Spring Review Panel Briefing

LWR Thermal Energy Extraction Pre-conceptual Design Studies

Flexible Plant Operations & Generation

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Sargent & Lundy (S&L) Areas of Support 2023 - 2024

- **Area 1: Preconceptual Design / Integration of 500MW HTSE Facility with LWR NPPs**

  (Completed Q2 2024 – Q3 2024)

  - ❑ **PWR Focus Areas**
    - NPP – H2 Thermal & Electrical Integration
    - 500MW_{DC} H2 Facility Design
  - ❑ **BWR Focus Areas**
    - NPP – H2 Thermal Integration (BWR-specific)

- **Area 2: High Volume TPD Analysis from Generic PWR**

  (Completed Q2 2023 – Q1 2024)

  - ❑ **Focus Areas (30%, 50%, and 70% TPD)**
    - Heat Balance
    - Plant Impacts
    - Equipment Evaluations

Area 1
Preconceptual Design and Integration of 500MW H2 Facility with LWR NPPs

PWR Design and Integration with 500MW SOEC Facility

Thermal / Electrical Energy

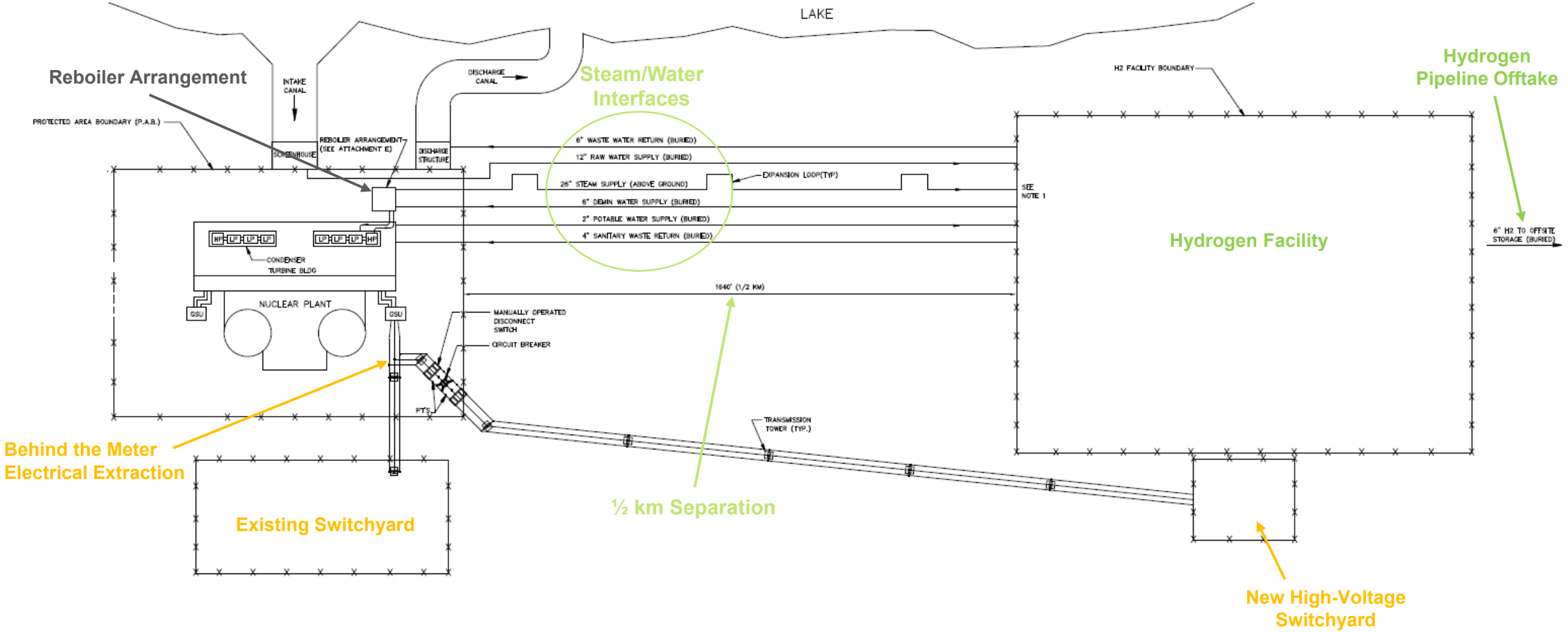
Focus Area

- **NPP Reference Plant**
  - Based upon typical US designs
    - Westinghouse 4-loop PWR (1/3 of US fleet)
    - 1,200 MW_e / 3,700 MW_{th} / SWYD: 345 kV

- **Hydrogen Facility Plant**
  - 500MW_{DC} SOEC Capacity
    - Thermal Load – 100 MW_{th}
    - H2 Production – 320 metric tons/day

