GE Hitachi Nuclear Energy

ESBWR Design Capabilities that Address NRC Bulletin 2012-01

Design Vulnerability in Electric Power System - Single Phase Open Circuit Offsite HV Power Condition

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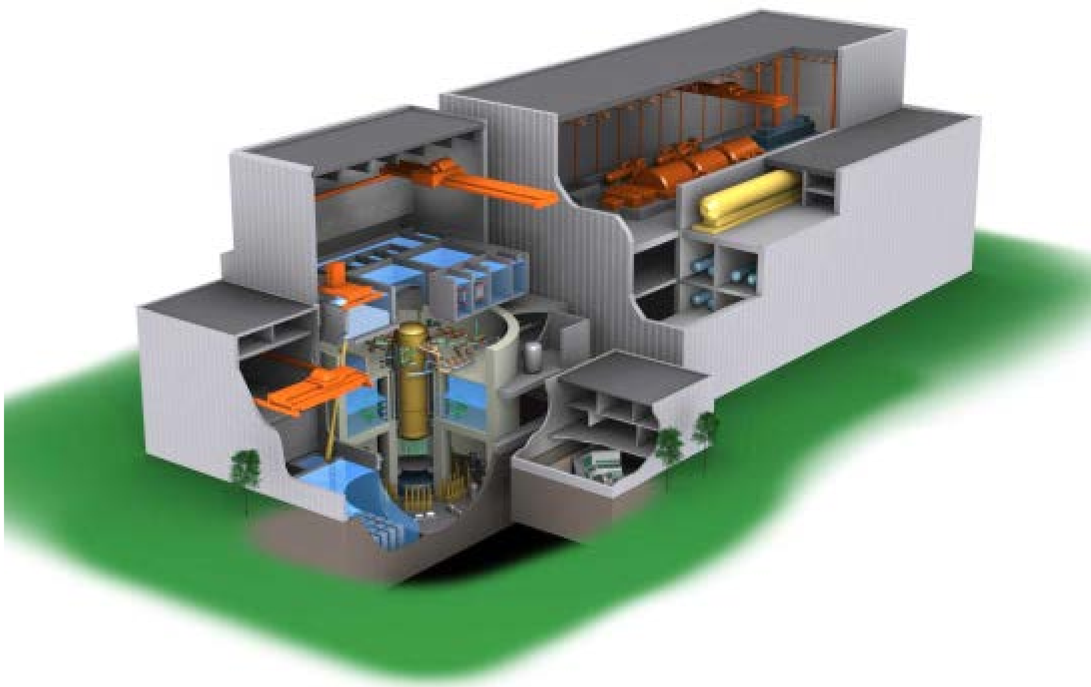

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ESBWR Capabilities With Respect to NRC Bulletin 2012-01- Summary of Conclusions

No changes or additions to the ESBWR electrical system design are required to be compliant with NRC Bulletin 2012-01

As applicable to passive plants, the ESBWR will be fully compliant with NRC Bulletin 2012-01, Design Vulnerability in Electric Power System

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ESBWR Capabilities wrt NRC Bulletin 2012 - 01- Detailed Summary and Conclusions

Neither ESBWR DCD figures nor text require change as a result of Bulletin 2012-01.

The ESBWR detailed design approaches described herein will be documented in the ESBWR Electrical Systems Design Requirements document (already in plans and requirements documents).

The ESBWR electrical systems design has anticipated the NRC concerns in the ESBWR detailed design.

For Plant Safety:

- ESBWR safety functionality is unaffected by the concerns expressed in NRC Bulletin 2012–01.
- ESBWR safety functionality does not depend on off-site preferred power or on-site diesel generated power.
- ESBWR will achieve a safe, stable shutdown condition with or without safety or nonsafety-related power without operator action and can maintain that state for >72 hours and beyond if water is added to the IC/PCCS and spent fuel pools.
- ESBWR passive design allows for either no operator action for 72 hours after an electrical systems loss or alternatively allows the operator more time to evaluate and manually restore power to the plant.

