Byron Station Single Phase Failure

NRC Meeting

March 22, 2012

Exelon Nuclear

Opening Remarks

Tim Tulon

Byron Site Vice President

Purpose

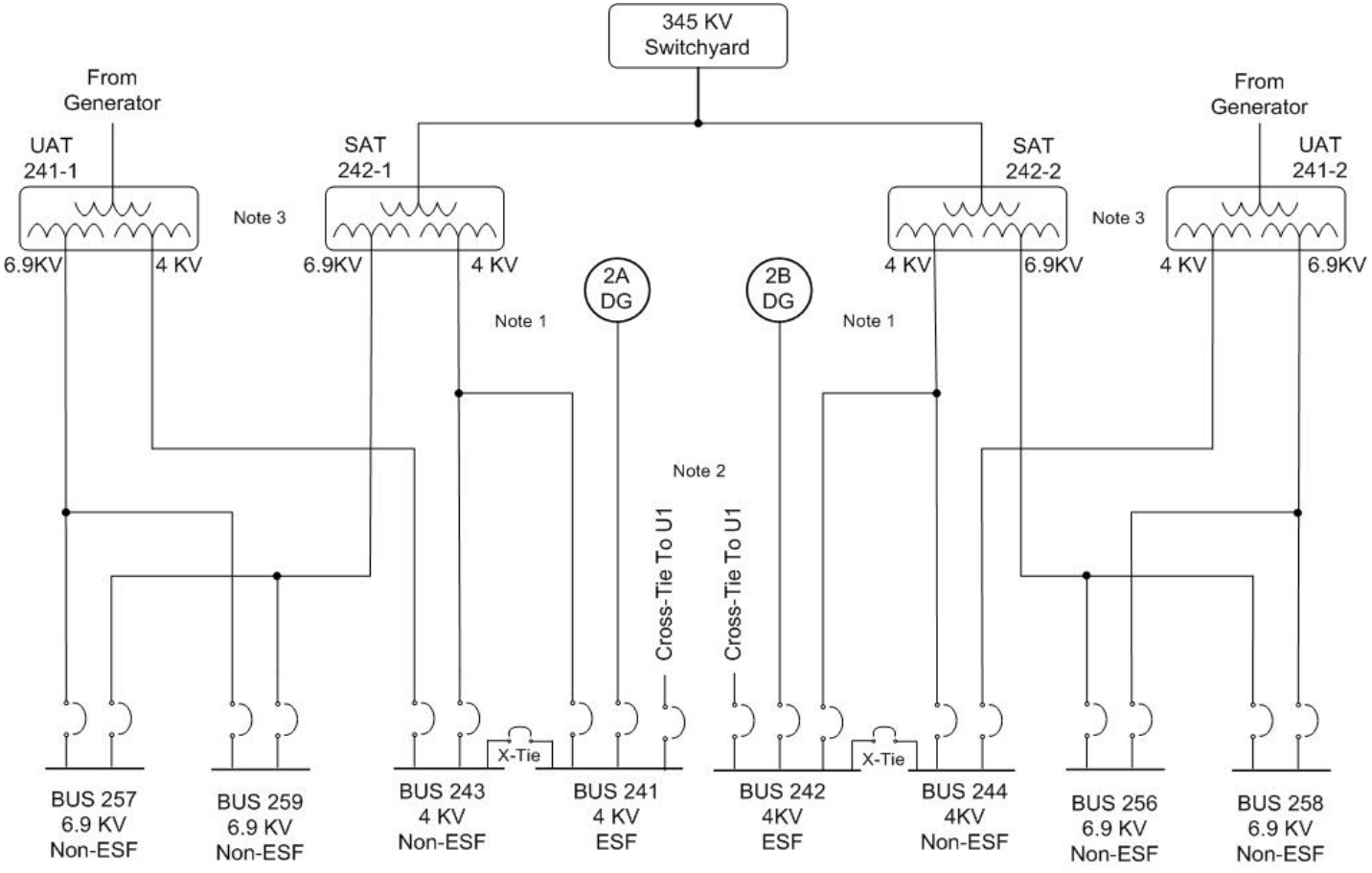
- ✓ Provide overview of loss of offsite power (LOOP) events
- ✓ Summarize failure analysis
- ✓ Discuss identified design vulnerability and extent of condition
- ✓ Describe design and licensing basis
- ✓ Highlight Exelon fleet planned actions and industry activities