Focus Area

PWR – 500MW SOEC Facility Integration: Site Layout



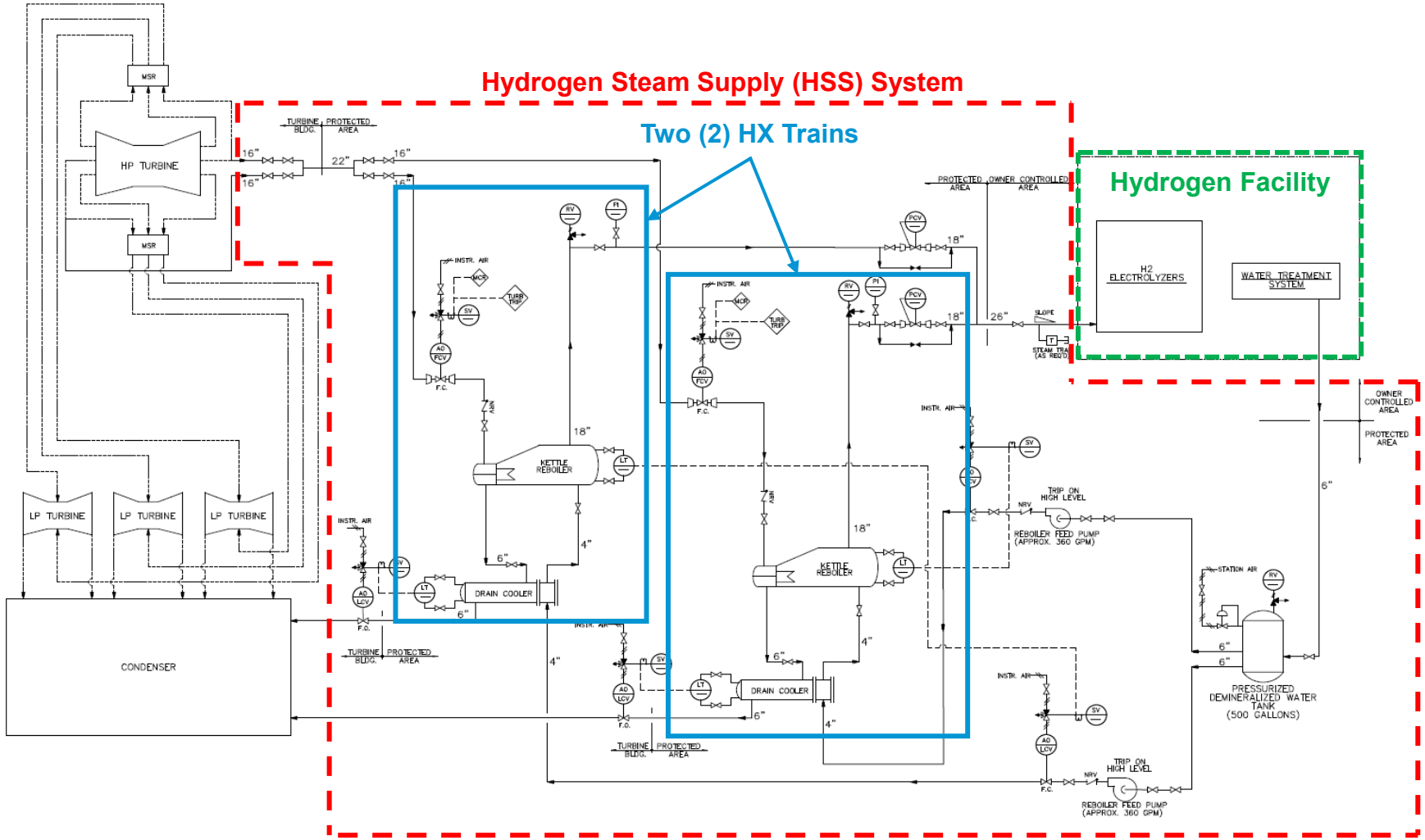
PWR – 500MW SOEC Facility Thermal Integration