For Diversity and Defense in Depth:

- ESBWR complies with GDC-17 for two physically independent circuits of offsite power; whether offsite or within the plant electrical system, a fault in the normal preferred high or medium voltage power circuits would result in an automatic transfer to the alternate preferred power circuit.
- Because the ESBWR off-site and on-site high and medium voltage circuits will be monitored and alarmed in the Main Control Room, operator manual action can address an issue and take actions to maintain power to nonsafety-related plant loads in the unlikely event that the automatic logic did not maintain power continuity (safety-related plant loads are continuous without operator action).
- Normally the ESBWR 100% load reject capability will allow the main generator to maintain house loads should the normal preferred circuits be lost. A turbine trip normally allows the normal preferred power sources to continue powering house loads but should the normal preferred power circuits be lost and the turbine tripped, the plant will automatically switch to the alternate preferred power source.

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NRC Bulletin 2012-01 Trigger – Byron NGS Event

The NRC bulletin concern is traced to an event where a nuclear plant offsite power feed lost one of the three phases to the auxiliary transformers.

Although the plant tripped as required, the lost phase was not detected by the equipment designed to separate the unit from offsite power and initiate the safety-related diesel generators.

The lost phase caused safety-related equipment to trip such that it was unavailable when the diesel generators were automatically started and supplying all three phases of power.

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NRC Bulletin 2012-01 – 3 Key Questions

The basis of the NRC concern is that unmonitored on or offsite electrical system conditions could cause the loss of the redundant GDC-17 preferred power feeds to the safety busses and that safety equipment could be damaged.

The concern leads to the following three questions of the NRC bulletin:

- Describe the protection scheme design for important to safety buses (non-safety or safety-related) to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on credited offsite power circuits.
- If the important to safety buses are not powered by offsite power sources during at power condition, then explain how the surveillance tests are performed to verify that a single-phase open circuit condition or high impedance ground fault condition on an off-site power circuit is detected.
- Describe the plant operating procedures, including off-normal operating procedures, that specifically call for verification of the voltages on all three phases of the ESF buses.