Overview of Events and Failure Analysis

Elmer Hernandez

Byron Site Engineering Director

Byron Unit 2 Single Line Diagram



Notes:
1) 4KV ESF buses are powered by SAT and EDG
2) Second off-site source to 4KV ESF buses is through opposite unit cross-tie breakers
3) Non-ESF buses have UAT and SAT feeds with Fast Bus Transfer scheme

Recent Events

Unit 2

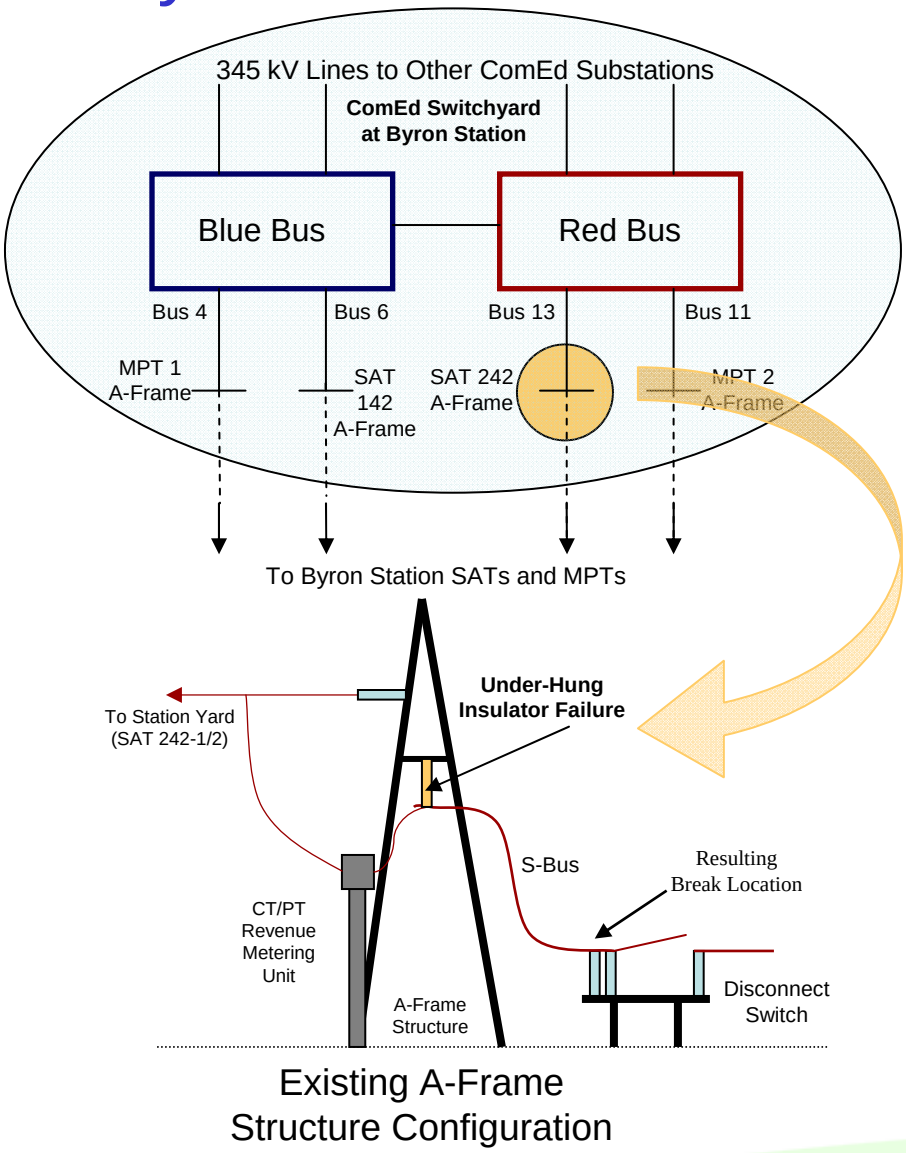
- ✓ January 30, 2012
- ✓ Mechanical failure of 345 kV under-hung porcelain insulator on SAT A-frame structure
- ✓ Open phase condition (primary grounded)
- ✓ LOOP
- ✓ Unusual Event
- ✓ Reactor trip
- ✓ Manual separation of ESF buses

