U.S.NRC
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Protecting People and the Environment

H.B. Robinson Fire Event
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Office of Nuclear Regulatory Research

Fire Research Branch

Presentation Overview

- Overview of fire event
- Sequence of events divided along electrical, fire, and plant response
  - Phase 1 (P1) : Initiated by initial fault and fire
  - Phase 2 (P2) : Initiated after plant stable from phase 1, by attempting to reset generator lockout relays
- Important insights from event

- References for presentation
  - Licensee Event Report, “Plant trip due to Electrical Fault,” May 27,2010, ADAMS#ML101530502
  - Augmented Inspection Team report, July 2, 2010, ADAMS # ML101830101

OVERVIEW

- At 18:52 on March 28, 2010, plant was operating at 99.5% power. No significant equipment out of service.
- Electrical fault and fire occurred on the 4kV feeder cable from Bus 4 to Bus 5
- Two successive fires occurred during the event, the latter which was a high energy arcing fault (HEAF).
- Failure of a 4kV breaker to isolate the initial fault led to other fires
- Plant response was complicated by equipment malfunctions and failure of the operating crew to diagnose plant conditions and properly control the plant

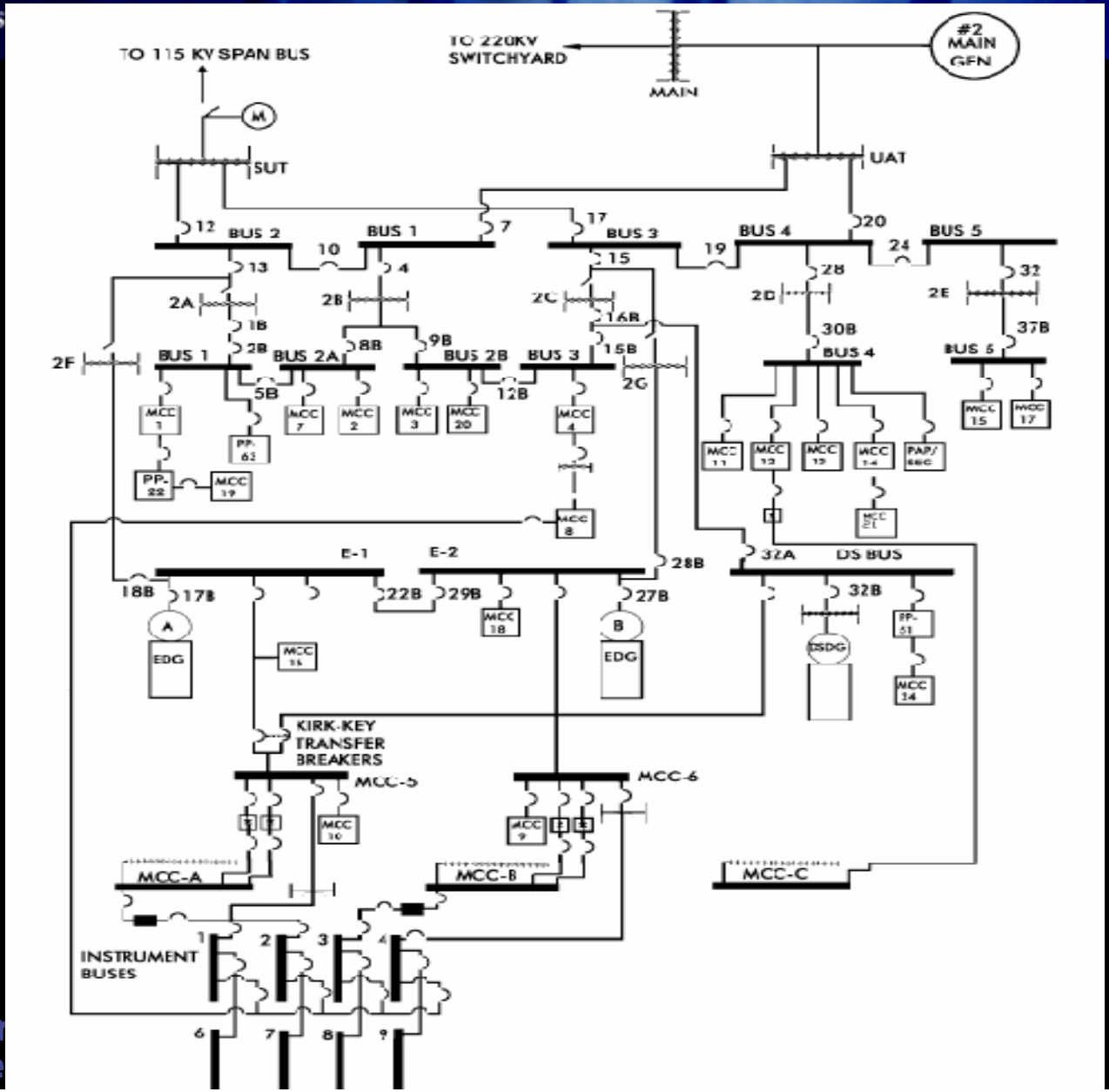
Sequence of Events: Electrical (P1)

