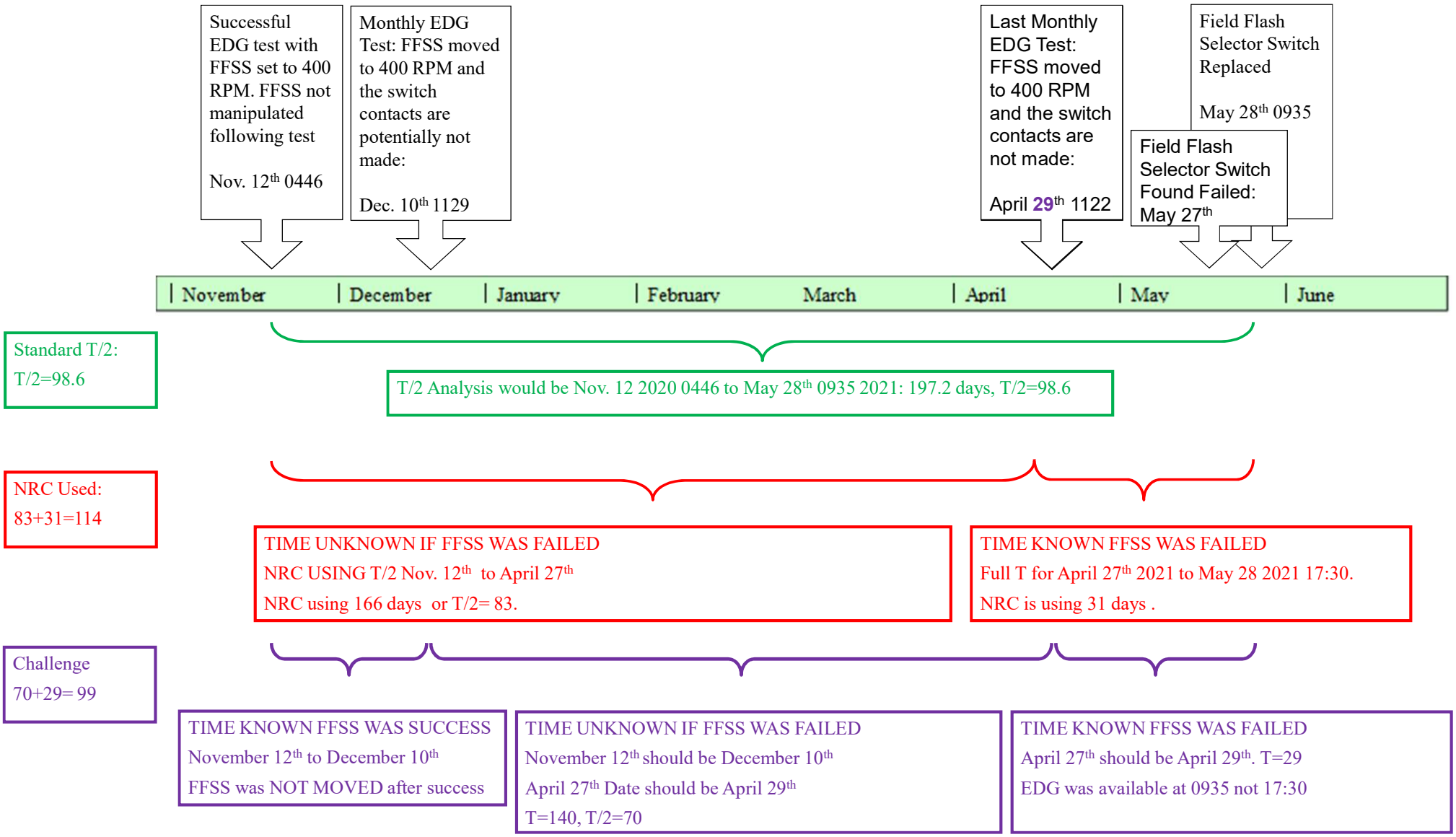


PRA Considerations

- Conservatisms in the PRA model were evaluated for the risk associated with the May 27th event
- Key areas evaluated are:
  - Exposure time
  - Operator Recovery
  - Model Conservatisms
- The significance of the event is estimated to be White, based on consideration of these key areas