Unit 1

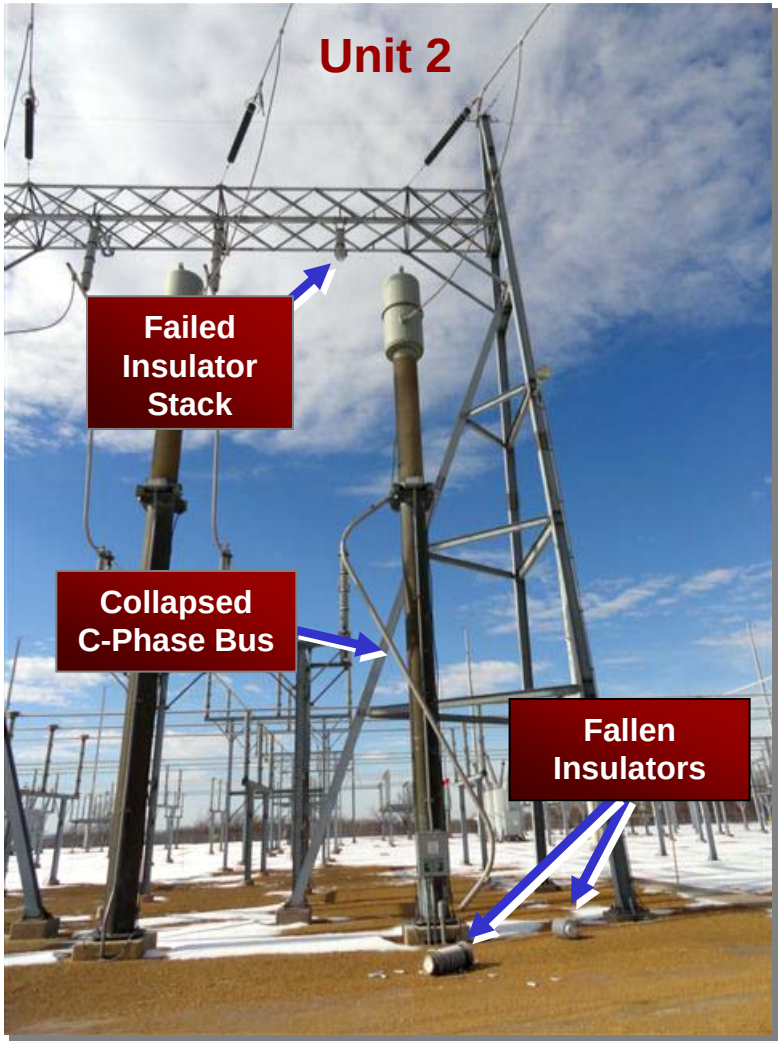
- ✓ February 28, 2012
- ✓ Mechanical failure of 345 kV under-hung porcelain insulator on SAT A-frame structure
- ✓ Open phase condition (345 kV faulted)
- ✓ LOOP
- ✓ Switchyard ground fault protective relaying isolated the fault and transferred BOP power to the UAT
- ✓ Unusual Event
- ✓ No reactor trip
- ✓ Automatic separation of ESF buses