- 18:52: Electrical fault and fire occurs on cable entering 4KV Bus 5. (Note that 4kV busses are not safety related)
- Tie breaker 52/24 fails to isolate fault (and remains closed during the event). Fault persists on 4kV busses 4 and 5.
- Unit Auxiliary Transformer (AUT) faulted prior to the timeout of bus 4 normal feeder breaker 52/20, causing a fast transfer of power for 4kV bus 4 from the UAT to the Start-Up Transformer, with power being fed through 4kV bus 3

Sequence of Events: Electrical P1 (cont)

- The resulting decrease in voltage on 4kV bus 3 initiated a start of “B” Emergency Diesel Generator (EDG). (This EDG powers safety related 480V bus E-2).
- Breaker 52/19 opened, isolating the faulted 4kV busses 4 and 5.
- Plant electrically stable once fault isolated (sequence of events terminates in approximately 20 seconds)

- Electrical Schematic



Sequence of Events: Fire (P1)

- 18:52: Fire from electrical fault occurred on a 4kV feeder cable where the cable entered the housing for Bus 5
- 18:57: Fire in bus 5 extinguished by two dry chemical extinguishers. (Fire reflashed several times)
- 19:02: Security personnel observed smoke and flames emanating from vents in the back of breaker 52/24 cubicle in 4kV electrical bus room (in turbine building one floor above 4kV bus 5). They extinguished the fire within 3 -5 minutes by discharging two fire extinguishers into the upper and lower vents of the cubicle.

Sequence of Events: Fire P1 (cont)

- 19:38: Fire Protection Auxiliary Operator notified Fire Brigade Incident Commander that security personnel had extinguished a fire in 4kV electrical bus room

- 20:34: Plant fire brigade report “all clear” for the 4kV electrical bus room and bus 5 area. (Fire alarms in the 4kV electrical bus room were not reset to allow subsequent detection of fires)

Sequence of Events: Plant Response (P1)

- 18:52: After electrical transient, plant left in following configuration:
  - Charging pumps “A” and “C” de-energized,
  - Flow Control Valve (FCV) for Component Cooling Water (CCW) closed since 480V bus E-2 temporarily lost power (isolated cooling to the RCP thermal barrier.)
  - 480V bus E-2 transferred to “B” EDG.
  - All Moisture Separator Reheater (MSR) Drain Tank Alternate Drain valves and MSR Timer valves failed open (will produce cooldown of Reactor Coolant System). Also valves could not be remotely closed.

Sequence of Events: Plant Response (P1) (cont)

- 18:53: Operators started charging pumps “B” and “C”.
- 18:58: Pressurizer level decreased off-scale by Control Room (CR) indications
- 19:00: Safety Injection (SI) actuated automatically due to low RCS pressure. Volume Control Tank (VCT) level decreased to setpoint for automatic transfer of charging pump suction to Refueling Water Storage Tank (RWST). However, transfer did not occur
- 19:12: VCT level decreases to approximately 2-3 inches (lowest in event)

Sequence of Events: Plant Response (P1) (cont)

- 19:13: SI pumps stopped injecting water into RCS.
- 19:24: “B” Reactor Coolant Pump (RCP) bearing high temperature annunciator alarmed.
- 19:25: Power lost to Instrument bus 3. Loss of power, coincident with low RCS average temperature, caused Main Steam Isolation Valves to close, terminating the uncontrolled RCS cooldown. Minutes later, instrument bus 3 re-energized.
- 19:30: “A” RCP bearing high temperature annunciator alarmed. “C” RCP bearing alarms 3 minutes later.

Sequence of Events: Plant Response (P1) (cont)

- 19:31: Pressurizer level increased on-scale by CR indications. FCV for CCW re-opened by CR operators
- 19:36: "A", "B", and "C" RCP bearing high temperature alarm cleared over next 8 minutes
- 19:37: Charging header pressure fluctuated rapidly, indicating that charging header flow was lost
- 19:46: Operator diagnose that suction from VCT had not realigned to RWST

Sequence of Events: Plant Response (P1) (cont)

- 19:50: Operators realigned suction to RWST
- 19:53: Operators restart “C” charging pump
- 20:44: Operators secured SI pumps
- 21:26: Operators transitioned to Post Trip Stabilization procedure

Sequence of Events: Electrical (P2)

- 22:34: Operators attempted to reset generator lockout relays. (locked in UAT fault pressure trip signal would not allow logic to be reset.) Lockout relay would not latch into reset position, and was released back to its tripped position by the operator. Upon release of handle, circuit breaker 52/19 was reset, arming the breaker to close again. 4kV bus 4 was repowered and the faulted cable re-energized.
- 22:35: Grounds occur on “A” and “B” DC busses. Ground on “A” DC train was caused by damage to main generator hydrogen control panel. Ground on “B” DC train caused by damage to bus 4.