PRA Considerations

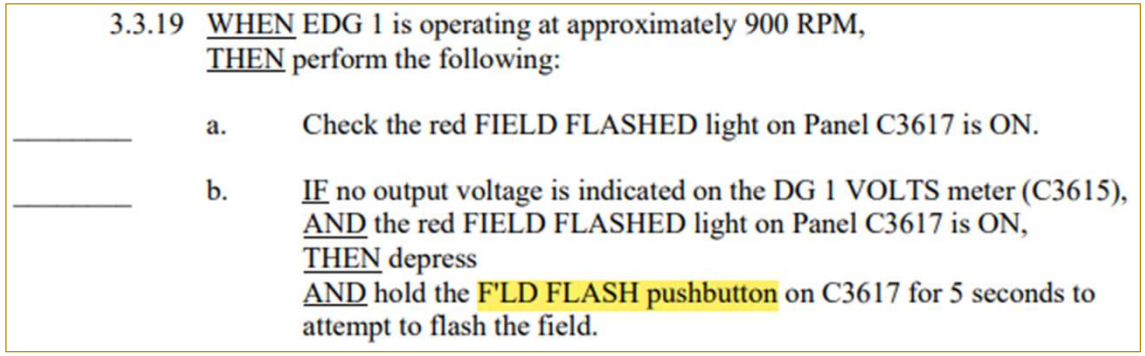
Exposure Time – EDG#1 FFSS Failure



PRA Considerations

Operator Response/Recovery

- Following fast start failure of EDG 1 during a Loss of Offsite Power with SBODG and EDG 2 unavailable
  - Crew would take actions for the Reactor Trip resulting from Loss of Offsite Power
  - EDG 1 would be emergency shutdown during the initial start
  - Extended Loss of AC and entering DB-OP-02700, Station Blackout. DB-OP-02700 has actions to mitigate a station blackout concurrent with a maximum of 111 gpm RCS leakage
  - The Shift Manager would pursue the recovery of EDG 1
  - Equipment Operators would be given direction to reset the lockout IAW DB-OP-06316, Emergency Diesel Generator Operating Procedure
  - Post start checks would identify the lack of voltage indication for the EDG with the red Field Flashed light still illuminated
  - Using guidance in the normal operating procedure and Conduct of Operations, the operating crew would depress the Field Flash Pushbutton to flash the EDG Field



3.3.19 WHEN EDG 1 is operating at approximately 900 RPM,
THEN perform the following:

_____ a. Check the red FIELD FLASHED light on Panel C3617 is ON.

_____ b. IF no output voltage is indicated on the DG 1 VOLTS meter (C3615),
AND the red FIELD FLASHED light on Panel C3617 is ON,
THEN depress
AND hold the F'LD FLASH pushbutton on C3617 for 5 seconds to attempt to flash the field.

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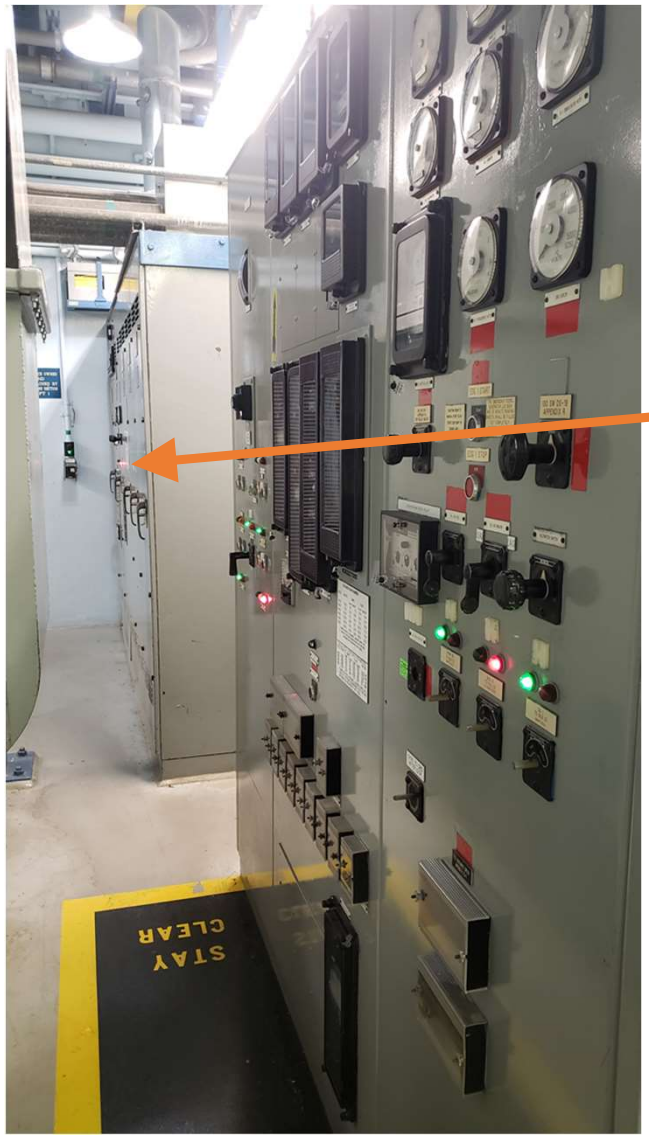
PRA Considerations

