

# Byron Station Single Phase Failure

NRC Meeting  
March 22, 2012

## Opening Remarks

Tim Tulon  
Byron Site Vice President

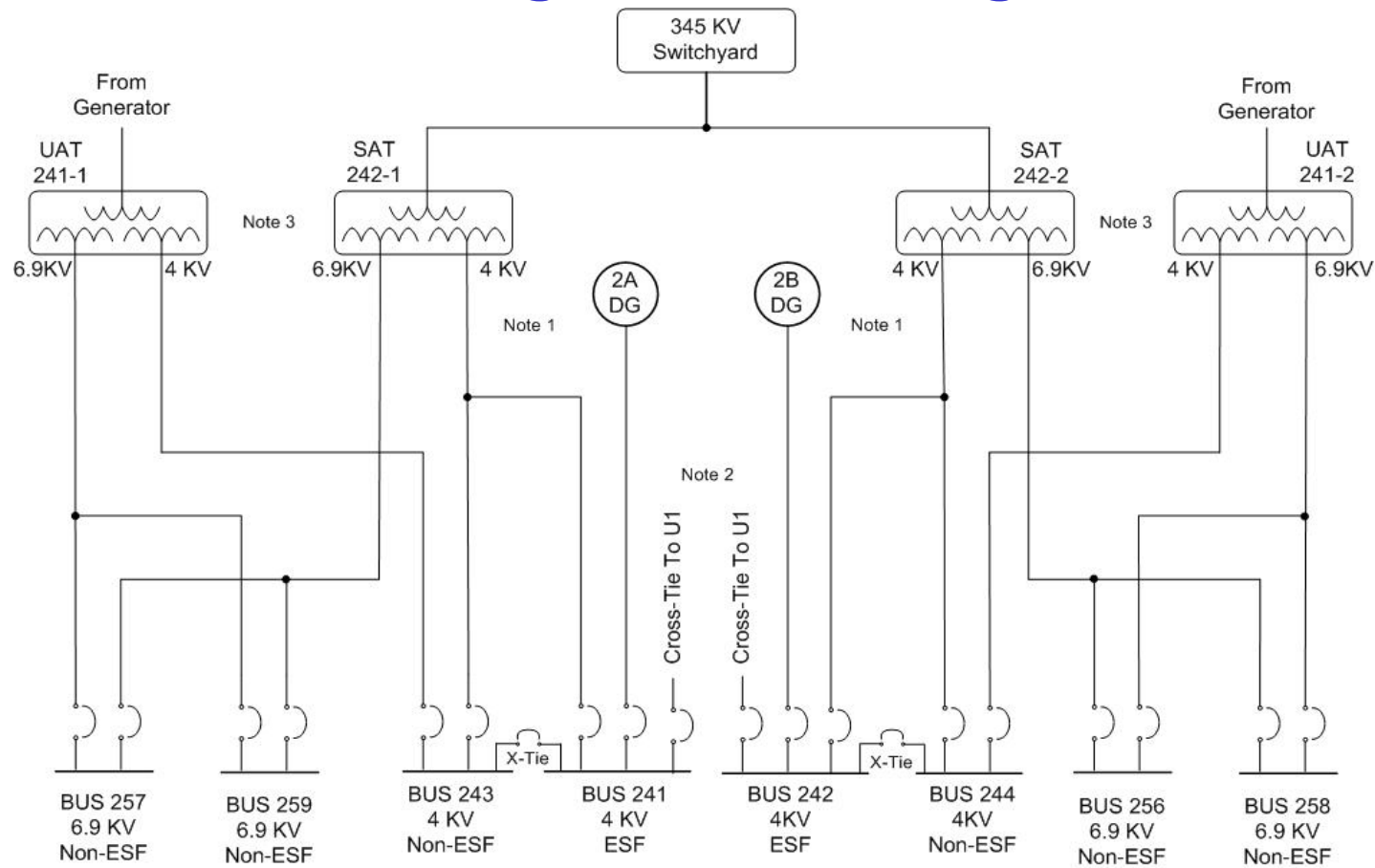
## Purpose

- ✓ 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

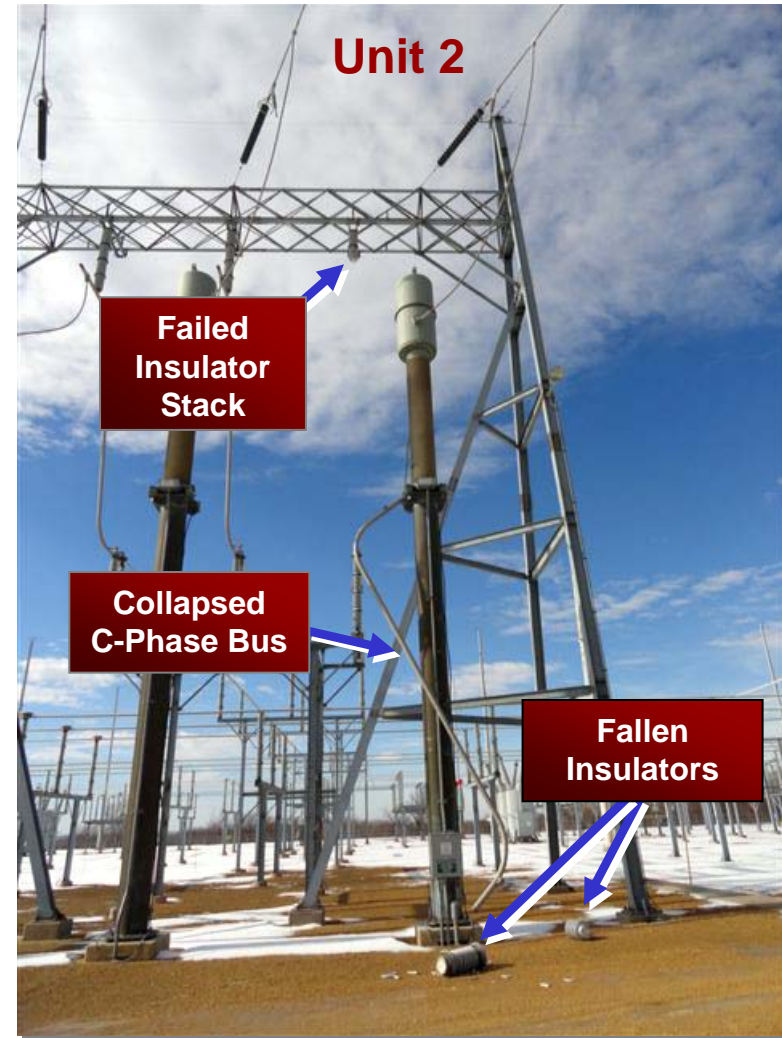