Cold Reheat Steam viable for 500MW SOEC H2 Facility

Main Steam needed to support a > 500MW$_{DC}$ SOEC H2 Plant

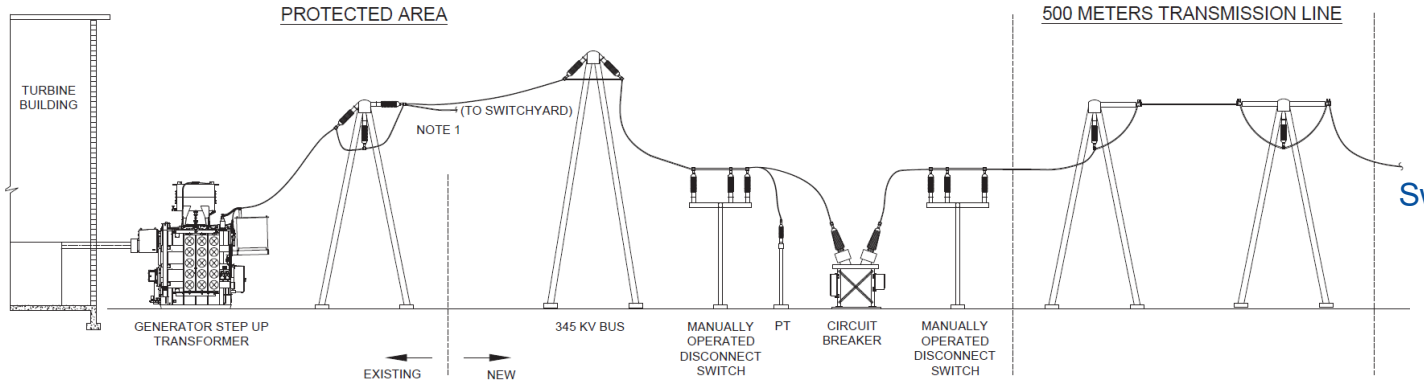
PEPSE – Thermal Extraction Analysis

AFT Arrow & Fathom – Steam and Water Piping Analysis

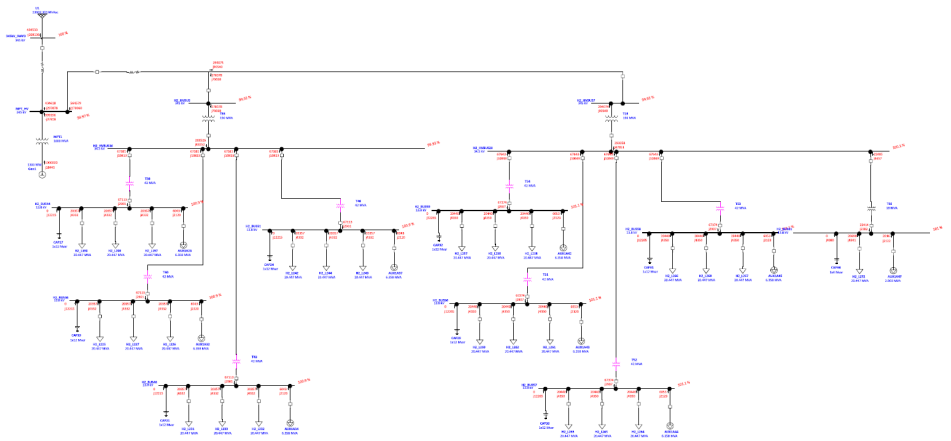


PWR – 500MW SOEC Facility Electrical Integration