Operator Response/Recovery



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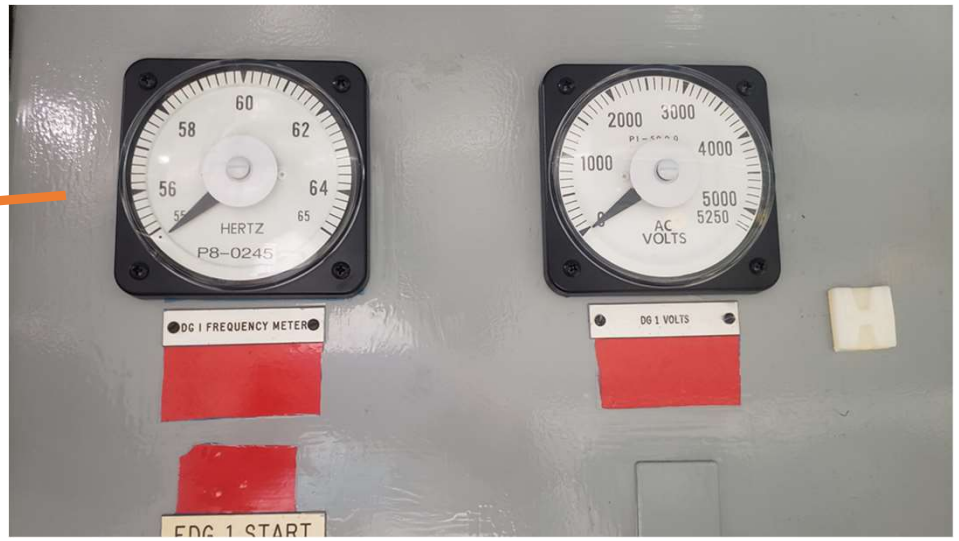
PRA Considerations

Operator Response/Recovery



PRA Considerations

Dominant Fire PRA Risk Scenarios

1) Fire in high voltage switchgear room 2 (Q-01).
2) Fire in control room (FF-01) or cable spread room (DD-01) requires control room abandonment due to loss of control.
3) Fire in low voltage switchgear room #2 (X-01) causes an overcurrent trip of Bus A

PRA Considerations

Conservatisms or non-conservatisms in the Davis-Besse fire PRA

Model Specific Non-Conservatisms:

- None

Model Specific Conservatisms:

- No credit given for RCPs tripping due to loss of power from fire impacts.
  - Impact of removing the conservatism:
    - All-hazards delta CDP reduction of 18%
- DC power is failed from low voltage switchgear ventilation failures even though the heat loading in the low ventilation SWGR is minimal when 480V bus power is lost.
  - Impact of removing the ventilation failures impact on the DC power system only for battery duration.
    - All-hazards delta CDP reduction of 12%

PRA Considerations

Conservatisms or non-conservatisms in the Davis-Besse fire PRA

EDG Recovery:

- No Credit given for recovery of the emergency diesel generator.
  - Impact crediting recovery (including recovery HEP of 0.723)
    - All-hazards delta CDP reduction of 27%

Combined effect of conservatism:

- Impact of removing conservatisms and considering EDG recovery concurrently:
  - All-hazards delta CDP reduction of 49%
  - Results in an all-hazards delta CDP of 8.79E-6, which is within the range of White Significance

Analysis of the effects of Conservatisms is documented in PRA-DB1-22-001-R00

PRA Considerations

Conservatisms or non-conservatisms in the Davis-Besse fire PRA

Non-quantifiable Sources of conservatism:

- NUREG-2230: Electrical Cabinet Fires
- NUREG-2178 vol. 2: Electrical Enclosure Fires, Motors and Dry transformers, Main Control board fire progression, Plant Trip probability <1.
  - Both of these require extensive Fire Detail Modeling to determine impact

Other possible conservatisms investigated:

- NUREG-1921 supplement 2: MCR Abandonment
  - Currently in alignment
- EPRI 3002016004: Alternate MCR Abandonment HRA
  - Negligible impact to analysis
- NUREG-2232, NUREG-2233: Transient Fires
  - Negligible impact to analysis

Independent Failure Analysis – MPR & Exelon Power Labs

- MPR and Associates
  - Non-intrusive inspection
  - Contact resistance checks
  - Functional testing
  - Failure modes analysis
- Exelon Power Labs
  - Contact resistance checks
  - Intrusive inspection
- MPR And Associates prepared final failure analysis report