Sequence of Events: Electrical (P2) (cont)

- 23:10: Plant personnel removed control power from 4kV busses 3, 4, and 5 in order to clear the ground on the “B” DC train.
- 23:29: Plant personnel opened DC breaker DP-A-15, Generator lockout relay 86P, in order to isolate a ground on 125V MCC DC “A”.
- 00:05: Plant personnel opened DC breaker to the Hydrogen Control Panel, clearing the ground on the “A” DC train.

Sequence of Events: Fire (P2)

- 22:34: Reclosing breaker re-energized bus 4 and initiated a fault at breaker 52/24. An arc flash breached the back of 52/24 cubicle, damaging surrounding equipment
- 22:40: Field personnel reported a fire at breaker 52/24. Operators dispatched fire brigade
- 22:50: Plant requested assistance from off site fire department
- 23:00: Plant fire brigade members entered 4kV electrical bus room to fight fire at breaker 52/24.

Sequence of Events: Fire (P2) (cont)

- 23:01: Fire brigade extinguished fire using 2 dry chemical fire extinguishers, began ventilating the area, and established a reflash watch.
- 01:00: Reflash watch was secured based on satisfactory temperature readings obtained from thermal imaging.
- 01:30: Plant fire brigade reported “all clear” for breaker 52/24.

Damaged Conduits from Bus 4 to Bus 5



52/24 Breaker HEAF at Back of Bus 4



Sequence of Events: Plant Response (P2)

- 23:00: Shift Manager determined that fire affected two trains of safety related DC equipment and declared an Alert
- (See electrical scenario for operator actions on DC power)
- 01:30: Alert terminated

Important Insights from Event

- Failure of Circuit Breaker
- Faulted Cable Specifications
- Charging Pump Realignment to RWST
- Closure of FCV for CCW
- Power Interruption to Instrument Bus 3
- Need for HEAF Program

Failure of Circuit Breaker

- Following event, licensee determined that one of control power fuses in the breaker trip circuit was failed. Breaker trip circuit deenergized, preventing circuit breaker from tripping.
  - Licensee personnel assumed the problem was light socket since replacing bulb did not repair indicating light. Work requests to repair socket were canceled.
  - Operations, maintenance, and engineering personnel did not fully understand significance of deenergized breaker indicating light
- NRC issued Information Notice 2010-09, dated April 14, 2010, "Importance of Understanding Circuit Breaker Control Panel Indications"

Faulted Cable Specifications

- Faulted cable did not meet many of the specifications for the design change that installed cable. This contributed to cable failure
  - Cable specifications did not meet standard specification L2-E-035 in Bill of Materials for “5,000 Volt Power Cable.”
  - Differences between cable and Standard Include: Cable installed had (1) uncoated conductors, (2) no jacket, (3) made no claims as to fire propagation properties, and (4) had inadequate insulation
- Poor quality control over non-safety related modification process for installing cable

Charging Pump Realignment to RWST

- Charging pump suction did not realign to RWST upon VCT low level setpoint
  - One of the two comparators which energizes a relay related to the VCT level transmitters was configured improperly upon installation.
  - Installed in 2008
  - Was not detected because of limited scope of post-installation testing.

Closure of FCV for CCW

- Valve closed when power to safety related 480V Bus E-2 was transferred to EDG.
- Plant staff unaware that FCV would close on a momentary loss of power.
  - Power for control circuit was Instrument Bus 4 (powered by 480V Bus E-2), rather than instrument bus 1 as procedure indicated.
  - Loss of power closed a contact in close circuit of FCV. When 480 Bus E-2 was re-energized, contacts sealed in to completely close valve

Power Interruption to Instrument Bus 3

- Loss of instrument bus 3 created condition, coincident with the RCS Low T_{avg} signal due to RCS cooldown, that generated a Main Steam Line Isolation signal
  - All MSIVs automatically closed
- Terminated the RCS cooldown in the event (operators failed to recognize uncontrolled RCS cooldown)

Need for HEAF Program

- NUREG/CR-6850 (Appendix M) “Zone Of Influence” potentially non-conservative
- Information is currently being assessed
- Have another HEAF event; research and testing needed for predictive modeling