Full Generator Output viable without plant instability issues

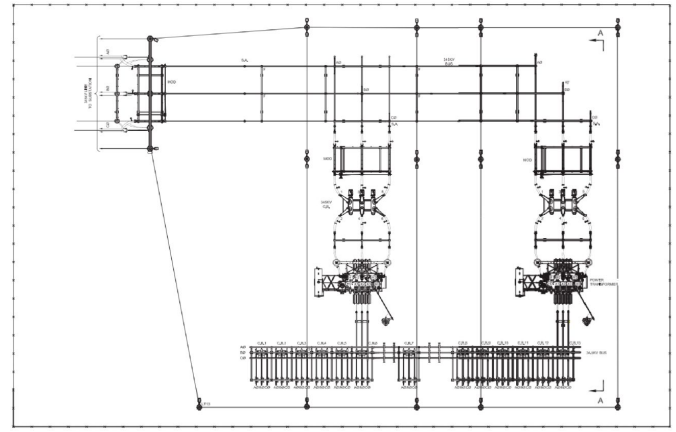


To H_2 Switchyard



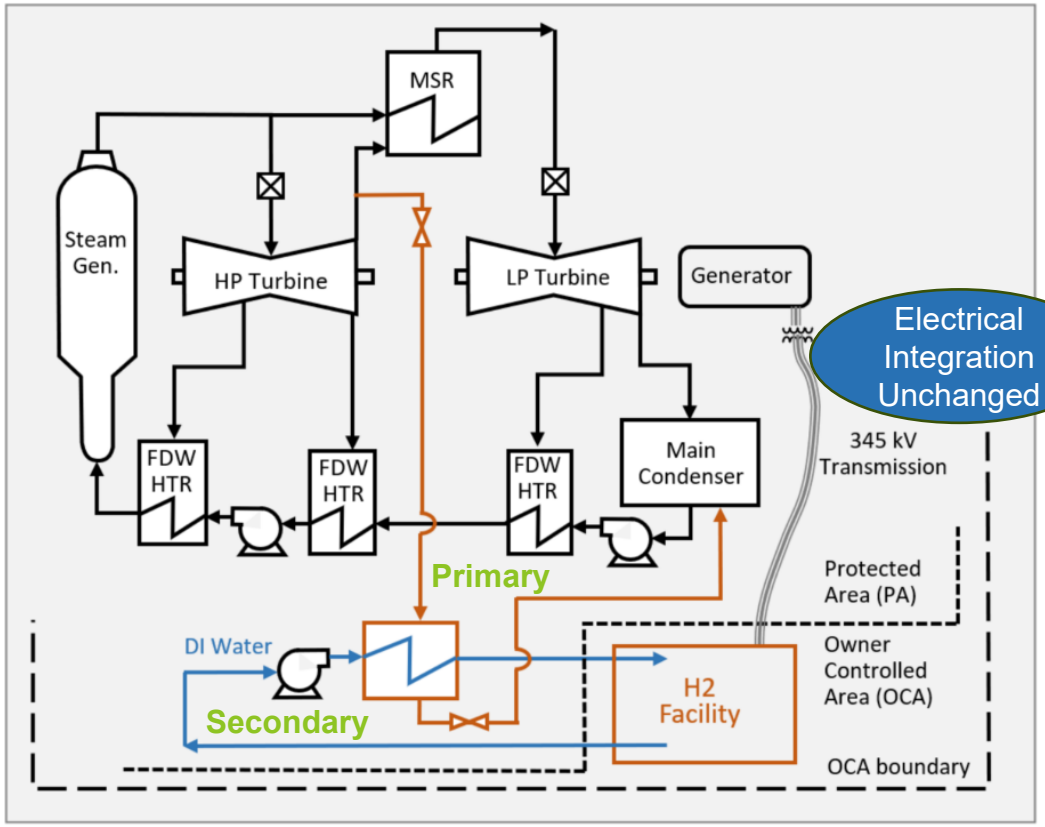
PSCAD - Electrical Transient Analysis

ETAP - Electrical Power Flow & Short Circuit Analysis



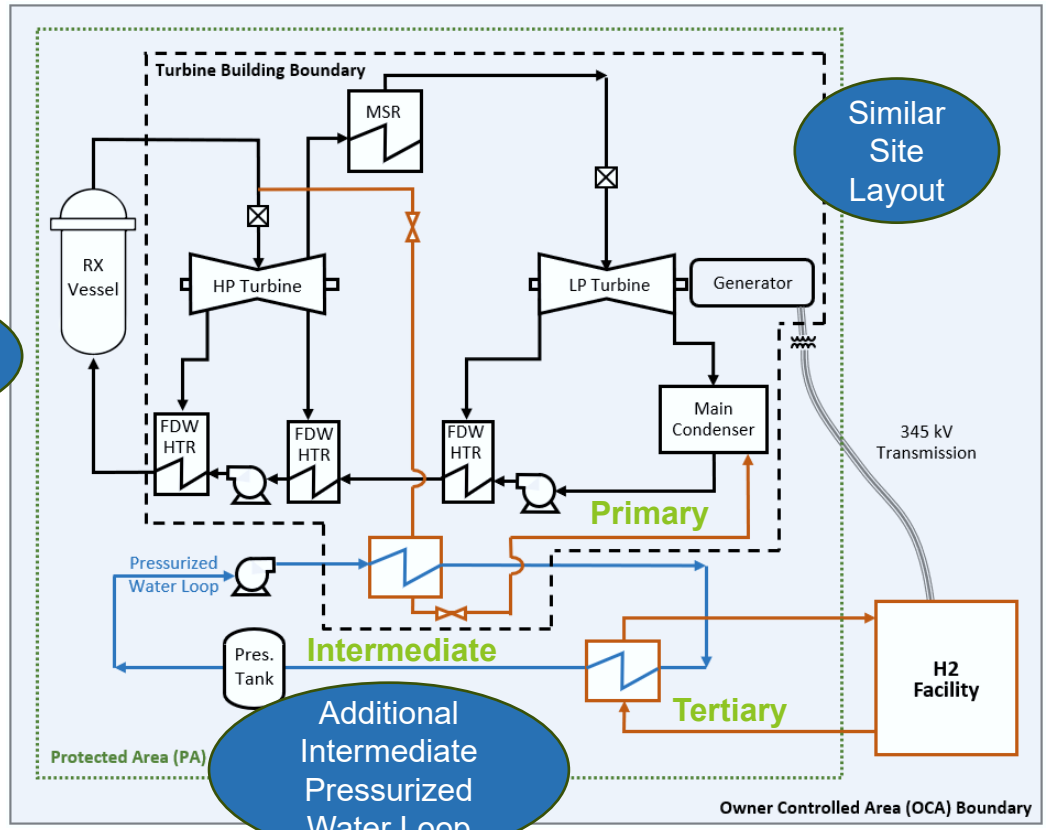
500MW SOEC Facility Integration: PWR vs. BWR