Independent Failure Analysis – MPR & Exelon Power Labs

Contact Resistance

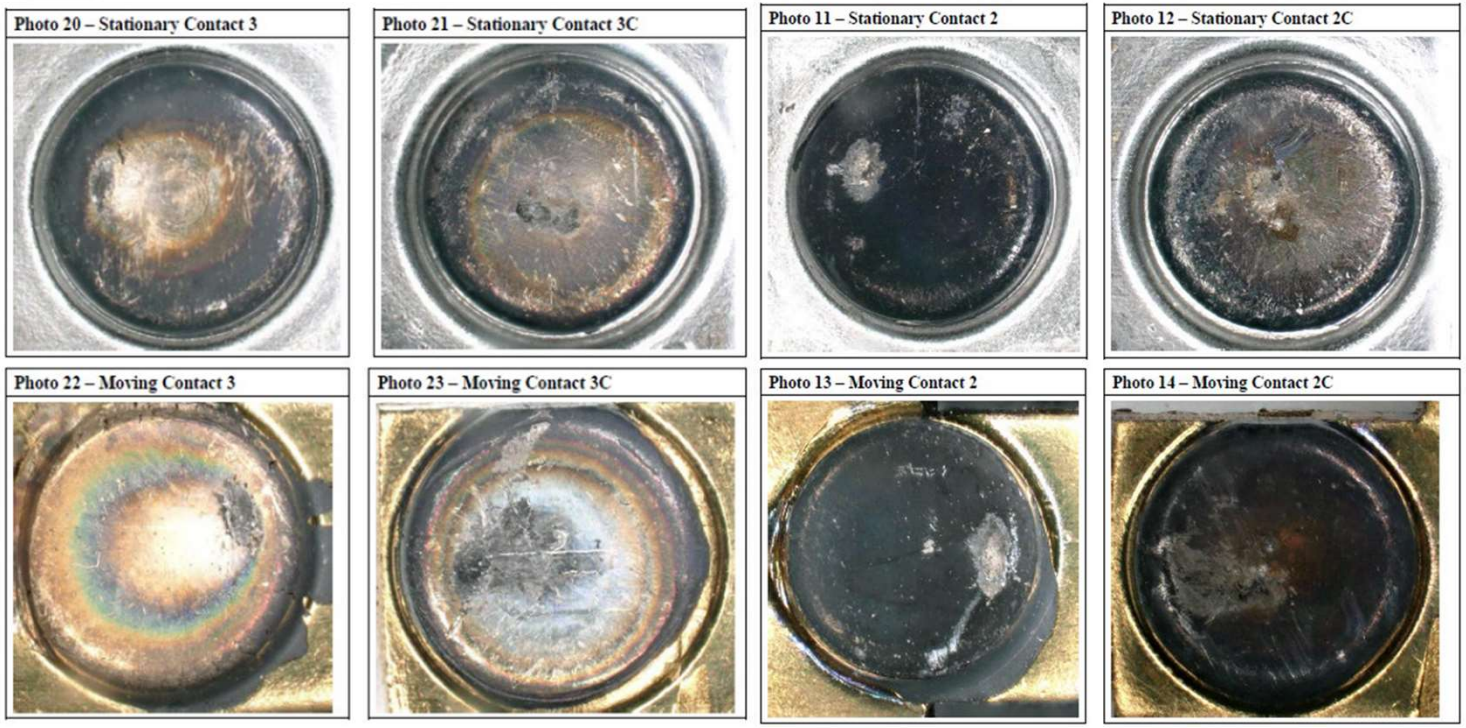
- Resistance values were consistently low and did **not** show an improving trend associated with FFSS operation
    - Indicates that operation of the switch during troubleshooting onsite and at the vendor simply maintained the as-found contact surface contamination and did not improve/condition the contacts
- Contacts 1 (spare) and 3 (400 RPM)
    - Closed except during some monthly surveillances
    - All 100 measurements of contacts 1 and 3 resistance were well below the 72 Ohms determined in the lab to be needed to prevent the field flash contactor pickup (90% below 1 ohm; 2.6 ohm maximum)
- Contacts 2 (800 RPM) and 4 (spare)
    - Open when 1 and 3 are closed
    - Higher resistance values than contacts 1 and 3, with an average reading of 3.7 Ohms, and only 1 of 100 just above 72 Ohms (73 Ohms)
- No contact resistance measured in the lab was in the range of thousands of Ohms as was observed 2 of 5 times while the switch was still installed following the failure. All lab-measured resistance values were orders of magnitude smaller and in a relatively narrow band.