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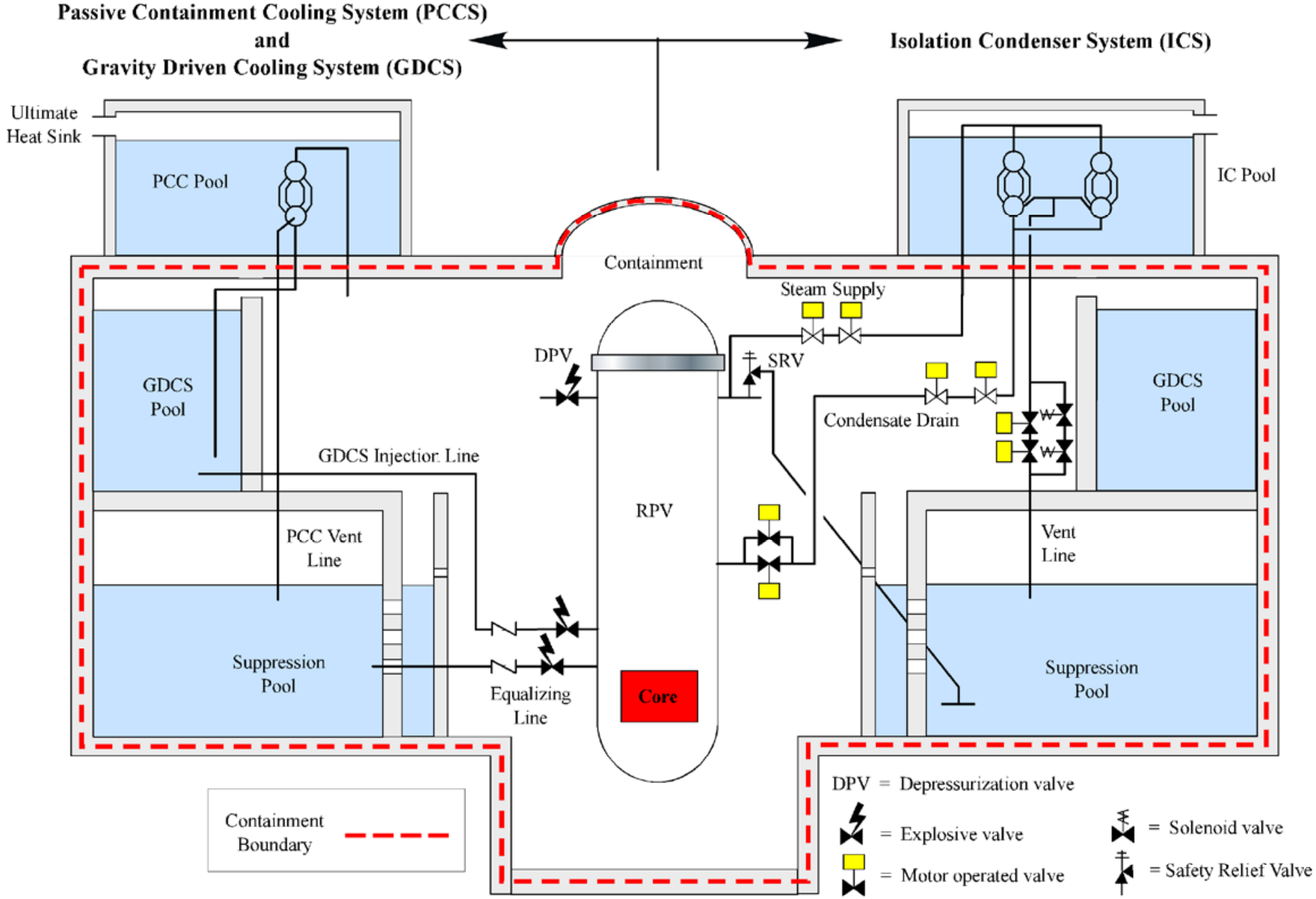
ESBWR IS A Gen III+ PASSIVE PLANT
Reactor Safety Systems Overview



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ESBWR is a Gen III+ Passive Plant

Before a detailed response to Bulletin 2012-01 is described, it is important to understand that the ESBWR is not an "active" plant and relies only safety-related passive systems to respond to transients and accidents.

Active AC power is not required nor are safety-related diesel generators provided for these events.

- Provision of offsite preferred power or on-site diesel generator power to the ESBWR safety electrical busses is not required for safety.
- ESBWR will actively or passively scram on loss of off-site power, isolate containment, and provide vessel decay heat removal whatever the status of off-site or on-site nonsafety-related power.
- ESBWR has no active safety-related medium or low voltage motors, pumps, fans or valves required to perform a safety function.
- Unlike other Gen III+ plants, ESBWR has no recirculation or primary coolant pumps dependent on stable operation of the offsite power grid. The ESBWR has no equipment dependent on off-site or diesel generated on-site AC power that is needed for safety functionality.

Concerns identified in NRC Bulletin 2012-01 do not affect safety-related functions of the ESBWR passive plant specifically.

ESBWR is a Gen III+ Passive Plant - Plant Response to Bulletin 2012-01 Events

If safety-related power is lost, failsafe Reactor Trip and Isolation Function (RTIF) will scram the plant.

- Safety-related AC power is required to NOT scram.

If off-site power is lost and safety power is not lost, RTIF will scram the plant.

If safety-related AC power is lost, isolation condensers will initiate.

If off-site power is lost and safety-related power is not lost, SSLC/ESF will initiate isolation condensers.

- Safety-related AC power is required to not initiate.

PCCS is always "on" and does not require initiation.

With or without power- ESBWR transitions to safe, stable shutdown with reactor scram, containment isolation, and passive reactor decay heat removal.