PWR



Electrical Integration Unchanged

BWR



Similar Site Layout

Additional Intermediate Pressurized Water Loop

BWR Design and Integration with 500MW SOEC Facility

Thermal / Electrical Energy

Focus Area

- **NPP Reference Plant**
  - Based upon typical US designs
    - GE Type 4 BWR
    - 1,365 MW_e / 4,000 MW_{th} / SWYD: 345 kV
- **Hydrogen Facility Plant**
  - 500MW_{DC} SOEC Capacity
    - Thermal Load – 100 MW_{th}
    - H2 Production – 320 metric tons/day

BWR – 500MW SOEC Facility Thermal Integration

Nuclear-Hydrogen Integration from a BWR is Feasible

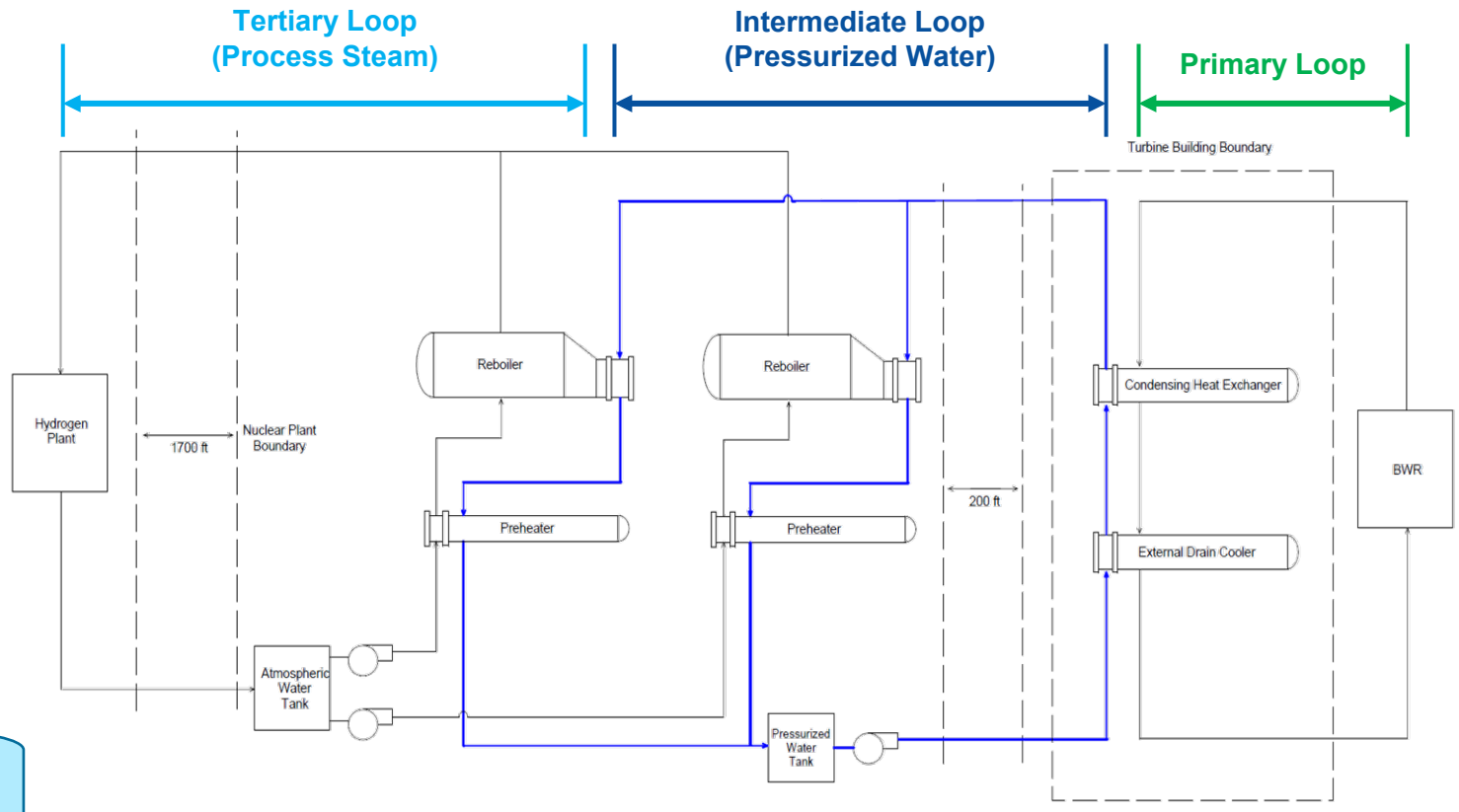
Limited Area in Turbine Building

Thermal and Electrical Transients Absorbed

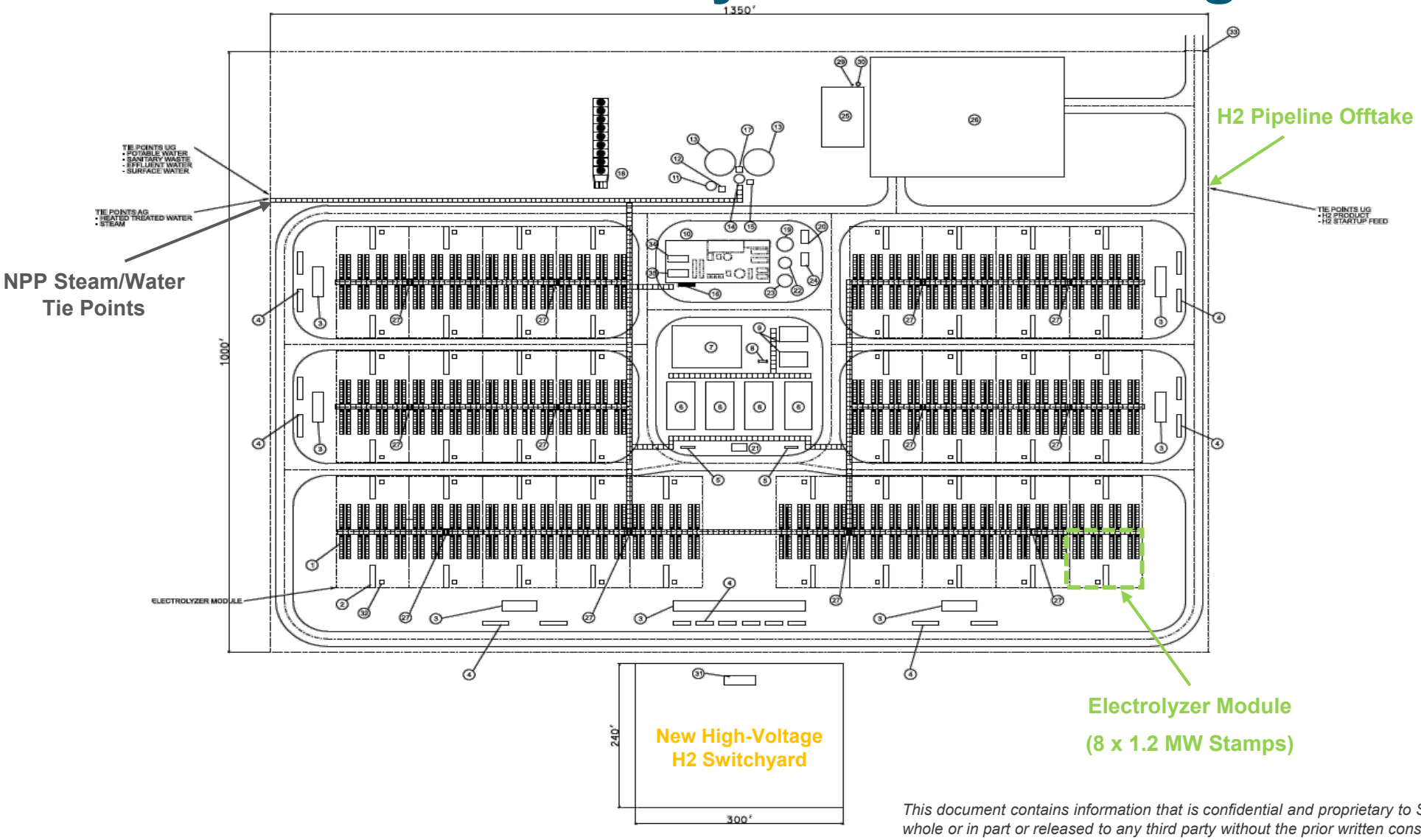
BWR Radiological Challenges addressed via Intermediate Pressurized Water Loop