Functional Testing and Conclusions

- Vendor recommended PM would not have prevented this issue
  - During the simulated functional testing with a field flash contactor, the 3-3C (400 RPM) and 2-2C (800 RPM) contacts functioned properly 100% of the time without failure.
  - It was identified the more heavily fouled contacts were for the 800 RPM circuit (slow start), which had not failed in the plant and did not fail in testing.
  - The visual condition of the 400 RPM contacts would not have led to cleaning/replacement of the FFSS
  - The resistance values for both the 400 & 800 RPM indicated acceptable contact performance
  - These visual and resistance measurement findings of the 400 RPM contacts, if observed during a PM, would have resulted in continued use of the FFSS

Surface Contamination

- Contact Surfaces:



400 RPM
Emergency Start
Normally Closed

800 RPM
Idle Start
Normally Open

Surface Contamination

- Based on the evaluation of the contact contamination and resistance measurements, MPR concluded the surface contamination was not the cause of the FFSS Failure.
- The black substance on the switch contacts is silver sulfide. This forms when silver reacts to sulfur found in the environment, such as Sulfur Oxides found in diesel exhaust.
- Silver sulfide buildup can cause electrical failures, especially on switches that are infrequently cycled, due to buildup. It is crumbly and does not flake off in large pieces.
- Contacts that are open have a greater buildup than the normally closed contacts, as observed with the FFSS.
- The GE SBM switch does have a self-cleaning wipe feature and the monthly cycling would help maintain acceptable surface conditions.

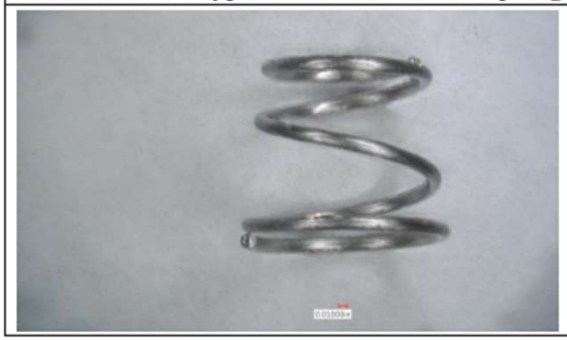
Photo 7 – Switch Contact Stage 3/4

Switch Alignment/Compression

- Observed proper switch alignment and spring compression
- All 4 moving contact springs were inspected prior to disassembly
  - These conical springs were installed correctly with the larger end nearest the contact and centered over the contact carrier nub
  - The contacts aligned consistently with each switch operation and appeared to be centered on each other. No issues were observed with contact alignment.

Photo 2 – Typical Contact Carrier Spring

Photos 3 & 4 – Typical Contact Carrier Spring



- Following disassembly, spring compression testing was performed with the moving contacts still connected to the cam followers
  - The values of all 4 contacts were consistent with each other and very repeatable from trial to trial

Disassembly and Inspection

- The switch operator mechanism was in very good condition
  - The latch arm rested firmly in the cam indents and the latch spring was positioned correctly
  - The stop tabs were set to provide the desired switch handle and shaft range of motion
- No foreign material was found in either stage body or in the switch operator mechanism housing
- All components within both contact stages were found in very good condition
  - The cams & cam followers showed little to no wear
  - The stationary contacts were in position and seated firmly in the stage body
  - The moving contact assemblies pivoted smoothly on the respective cam follower

Independent Failure Analysis – MPR & Exelon Power Labs

Scanning Electron Microscope/Energy Dispersive Spectroscopy (SEM/EDS)

- Examination by SEM/EDS identified foreign material on a contact surface
- Contact 2-2C (800 rpm) was visually the worst of the set with the black substance covering nearly all four contacts
  - Identified black substance as sulfur. The silver-plated contacts are succumbing to silver sulfidation.
- Contact 3-3C (400 rpm) did not have as much sulfur cover as the even numbered contacts
  - There was no wear or unusual scarring on the mating surfaces that would identify it as having a potential for poor electrical connection
  - Stationary Contact 3C (mating area) – Detected nickel (Ni) **[Discovery - Cause – Foreign Material]**
- Material Identification of Switch Parts
  - A transverse cross section of the stationary Contact 4C was completed. The silver on the contact surface was attached to a copper-zinc-tin (Cu-Zn-Sn) alloy. No nickel (Ni) was detected.

Scanning Electron Microscope/Energy Dispersive Spectroscopy (SEM/EDS)

- The following switch parts were tested:
  - Terminal screws (on outside of switch body) – nickel plated brass
  - Shaft – material was consistent with carbon steel with zinc plating
  - Stationary contact supports – material is consistent with a copper-zinc-tin alloy base material with tin plating
  - Movable contact support – material is consistent with brass (copper and zinc)
  - Latch arm – the material is consistent with a carbon steel base material with a zinc-chromium plating
  - Moving contact assembly spring – stainless steel
- Nickel should not be on Stationary Contact 3C (400 rpm)
  - Source of nickel on 3C unknown; possibly terminal screw

