Effects of Medium-Voltage Switchgear Aging on Energetic Faults in Nuclear Power Plants

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by Robert J. Lofaro
Brookhaven National Laboratory

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J. Vora, Program Manager

Background

- In March 2001 the Maanshan nuclear power plant in Taiwan experienced a fire and station blackout due to an electrical energetic fault in a safety-related 4.16 kV switchgear. This plant is a PWR designed to U.S. regulations and standards.
- The initial fault caused explosions, arcing, smoke and ionized gases which propagated damage to adjacent safety-related 4.16 kV switchgear
- The event resulted in complete loss of one safety bus and loss of capability to feed the other safety bus.

Background (continued)

- The NRC evaluated this and five similar events in U.S. plants over the past 15 years.
  - Four events took place following a bus transfer and involved stuck or slow operation of the bus supply circuit breaker.
  - One event was due to degraded insulation
  - One event was due to a loose bus bar connection

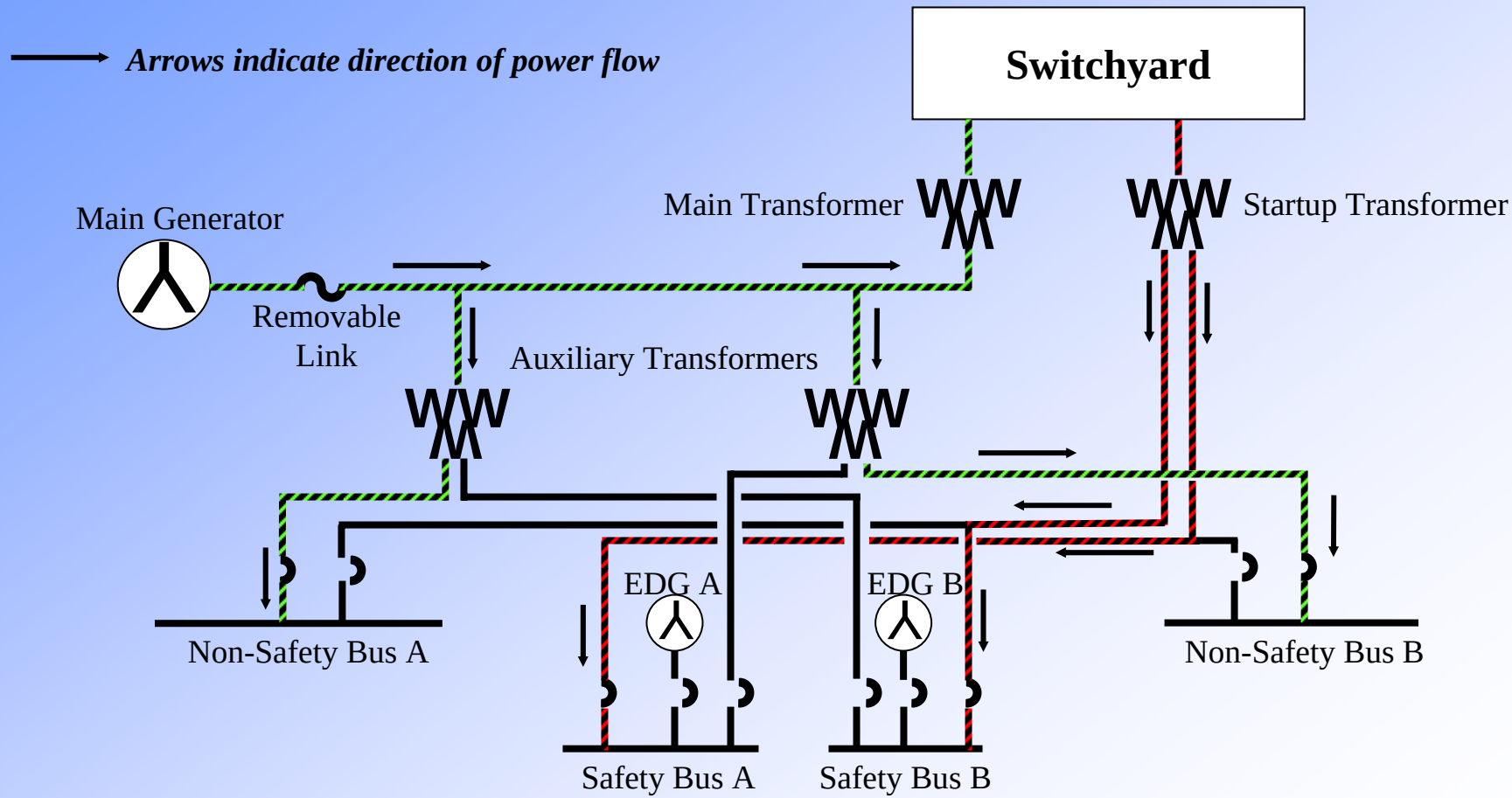
- Conditional Core Damage Frequency estimates showed these events could be important accident precursors (CCDF>1E-04)
  - Maanshan CCDF 2.2E-03
  - Two U.S. events CCDF 9E-05

What is an Energetic Fault?

