In the Eye of the Hurricane: Super Storm Sandy PSEG Nuclear Preparations, Impacts and Lessons Learned

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Salem and Hope Creek Generating Stations

Forecast vs. Actual

- **Forecasts** on October 29th at 6 pm called for:
  - Additional rainfall of another ¼ - ¾”
  - Winds through midnight will be sustained at 30-45 mph with gusts of 45-65 mph
  - Overnight winds will be sustained at 15-30 mph with gusts of 30-50 mph
  - Storm surge will be 3-6’ and will peak around midnight. Storm surge should recede by mid morning

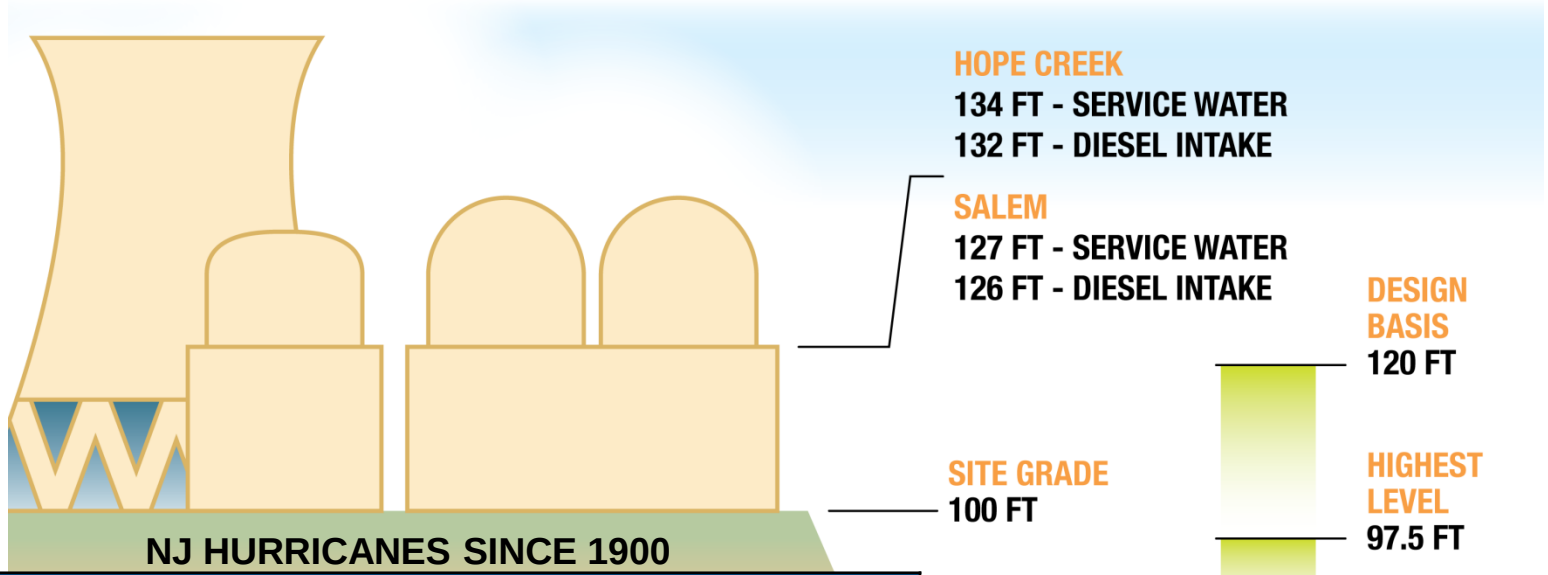
Forecast vs. Actual

- **Actual** weather from landfall at 8 pm through the early morning
  - Rainfall was consistent with forecast
  - Winds through the evening were 40-60 mph with gusts upon landfall of up to 90 mph
  - Winds were sustained through the night precluding storm restoration to begin until 7 am
  - Storm surge ranged from 11-13.6', causing widespread flooding and devastation to the region

PSEG Nuclear Unit Status

- Hope Creek - 100% Rated Thermal Power
- Salem Unit 1- 100% Rated Thermal Power
- Salem Unit 2 (two days prior to Sandy's arrival):
  - Defueled, Full Core offload, in Spent Fuel Pool
  - Defueled Mid Loop
  - Single Source of Off-site power
  - Major Equipment OOS
    - 2B Emergency Diesel Generator, 2B Vital Bus OOS
    - 2B 125V DC batteries
    - 21 SW Nuclear Header