Independent Failure Analysis – MPR & Exelon Power Labs

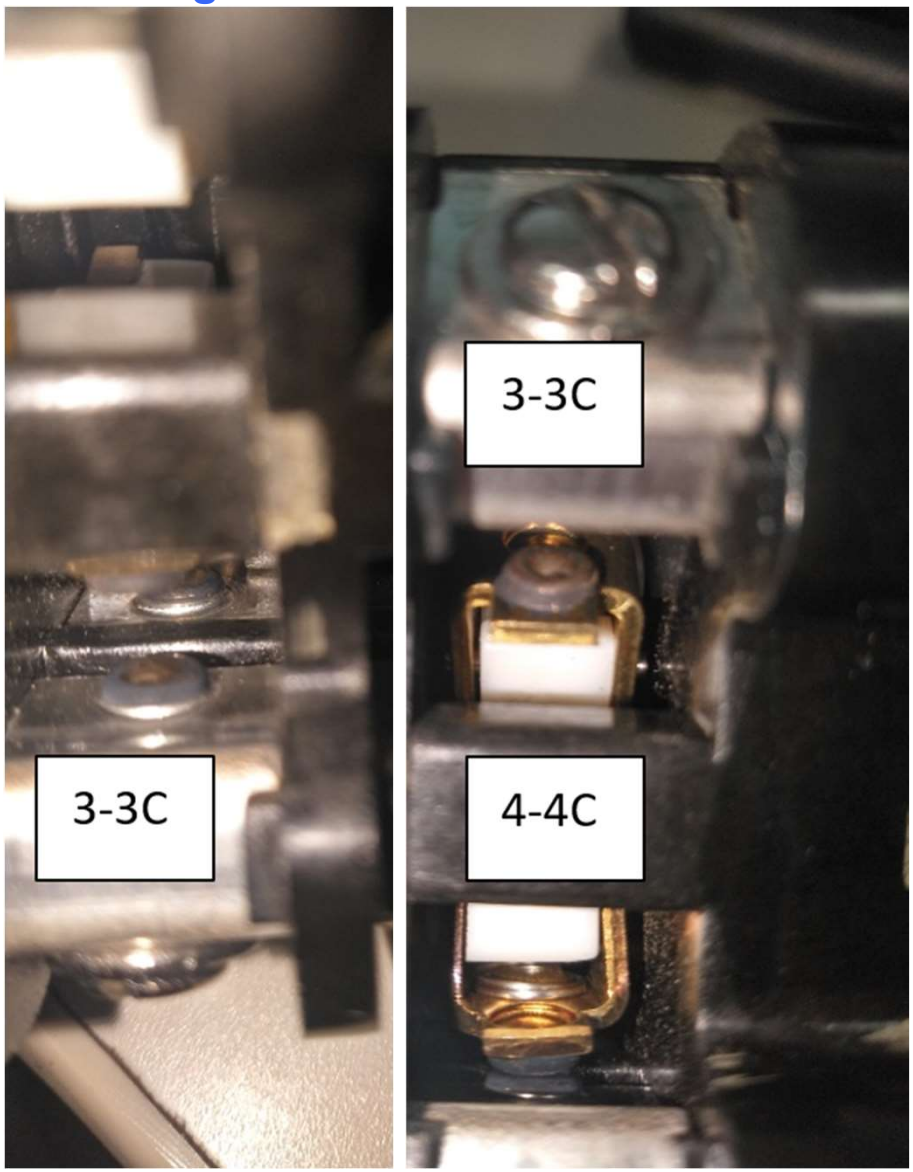
Failure Analysis Results and Conclusions

- Resistance and Functional Tests
  - Intermittent, very high contact resistances (> 1000 Ohms) measured in place at the station could not be repeated in laboratory
  - 400 rpm contacts – All laboratory-measured resistances were significantly lower than those measured at the station, and all were well below the measured threshold resistance needed to prevent field flash contactor pickup. All functional tests picked up contactor
  - 800 rpm contacts – Were found to be in worse condition than 400 rpm contacts by visual inspection, resistance measurement, and material analysis; all but one measured resistance was below the measured threshold resistance. All functional tests picked up contactor
- Internal Inspection and Material Analysis
  - All contact surfaces were found to be in good shape, but with some surface sulfidation present (worse for 800 rpm contacts). 400 rpm contacts had little to no sulfidation at mating areas.
  - Switch operating mechanism and contact mechanisms were in good operating condition
  - One moving contact, 3C, had nickel deposits on surface, mostly in the mating area. Contacts are silver plated, and nickel should not be present (i.e., it is foreign material)
  - Source of nickel on 3C contact surface unknown; could be terminal screw plating or another unidentified source
- Conclusion
  - Evidence supports the postulated failure cause being high contact resistance due to presence of foreign material
  - The observed switch visual and functional condition would not have prompted a PM to clean contacts or replace the switch

Independent Failure Analysis – MPR & Exelon Power Labs

Manipulation of the FFSS during initial troubleshooting

- Initial FFSS contact 3-3C (400 RPM) checks following EDG Shutdown showed continuity across contact.
- With the switch still installed additional troubleshooting operated the FFSS 5 times.
- Following removal, the switch was delivered to the PSDM team and then to the system engineer.
- The switch was manipulated for visual inspection between removal and delivery to the system engineer.
- Pictures of 3-3C contact surfaces were taken on 6/3/21.
- After these pictures were taken the following was performed on the switch between 6/3/21 and 9/9/21
  - FFSS cycled for visual inspections of contacts.
  - Plate on front end of switch was removed for visual inspection Switch operator Mechanism and re-installed.
  - Main bolts loosened slightly (~ ¼") to attempt better visual inspection of contact surfaces and bolts were re-snugged.
- On 9/9/21 switch is prepared for shipment.