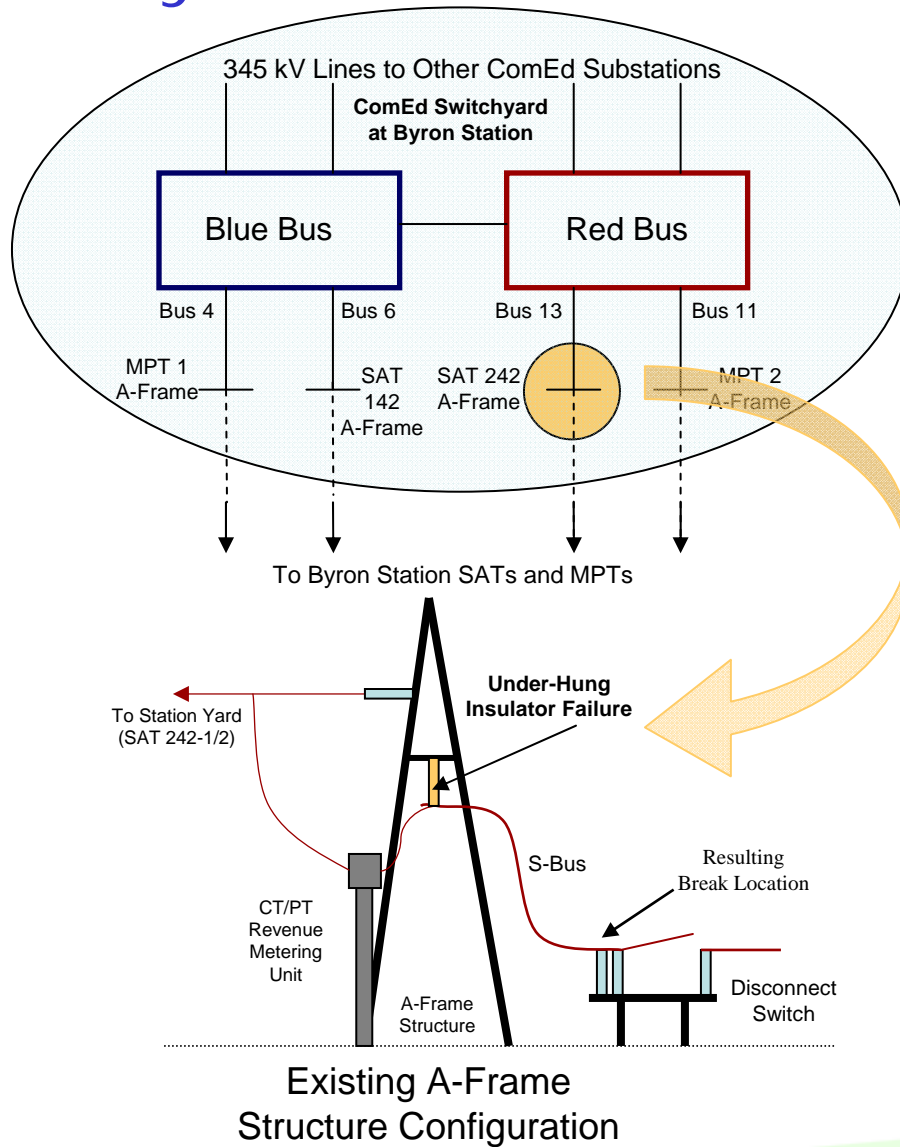
- ✓ January 30, 2012
- ✓ Mechanical failure of 345 kV under-hung porcelain insulator on SAT A-frame structure
- ✓ Open phase condition (primary grounded)
- ✓ LOOP
- ✓ Unusual Event
- ✓ Reactor trip
- ✓ Manual separation of ESF buses