Salem and Hope Creek Flood Design



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SEVERITY	SPEED (MPH)	OCCURANCES
Category 1	74 – 95 MPH	1
Category 2	96 – 110 MPH	0
Category 3	111 – 130 MPH	0
Category 4	131 – 155 MPH	0
Category 5	> 155 MPH	0

Salem and Hope Creek Shutdown Criteria

- IF AT ANY TIME the river level is >98.5 ft, THEN INITIATE actions to place the Unit in Mode 3 within 6 hours and in Mode 5 within the next 30 hours.
- IF hurricane force winds are imminent, THEN **INITIATE** preparations such that the Unit is in Hot Standby (Mode 3) at least two hours prior to the projected arrival of hurricane force winds.

Salem and Hope Creek Emergency Action Levels (EALs)

- Unusual Event (UE)
  - Delaware River level reaches 99.5 feet at Salem units, 99.5 feet at Hope Creek
  - Average Wind Speed >95 mph for any elevation
- Alert – Escalation with UE conditions
  - Visible damage to Safety Related Structures

Implementation of Severe Weather Guidelines – Phase 1 (T-3)

- Operations
  - Inspect station blackout equipment
  - Verify remote shutdown panel communications
  - Indication and switch alignment
  - Hope Creek blockhouse sump pump staged

Implementation of Severe Weather Guidelines – Phase 1 (T-3)

- Maintenance
  - Protect spare equipment required for recovery
  - Inspect/remove/secure outside areas for potential missiles
  - Staging of sump pumps and sandbags
  - Availability of emergency supplies like flashlights, potable water, etc.

Implementation of Severe Weather Guidelines - Phase 2 (T-2)

- Site walkdowns
- Verifying water tight doors
- Emergency diesel generator availability
- Return Major Plant Equipment for Shutdown Safety
- Ensuring water intakes prepared for severe weather
- Address potential staffing requirement

Staffing requirements

Only essential personnel req'd to report

- Specific responders from two ERO teams
- Operations Support Center (OSCs)
- Technical Support Center (TSC)
- Emergency Operations Facility (EOF)

Implementation of Severe Weather Guidelines - Phase 3 (T-0)

- Close watertight doors
- Relocate personnel
- Implement preplanned sandbagging
- Relocate vehicles to shelter
- Establish Fire Protection command post
- Complete various Service Water Bay penetration repairs

Superstorm Sandy impacts

- Hope Creek - Remained at 100%, HC output greater than demand on PJM
- Salem Unit 1 manually taken offline at 1:09 am (5 day forced outage)
  - Four of the six circulating water pumps no longer available
  - Heavy debris, waves resulted in Travelling water screens stopping
- Non-vital Switching Station lost due to water intrusion
  - Loss of power to several buildings onsite
  - Lost onsite intranet, phones, met tower data to Salem control rooms

Staffing Requirements

- Suspended Salem Unit 2 refueling outage activities on Sunday evening, October 28
  - All equipment, except SW header, returned to Operations
  - Reactor Cavity flooded up to Refueling level for defense in depth
  - All contractors left site that weekend
  - First time in operating history to suspended refueling outage

Superstorm Sandy Lessons Learned

- Equipment Issues / Storm Preparations
  - Substation enclosures are susceptible to water intrusion
  - Lack of outage contingencies for loss of building capabilities
  - Lack of adequate sleeping arrangements for essential personnel.
  - Access road monitoring and shoring – extra fill / seawall

Lessons Learned – Root Cause

- Abnormal Procedure Guidance
  - Inadequate severe weather guidance in Abnormal procedure for wind speed, direction, grassing levels, tide, etc.
  - Decision Making on unit power did not account for wave action effects
  - Severe Weather Guide – No single designated information source for decision-making

Lessons Learned – Corrective actions

- Previous Shutdown Criteria
  - IF AT ANY TIME river level is >98.5 ft…
    - Maximum Tide was 97.2 feet
  - IF hurricane force winds are imminent...
    - Maximum average wind speed was 59 miles per hour
    - Wind direction shifted 180° in four hours directed at CWIS

Lessons Learned – Corrective actions

- New Shutdown Criteria
  - CW intake degradation index
    - Uses grassing, tide, wind speed and direction
    - Guidance to shutdown as a composite
  - If hurricane is to pass within 50 miles of site - shutdown