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Other Postulated Failure Modes

Failure Mechanism	Description	Disposition	Evaluation
Other component in the K2 circuit failed	The switch may be a potential "red herring" and the actual cause of the failure is unrelated to the FFSS.	Not a credible cause	Following the failed field flash, the FFSS was placed in the 800 rpm position. The field flashed successfully with all other variables and components in the circuit remaining the same.
Poor contact spring pressure	Reduced contact resistance is a function of increased spring pressure. If the spring weakens over time, the resistance may increase.	Not a credible cause	Measured resistance values indicate this is unlikely and an intermittent change in pressure is not expected. Spring pressure was measured by EPL and found all contact springs to be similar and installed correctly.
Switch in indeterminate position	The GE SBM type switch may be operated such that the handle sits in an indeterminate position that results in all sets of contacts being in the opened state.	Not a credible cause	The indeterminate state would have required the switch handle to be in between the 400 rpm and 800 rpm positions. The switch requires an intentional operation to be placed in such a state, as the mechanism is spring loaded and snaps to the desired position when just off center. Disassembly of the switch by EPL found the cams and springs that produce the snap action to be in excellent condition.
Contact Fretting	Contact fretting is a phenomenon that can lead to high contact resistance when mated contacts experience relative movement that can either damage the contact surface or generate insulating particulates that build up at the contact interface (Reference 2)	Not a credible cause	Pure silver plating is not typically susceptible to fretting due to silvers' high coefficient of friction that promotes vibrational stability (Reference 4). Furthermore, inspection by EPL indicates no visible evidence of contact fretting on the 3-3C contacts.

Additional Considerations

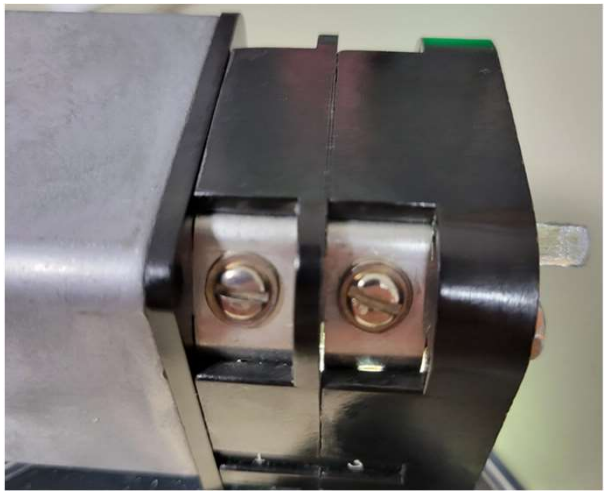
How a FFSS PM will not prevent failure by FM

- Presence of FM is a unique and unpredictable incident and not the result of a performance deficiency
- A FFSS Preventive Maintenance task to inspect is not likely to prevent failure by FM
  - Introduction of FM is not ruled by a timing function that is predictable
  - Example:
    - A FFSS PM to inspect is performed on Day X
    - FM is introduced in FFSS on Day X+1
    - FFSS fails performance on Day X+2
      - FFSS failure by FM NOT preventable by PM

Additional Considerations

Foreign Material Source

- Source of Foreign material is indeterminate
- The foreign material most likely came from within the switch (terminal screw)
  - Additional testing identified nickel on the FFSS terminal screws
  - Small openings exist that could allow material from the terminal screws to fall onto the switch contacts.
  - Switch is open to environment, but switch is configured so opening faces down
  - There is no forced air flow within the cabinet
  - A visual inspection of the cabinet was performed and the cabinet was found to be clean



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Additional Considerations

Operating Experience

- Three SBM switch failure OEs related to contact contamination and identified by Davis-Besse were reviewed and were determined to not be comparable to the FFSS failure at Davis-Besse based on the failure analysis performed.
- Plant 1:
  - Identified dirt, fuzz-like foreign material and contact surface sulfidation as the cause.
  - Davis-Besse FFSS was found to be in good material condition and no dirt or fuzz-like material was found, thus this failure is not comparable.
- Plant 2:
  - Identified contact corrosion, but no detailed failure analysis performed to support.
  - Since there was no detailed analysis performed of the failed switch this OE could not be compared to the failure analysis results of the Davis-Besse FFSS.
- Plant 3:
  - Identified contact contamination due to silver sulfide as the cause and lack of regular operation was identified as contributing (only during deep downpowers or forced outage maintenance).
  - Davis-Besse FFSS 400 RPM contacts were found to be significantly less fouled than the Plant 3 contact surfaces.