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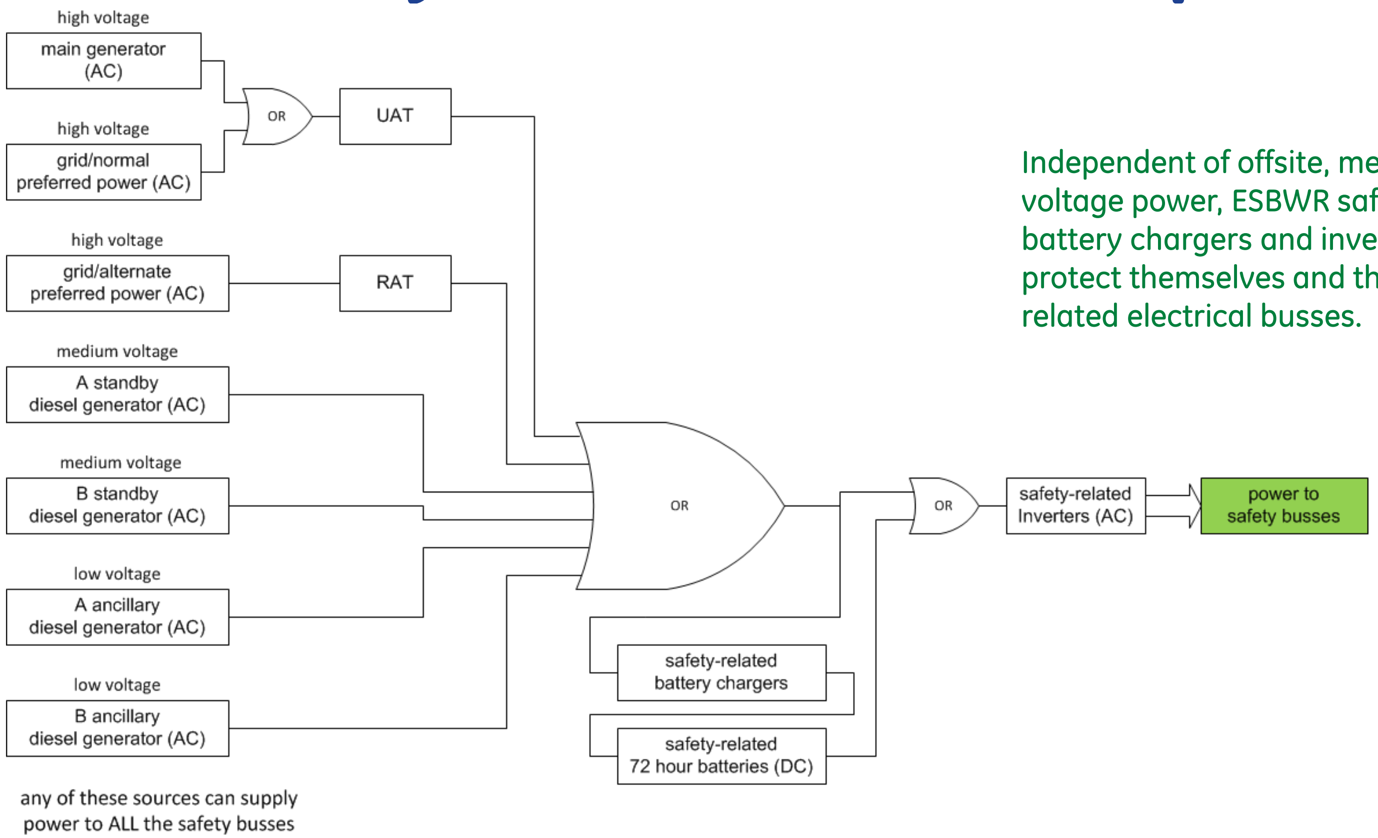
ESBWR is a Gen III+ Passive Plant - Plant Key Safety Highlights

- No operator action is required to reach safe, stable shutdown condition.
- No operator action or electricity or water is necessary for 72 hours after reaching safe, stable shutdown condition.
- Post 72 hours AC power is not required; safe, stable shutdown can be maintained by adding water to the IC/PCCS and spent fuel pools.
  - Without AC power, water can be added by the diesel driven fire pump or portable pumps.
  - With minimal AC power, water inventory can be added to the IC/PCCS and spent fuel pools using several plant pumps or external building connections.