Key Difference – No Fault versus Fault

Byron Unit 2 Insulator Failure



Existing A-Frame Structure Configuration



Failed Insulators

Unit 2 Failed Insulator

Unit 1 Failed Insulator

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Design Vulnerability

Scot Greenlee

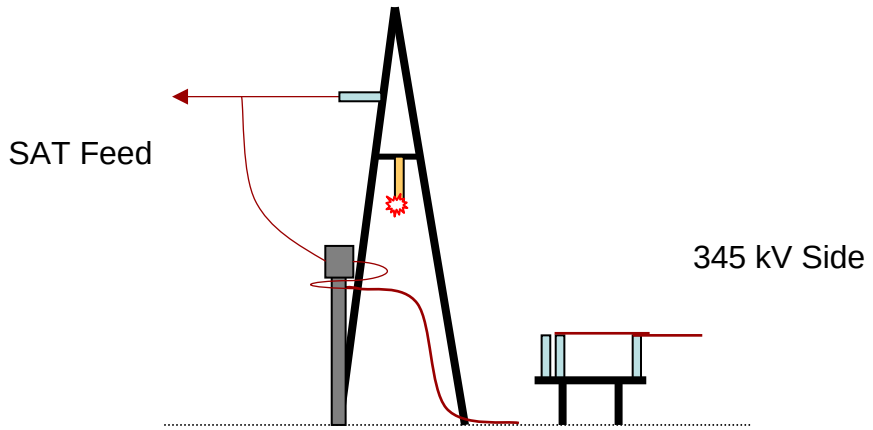
Corporate Vice President
Engineering

Design Vulnerability

- ✓ Failure of Unit 2 'C' Phase insulator resulted in an open circuit and voltage imbalance (high impedance ground on high side of SAT, open phase on the 345 kV side of disconnect)
  - Did not result in a fault that actuated the existing protective relay scheme
- ✓ Voltage imbalance propagated through the SATs to the ESF buses
  - Under voltage or degraded voltage relays did not initiate an EDG start signal because the relays sensed adequate voltage between 'A' and 'B' Phases

Impact of Open Phase

- ✓ Due to ground, significant voltage imbalance
  - 4.16 kV safety bus per unit (pu) voltage
    - Vab 1.0142 pu (on a 4160 V base)
    - Vbc 0.5912 pu (lasted 12 seconds, then cleared)
    - Vca 0.5870 pu



Impact of Open Phase – Not Grounded
(Beaver Valley Event Applied to Byron Station)

- ✓ Open phase 4.16 kV safety bus per unit voltage under light loading
  - Vab 1.0408 pu (on a 4160 V base)
  - Vbc 1.0407 pu
  - Vca 1.0180 pu
- ✓ Cannot detect by voltage magnitude

Design Vulnerability

- ✓ Under voltage relay schemes are not always able to detect a single open phase
- ✓ Although the plant was determined to be designed consistent with applicable design and regulatory requirements, it is recognized that additional actions should be taken to address this vulnerability

Exelon Fleet Actions

- ✓ Implemented compensatory measures to minimize operator recognition time for this event
- ✓ Communicated issue to Exelon fleet and industry
- ✓ Implemented changes, as necessary, for annunciation logic to detect and alarm the phase imbalance

Exelon Fleet Actions (cont.)

- ✓ Interactions with industry and A/Es identified no design currently exists to resolve this vulnerability
- ✓ Developing modification to detect the phase imbalance (open phase) condition and automatically separate the station busses from the offsite power source for this condition
  - Evaluated over 30 different potential designs
  - Prevent unnecessary trip of ESF bus power sources
  - Avoid impact on existing coordination scheme
  - Minimize unintended consequences

Industry Actions

- ✓ Industry briefed via INPO webcast to alert the industry to the vulnerability
- ✓ INPO issued Level 2 IER outlining industry actions (based on input from Exelon)
- ✓ NEI established a working group to evaluate vulnerability solutions – Ongoing weekly meetings
- ✓ NRC published Information Notice 2012-03, "Design Vulnerability in Electric Power System" (Byron Station event included)
- ✓ Exelon meeting with NRC to discuss the design vulnerability and industry implications
- ✓ INPO hosting April 2012 industry workshop to evaluate vulnerability solutions