We have presented and provided written responses for:

- The assumed exposure period used in the NRC preliminary evaluation
- Actions that can be taken by operators to recover from a fast start failure of the EDG, including operator training on the FFSS
- The feasibility and reliability of the operator actions to recover from the fast start failure of the EDG, particularly during the dominant fire risk scenarios
- Conservatisms or non-conservatisms in your fire PRA that could affect the outcome of this evaluation
- Why you believe the contact contamination is not a credible cause of the FFSS that occurred during testing, including how inspection and preventive maintenance would not prevent the failure

Conclusions

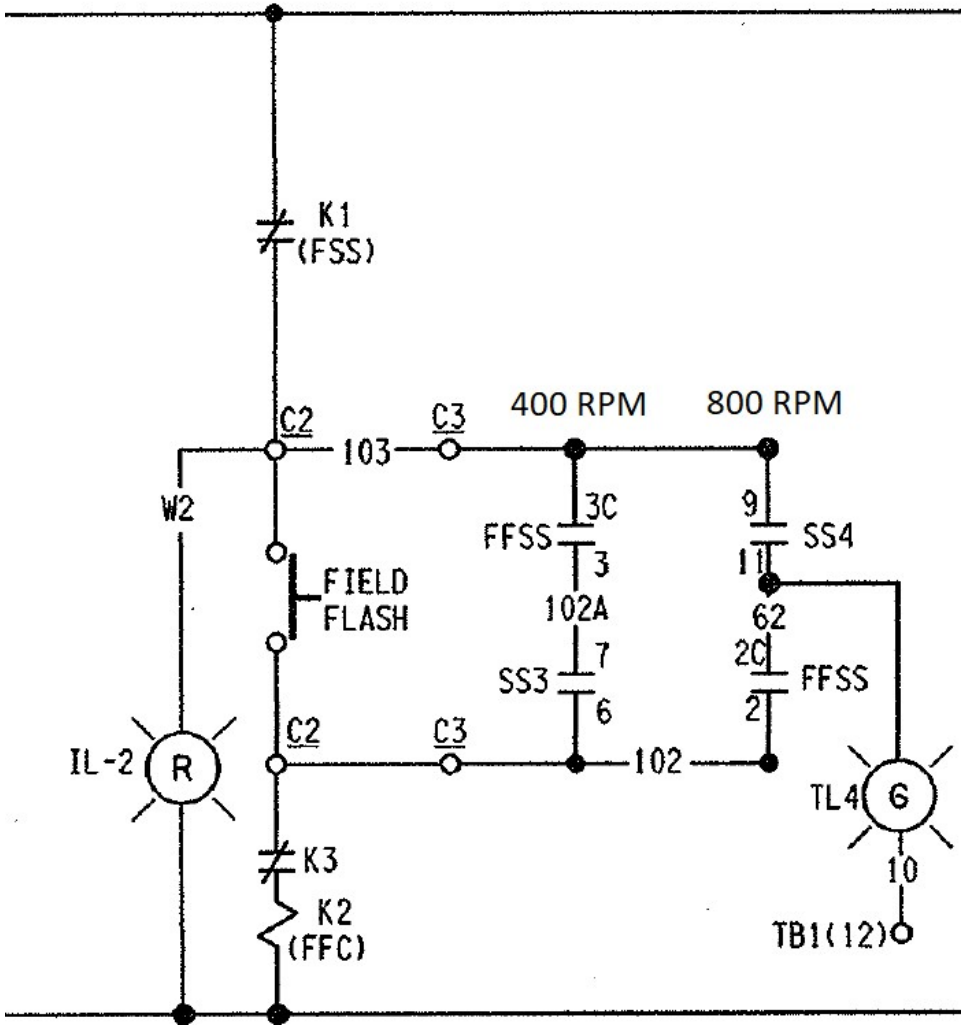
Summary of Energy Harbor Position

- Based on our PRA insights and review of conservatisms, the significance of the event would be White
- An independent failure analysis eliminated silver sulfidation as the cause of the FFSS failure and determined the failure was most likely caused by foreign material
- It is Davis-Besse's perspective that an inspection of the FFSS would not have prevented the failure of the EDG on May 27th
  - The significance of not having a PM schedule for the inspection of the FFSS should be Green (Very Low)

Questions?

Additional Information Slides

Field Flash Circuit



FFSS

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