ESBWR does not require AC or DC power to achieve or maintain a safe, stable shutdown condition.

ESBWR is a Gen III+ Passive Plant - AC and DC Power Diversity and Defense in Depth



Independent of offsite, medium, or low voltage power, ESBWR safety-related battery chargers and inverters will protect themselves and the safety-related electrical busses.

ESBWR DCD and Detailed Design has multiple layers of AC and DC Power Diversity and Defense-in-Depth.

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ESBWR is a Gen III+ Passive Plant - Response time constraints for AC Power

A premise of the three NRC questions in Bulletin 2012-01 is the potential loss of safety-related equipment caused by unmonitored and unknown abnormal preferred power conditions.

In the unlikely event that the incoming GDC-17 power feeds and the standby diesels were made inoperative by electrical faults or open circuits on the offsite preferred power feeds, the ESBWR can passively remain in safe shutdown without electricity (by adding water to the IC/PCCS and spent fuel pools; for example using portable or fire pumps) until the inoperative equipment is made available.

Independently of the monitoring of the incoming normal and alternate switchyard power feeds and plant medium voltage busses, the ESBWR inverters and battery chargers protect the safety-related busses and loads from abnormal voltage and frequency conditions.

Nevertheless, the nonsafety-related off-site power feeds, busses and diesel generators are continuously monitored to protect the busses and loads.

Other than to provide for plant monitoring… ESBWR passively remains in a safe shutdown condition without electrical power.

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ESBWR is a Gen III+ Passive Plant - Commitment to GDC-17

Although the subject of the bulletin involves monitoring, the bulletin additionally references GDC -17.

- *An onsite electric power system and an offsite electric power system shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to assure that*
  - *(1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences, and*
  - *(2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents….*

Given the two off-site preferred power connections and on-site safety-related 72-hour batteries and inverters, the ESBWR complies with GDC-17. The ESBWR design includes both standby and ancillary diesels that represent additional electrical system conservatism with respect to GDC-17 since neither the off-site or on-site diesel generated AC power are required to assure safety functionality.

ESBWR is committed to GDC-17 in the DCD and complies with the GDC requirements.

NRC Bulletin 2012-01 – "ESF" AC Busses

The ESBWR safety-related electrical systems are configured as four divisions of low voltage 120 VAC, there are no medium voltage loads.

- Each division is operated with redundant (2 X 100%) safety-related inverters that are backed by 72-hour safety-related batteries.
- Each division is provided with two safety-related battery chargers.
- The divisional safety-related busses can be powered indirectly from the isolation load centers through the inverters or from the 72-hour batteries through the inverters.
- Each of the divisional isolation load centers can be powered from either of the two GDC 17 offsite power sources or the diesel generator sets.
- The ESBWR safety divisions are arranged in an "N+2" configuration such that only any two of the four divisions are necessary to provide ALL safety functions.
- Whatever the status of incoming off-site or on-site power and independently of other monitoring schemes, the ESBWR inverters and battery chargers will individually protect themselves and the safety-related busses.
  - The passive design allows the inverters and chargers to separate from offsite or on-site generated AC power without adversely affecting safety.
- Safety-related power is necessary only for monitoring or in the event of a design basis accident.

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NRC Bulletin 2012-01 – Question 1

NRC Concern or Question:

"Describe the protection scheme design for important to safety buses (non-safety or safety-related) to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on credited offsite power circuits."

ESBWR Capabilities:

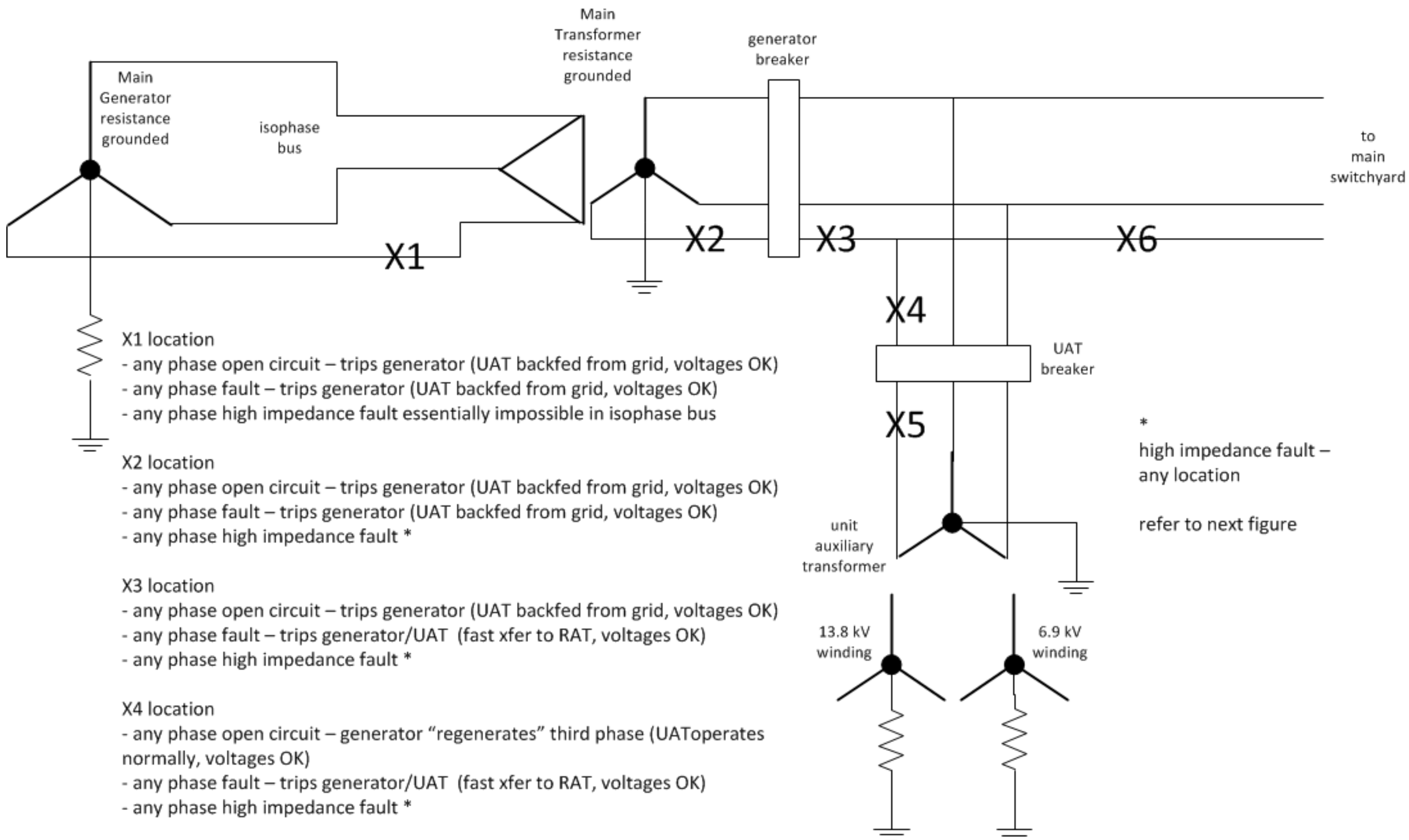
Specifically, the ESBWR has no "credited" off-site power sources since they are not needed for safety.

The following figures describe the ESBWR response to various off-site power source electrical faults and conditions.

Off-site normal or alternative preferred power abnormalities will not result in abnormal plant voltages either because of protective relaying trips, fast transfers, or main generator capacity.

All phases of off-site (and on-site) power are monitored and alarmed for abnormal voltages.