Thermal Extraction from Main Steam

Intermediate HXs in Turbine Building or New Shielded Building



500MW SOEC H2 Facility: General Arrangement



LEGEND	
01	1.2MW ELECTROLYZER STAMP (QTY 416)
02	RECTIFIER/TRANSFORMER (QTY 52)
03	PDC
04	TRANSFORMER
05	HEAT EXCHANGER
06	LOW PRESSURE COMPRESSION
07	PURIFICATION AND DRYING
08	HYDROGEN BUFFER VESSEL
09	HIGH PRESSURE COMPRESSION
10	UTILITY AIR AND WATER TREATMENT BLDG.
11	SLUDGE HOLDING TANK
12	FILTER PRESS FEED PUMPS
13	CLARIFIER
14	CLEARWELL
15	CLARIFIED WATER PUMPS
16	NITROGEN PRESSURE VESSELS
17	CLARIFIED SLUDGE PUMPS
18	COOLING TOWER
19	SERVICE/FIRE PROTECTION TANK
20	FIRE PROTECTION PUMPS
21	CONDENSATE RECOVERY SUMP
22	TREATED WATER TANK
23	EFFLUENT TANK
24	WATER PUMP HOUSE
25	ADMINISTRATION/CONTROL BUILDING
26	PARKING AND STAGING AREA
27	MODULE CONDENSATE SUMP
28	SWITCHYARD
29	POTABLE WATER BLADDER TANK
30	SANITARY LIFT STATION
31	HIGH VOLTAGE PDC
32	TELEMETRY CABINET (QTY 52)
33	ENTRY GATE
34	INSTRUMENT AIR SKID
35	NITROGEN SKID

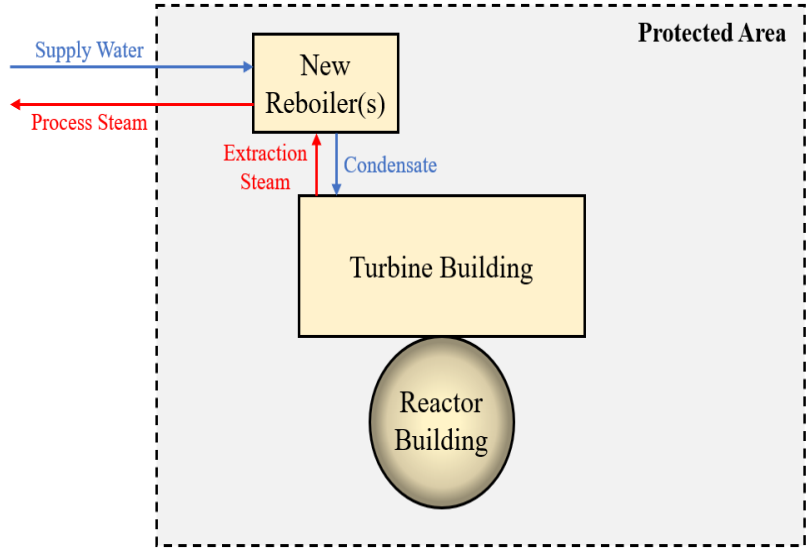
Area 2
High Volume TPD Analysis from Generic PWR

High Volume Thermal Power Dispatch (TPD) Objective

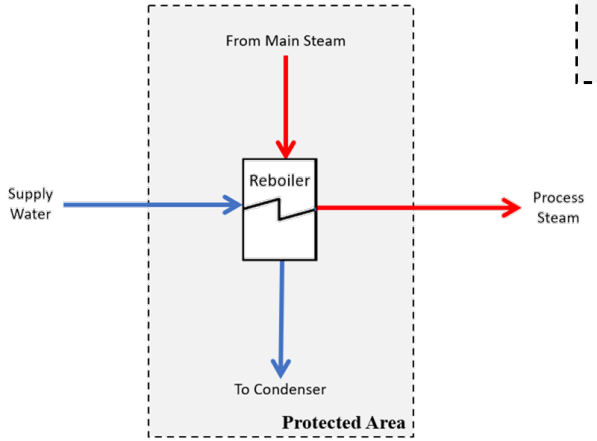
Assess feasibility of extracting large volumes of thermal energy (i.e., steam) from a PWR for industrial steam applications

- Heat Balance Modeling
- Plant Impacts and Considerations
- Plant Secondary Equipment Evaluations
  - ✓ High Pressure Turbine (HPT)
  - ✓ Low Pressure Turbines (LPTs)
  - ✓ Condenser
  - ✓ Power Train Pumps
  - ✓ Moisture Separator Reheaters (MSRs)
  - ✓ Feedwater Heaters (FWHs)
  - ✓ Extraction Steam Lines
  - ✓ Heater Drains

PEPSE – Thermal Extraction Analysis



Reference Plant General Arrangement



Supply/Return Locations

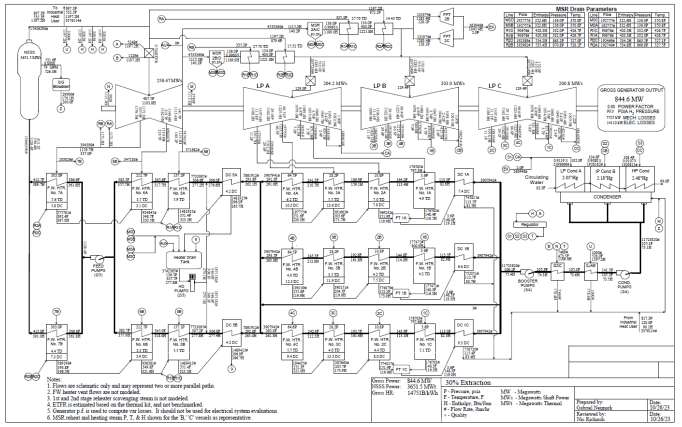
High Volume Thermal Power Dispatch (TPD) Design and Modeling