### 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

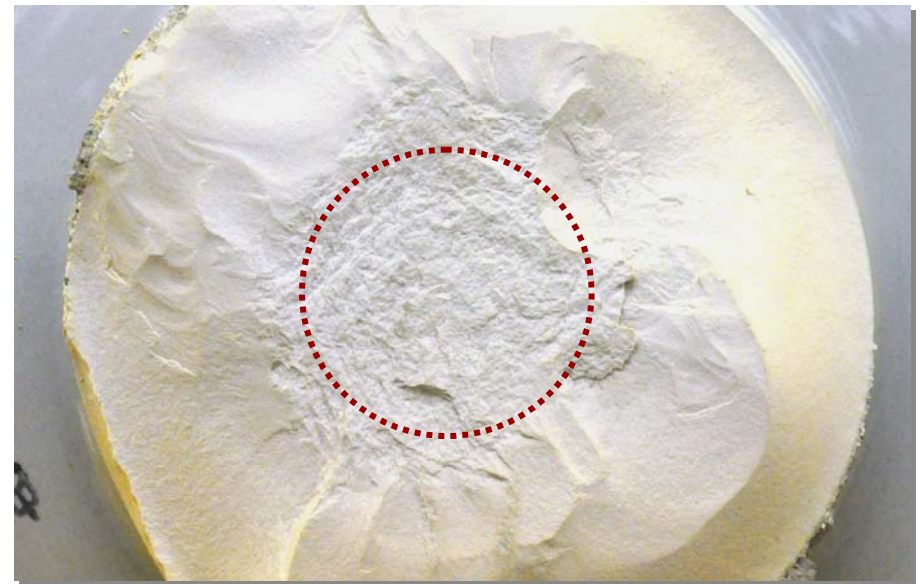


# Failed Insulators

**Unit 2 Failed Insulator**



**Unit 1 Failed Insulator**





## Design Vulnerability

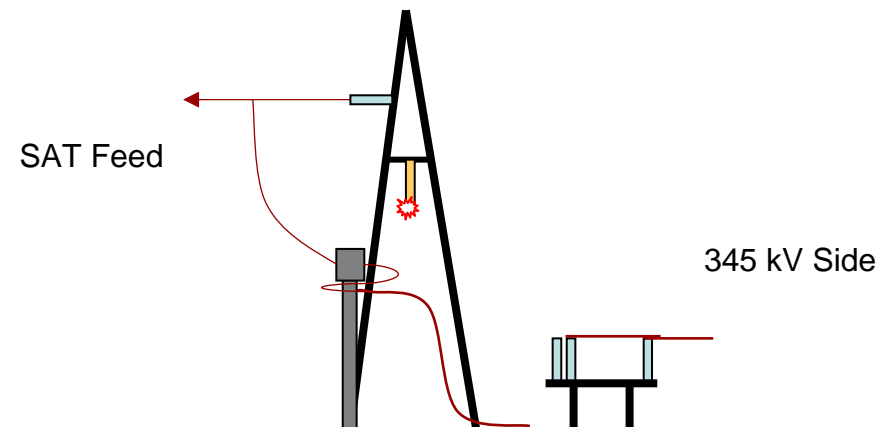
Scot Greenlee  
Corporate Vice President  
Engineering

## 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
    - $V_{ab}$  1.0142 pu (on a 4160 V base)
    - $V_{bc}$  0.5912 pu (lasted 12 seconds, then cleared)
    - $V_{ca}$  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
  - $V_{ab}$  1.0408 pu (on a 4160 V base)
  - $V_{bc}$  1.0407 pu
  - $V_{ca}$  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

Scot Greenlee  
Corporate Vice President  
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
      - o Drop out set at 69% of rated voltage
  - Degraded Voltage
    - Two out of two, Class 1E, relay logic
      - o Minimum drop out set at 92.5% (3847.5 V)
      - o 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

## Summary

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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