NRC Bulletin 2012- 01-
Where could faults occur? 1/2



X1 location
- any phase open circuit – trips generator (UAT backfed from grid, voltages OK)
- any phase fault – trips generator (UAT backfed from grid, voltages OK)
- any phase high impedance fault essentially impossible in isophase bus

X2 location
- any phase open circuit – trips generator (UAT backfed from grid, voltages OK)
- any phase fault – trips generator (UAT backfed from grid, voltages OK)
- any phase high impedance fault *

X3 location
- any phase open circuit – trips generator (UAT backfed from grid, voltages OK)
- any phase fault – trips generator/UAT (fast xfer to RAT, voltages OK)
- any phase high impedance fault *

X4 location
- any phase open circuit – generator "regenerates" third phase (UAToperates normally, voltages OK)
- any phase fault – trips generator/UAT (fast xfer to RAT, voltages OK)
- any phase high impedance fault *

X5 location
- any phase open circuit – generator "regenerates" third phase (UAToperates normally, voltages OK)
- any phase fault – trips UAT (fast xfer to RAT, voltages OK)
- any phase high impedance fault *

X6 location
- any phase open circuit – trips generator (fast transfer to RAT, voltages OK)
- any phase fault – trips generator/UAT (fast xfer to RAT, voltages OK)
- any phase high impedance fault *

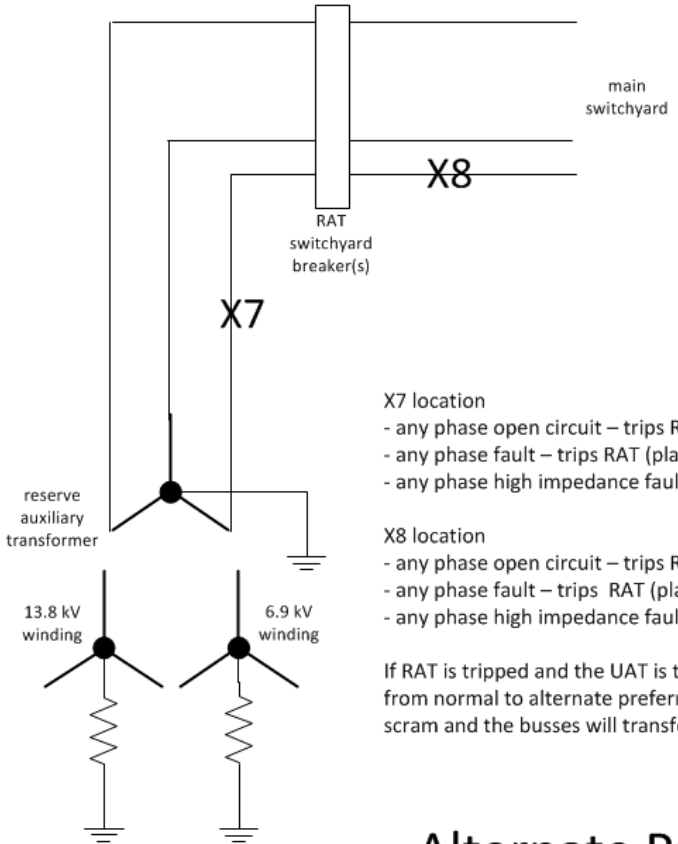
* high impedance fault – any location

refer to next figure

Normal Preferred Power

(**X** indicates possible fault location)

NRC Bulletin 2012- 01-
Where could faults occur? 2/2



X7 location
- any phase open circuit – trips RAT (plant continues operating from UAT, voltages OK)
- any phase fault – trips RAT (plant continues operating from UAT, voltages OK)
- any phase high impedance fault*

X8 location
- any phase open circuit – trips RAT (plant continues operating from UAT, voltages OK)
- any phase fault – trips RAT (plant continues operating from UAT, voltages OK)
- any phase high impedance fault *

If RAT is tripped and the UAT is tripped or otherwise unavailable, the fast transfer scheme from normal to alternate preferred power will not be attempted, instead the plant will scram and the busses will transfer to the standby diesel generators

Alternate Preferred Power

(**X** indicates possible fault location)

*
high impedance fault – any location

High impedance faults are uncommon and many will proceed to become lower resistance faults that result in detection and trip

Whether the fault is detectable is a function of how much current is flowing through the fault (i.e. how high or low is the fault resistance).