TPD Cases

1. 30% TPD (June 2023)
   - ~1,100 MWt Extraction
2. 50% TPD (November 2023)
   - ~1,825 MWt Extraction
   - Alternate FWH bypass scenario
3. 70% TPD (January 2024)
   - ~2,550 MWt Extraction

Reference Nuclear Power Plant

- Westinghouse 4-loop PWR
  - Capacity: ~1,200 MWe (3,650 MWt)
  - Main Steam Extraction
  - Condenser Return



High Volume Thermal Power Dispatch (TPD) Plant Impacts

Mechanical Transients

- 30% TPD → 22% of Main Steam Flow
- 50% TPD → 38% of Main Steam Flow
- 70% TPD → 55% of Main Steam Flow

30% TPD Operation is Well within NPP Control System Capabilities

Plant Hazards

- HELB Program impacts
- Water/steam hammer considerations

50% TPD Operation may Challenge NPP Control System Capabilities

Core Reactivity and Plant Response

- Startup/shutdown
- Thermal Load Rejection

Station Specific NSSS Evaluation Required

70% TPD Operation expected to Challenge NPP Control System Capabilities

High Volume Thermal Power Dispatch (TPD) Conclusions

Minimal Adverse Impacts

- ✓ High Pressure Turbine (HPT)
- ✓ Low Pressure Turbines (LPTs)
- ✓ Condenser
- ✓ Power Train Pumps
- ✓ Moisture Separator Reheaters (MSRs)
- ✓ Heater Drain Tanks

No Major Equipment Replacements Expected for 30% TPE

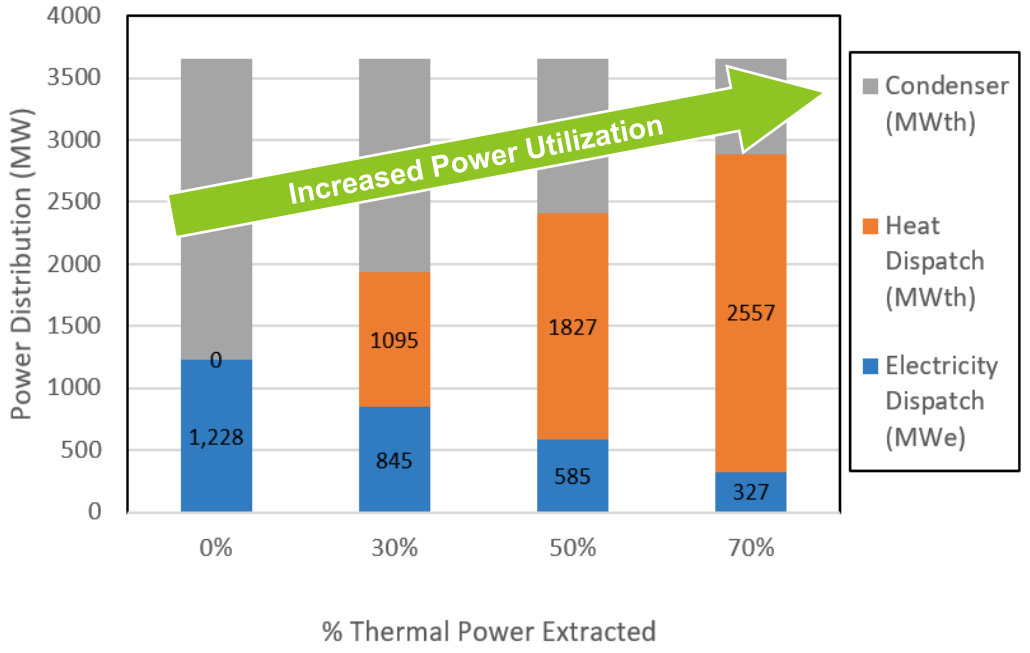
Minor Equipment Replacement and/or Operational Change Expected for 50% TPE

Major Equipment Replacement and/or Operational Change Expected for 70% TPE

Significant Adverse Impacts Above 50% TPD

- ❖ Feedwater Heaters (FWHs) – Flow Accelerated Corrosion
- ❖ Extraction Steam Lines – Increased dP and Liner Thicknesses
- ❖ FWH Drain Control Valves – Increased C_v and Potential Operational Impacts

Additional Minor Upgrades and Maintenance may be Required for Specific Components



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