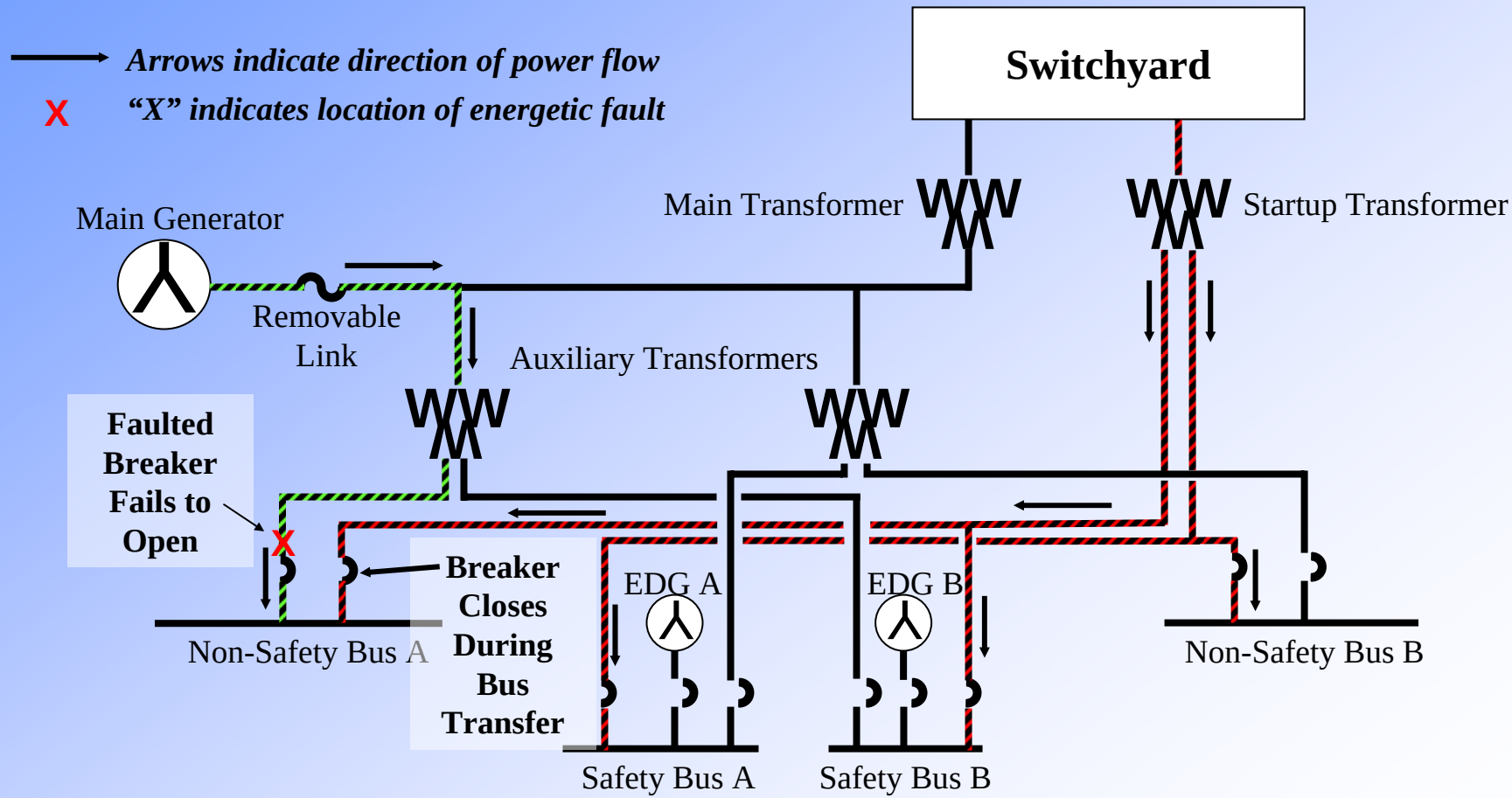
- An energetic fault is one in which an electrical short develops and is not immediately cleared by a protective device, such as a circuit breaker.

- The fault continues to be fed from an available power source, such as coast down of the plant's main generator, or by another large rotating machine in close proximity to the fault.

Power Flow during Normal Operation- Typical Unit Connected ac System



Power Flow for Postulated Energetic Fault Occurring During Bus Transfer Following Main Generator Trip



Results of an Energetic Fault

- Energetic faults result in fires and explosions that can cause severe damage to equipment and contribute to plant risk

Results of an energetic fault in a switchgear compartment

Objectives of this Study

- Energetic faults have occurred in U.S. nuclear power plant electrical distribution systems resulting in fires, explosions, and collateral damage.

- Aging of Class 1E equipment may increase the frequency and/or severity of energetic faults. This research program will evaluate the impact of aging on these events.

Phased Approach

- Phase I – Determine if aging of Class 1E power system components could increase the frequency or severity of energetic faults and evaluate the risk significance
- Phase II – Evaluate the impact of equipment aging and bus protective schemes on energetic faults, and identify potential mitigating actions

Phase I

- Task 1: Aging Assessment
  - Review operating experience to characterize aging of Class 1E components
    - LERs
    - NPRDS
    - EPIX
  - Visit at least one operating plant to obtain plant insights on aging and maintenance of Class 1E equipment

Phase I (continued)

- Task 2: Risk Sensitivity Study
  - Perform a risk sensitivity study to determine the impact of energetic faults resulting from aging of Class 1E equipment on plant risk
  - Use SPAR models currently available
  - Vary failure frequency of components to simulate the effects of aging

Phase II

- Task 3: System Level Evaluation of Electrical Distribution System
  - Quantify the impact of equipment aging on system performance related to energetic faults
    - Computer modeling of typical ac distribution system to evaluate potential initiators of energetic faults, such as switching transients
    - *ETAP* software program for modeling
  - Identify effective maintenance, monitoring practices to mitigate the effects of energetic faults

Phase II (continued)

- Task 4: Evaluation of Bus Protection Schemes
  - Evaluate impact of equipment aging on system protective schemes including
    - Circuit breaker and relay performance
    - System level protection coordination
    - Transient over-voltage protection
    - Fault current limiters