Design/Licensing Basis

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Engineering

GDC 17

- ✓ Electric power from the transmission network to the onsite electric distribution system shall be supplied by:
  - Two physically independent circuits
  - Each circuit shall be designed to be available in sufficient time to assure that design conditions of the fuel and reactor coolant pressure boundary are not exceeded
  - One of these circuits shall be designed to be available within a few seconds following a loss-of-coolant accident (LOCA)
  - Onsite electrical power systems were designed to perform their safety function assuming a single failure
- ✓ Provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with:
  - The loss of power generated by the nuclear power unit,
  - The loss of power from the transmission network, or
  - The loss of power from the onsite electric power supplies

GDC 17 Conformance

- ✓ Byron Station electric power systems were designed to meet GDC 17
- ✓ Byron Station has two SATs per unit, sized to handle normal and accident loads
- ✓ Second GDC 17 offsite source is through the other unit's SATs
- ✓ Loss of feed to the unit SATs does not impact the other unit's SATs
- ✓ Studies performed address:
  - Both normal and accident conditions on loss of the unit
  - Loss of a transmission line feeding the switchyard Ring Bus
  - Voltage levels down to and including minimum grid voltages, coordinated through transmission system operator
  - Protection from short circuits

Degraded Voltage

- ✓ Grid events at Millstone in July 1976 demonstrated that sustained degraded voltage conditions on the grid can cause adverse effects
  - Further evaluation revealed that improper voltage protection logic can also cause adverse effects
- ✓ Degraded voltage event at ANO in September 1978 demonstrated that degraded voltage conditions could exist on Class 1E buses, even with normal grid voltages
  - NRC issued Information Notice 79-04 to inform the industry
  - Generic Letter 79-36 issued to identify specific actions to be taken by licensees
    - Requires utilities to install second level of under voltage relay protection
  - Branch Technical Position (BTP) PSB-1 was issued in July 1981
    - Incorporated NRC positions to meet GDC 17 requirements
    - Provides a design approach with respect to the selection of the time delay for the degraded voltage relay circuit
    - Voltage sensors were designed to meet requirements derived from IEEE 279-1971

BTP PSB-1

- ✓ During sustained degraded voltage condition, the degraded voltage relay design should:
  - Protect Class 1E buses and components
  - Separate Class 1E buses from the grid within a few seconds if an accident occurs
  - Automatically separate Class 1E buses from the power supply within a short interval, during normal plant operation
  - Minimize inadvertent separation from offsite power (e.g., coincident logic)
- ✓ Time delays should be optimized

BTP PSB-1 Conformance

- ✓ Byron Station has two distinct under voltage relay schemes
  - Loss of Power
    - Two out of two, Class 1E, relay logic
      - Drop out set at 69% of rated voltage
  - Degraded Voltage
    - Two out of two, Class 1E, relay logic
      - Minimum drop out set at 92.5% (3847.5 V)
      - Maximum reset set at 93.8% (3902.3 V)
    - Time Delay
- ✓ Byron Station Safety Evaluation Report (NUREG-0876) was issued in February 1982
  - Chapter 8 of the Byron Station FSAR was reviewed in accordance with the July 1981 edition of the SRP
  - Subsection 8.2.4 documents the NRC conclusion that the Byron Station design conforms with BTP PSB-1

Degraded Voltage Licensing Basis

- ✓ Confirmed that the design of the auxiliary power system meets GDC 17 requirements
- ✓ Confirmed the degraded voltage relay scheme is in compliance with BTP PSB-1 and pertinent requirements of IEEE-279
- ✓ Event revealed a design vulnerability that was not detected by the existing protective relay scheme
  - Existing SAT neutral overcurrent protection was not sensitive enough to detect the open phase condition
  - Detection down to the level of this type of failure is beyond the requirements of GDC 17 or BTP PSB-1
- ✓ Overall conclusion is that the Byron Station power system and degraded voltage design is consistent with the licensing basis

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Summary

Tim Tulon

Byron Site Vice President

Summary

- ✓ Events at Byron Station Units 1 and 2 were caused by an insulator failure in a single phase of offsite power
- ✓ Detection and mitigation of a single phase failure in the offsite power supply to an ESF bus is a design vulnerability outside scope of current design and licensing basis
- ✓ Exelon is taking aggressive fleet wide actions to address the design vulnerability, including working with the industry