A high current, low impedance fault:

- this type of fault will distort the affected bus voltage but is easily detected by ESBWR protective relaying and will always result in a protective relaying trip. It is also easily detected by the DCIS monitoring and alarm systems. The solidly grounded high voltage normal and alternate preferred power feeds are “biased” towards this type of fault

A low current, high impedance fault:

- this type of fault will produce too low a current to distort plant voltages, the protective relaying schemes will usually be able to detect the fault by ground or phase current measurement and trip. Additionally the DCIS monitoring will usually be able to detect and alarm discrepancies in ground current.

- in the unlikely event that the fault produces too low a current to distort plant voltages or result in a protective relaying trip, it may not be detected by other than visual means on inspection tours, however, by definition the plant voltages and operation remain unaffected

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NRC Bulletin 2012-01 – Question 2

NRC Concern or Question:

"If the important to safety buses are not powered by offsite power sources during at power condition, then explain how the surveillance tests are performed to verify that a single-phase open circuit condition or high impedance ground fault condition on an off-site power circuit is detected."

ESBWR Capabilities:

Other than the low voltage safety-related inverter and battery backed four divisional 120 VAC and 250 VDC busses, the ESBWR has no "important to safety" busses.

However, nonsafety-related off-site high voltage transformer input busses, medium voltage transformer output busses, standby and ancillary diesel busses are continuously monitored and alarmed; no surveillance tests are necessary.

Safety-related busses are continuously monitored and alarmed for abnormal voltages and frequency.

ESBWR bus monitoring and protection are summarized in the next slide.

ESBWR Detailed Design Features – Electric System Monitoring

ESBWR electrical system monitoring

- All three phases of ESBWR high voltage (offsite power) transformer inputs are monitored
- All three phases of ESBWR medium voltage transformer outputs (buss voltages) are monitored
- All three phases of ESBWR standby diesel generator voltages are monitored
- All three phases of ESBWR ancillary diesel generator voltages are monitored

Monitoring/alarm/recording

- Above three phases are monitored and alarmed for over voltage, under voltage, and voltage consistency

Trips/initiations

- Degraded voltage monitoring and diesel generator initiation logic monitor all three phases using two-out-of-three logic connected such that a single phase under voltage will trip the 2/3 logic

Protective relaying

- Protective relaying trip logic will be developed during detailed design. Normally all three phases of voltage and current (phase and ground) monitoring are used for medium voltage electrical loads and at least all three phases of current are used for low voltage electrical feeders.
- All three phases of voltages and currents and ground currents on the primary and secondary sides are used for main, UAT and RAT transformer protection.

DCIS and Safety Important Electrical Monitoring

- All inverter phase voltages are monitored and alarmed for under/over voltage and frequency
- Inverter output current is monitored and alarmed.
- All battery voltages and currents are monitored and alarmed.
- All battery chargers are voltage and current monitored and alarmed.
- Isolation power center three phase voltages and frequencies are monitored and alarmed.
- Additionally the isolation power center outputs are monitored independently by each of the safety-related inverters and battery chargers such that they will automatically disconnect for abnormal conditions to protect their loads/batteries

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NRC Bulletin 2012 -01– Question 3

NRC Concern or Question:

"Describe the plant operating procedures, including off-normal operating procedures, that specifically call for verification of the voltages on all three phases of the ESF buses."

ESBWR Capabilities:

The ESBWR "ESF" busses are not three phase but instead four divisions of 120 VAC single phase inverter backed power and 250 VDC battery power.

The response of the ESBWR to losing the safety-related busses is to scram, isolate containment, and initiate passive reactor decay heat removal.

However the ESBWR safety-related busses are continuously monitored and alarmed for abnormal voltages and frequencies.

NRC Bulletin 2012-01 – Actions for Passive Designs

- Based on NRC draft feedback provided to NEI group, the ESBWR passive design would need to have detection and alarms of three phases of AC power.
- ESBWR detailed design already includes plans and requirements documents for detection and alarms of three phases of AC power.
- No further action is necessary for ESBWR design capabilities to address NRC Bulletin 2012-01.

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