Geothermal Fleet Optimization: Data-Driven Models for improved Performance and Flexibility

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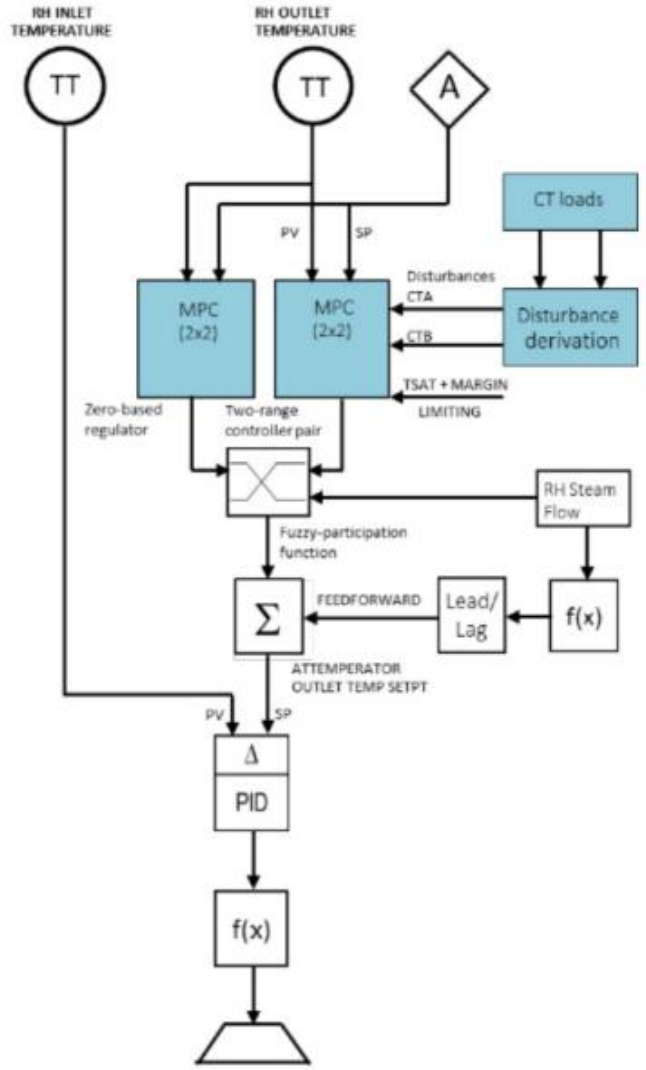
Motivation

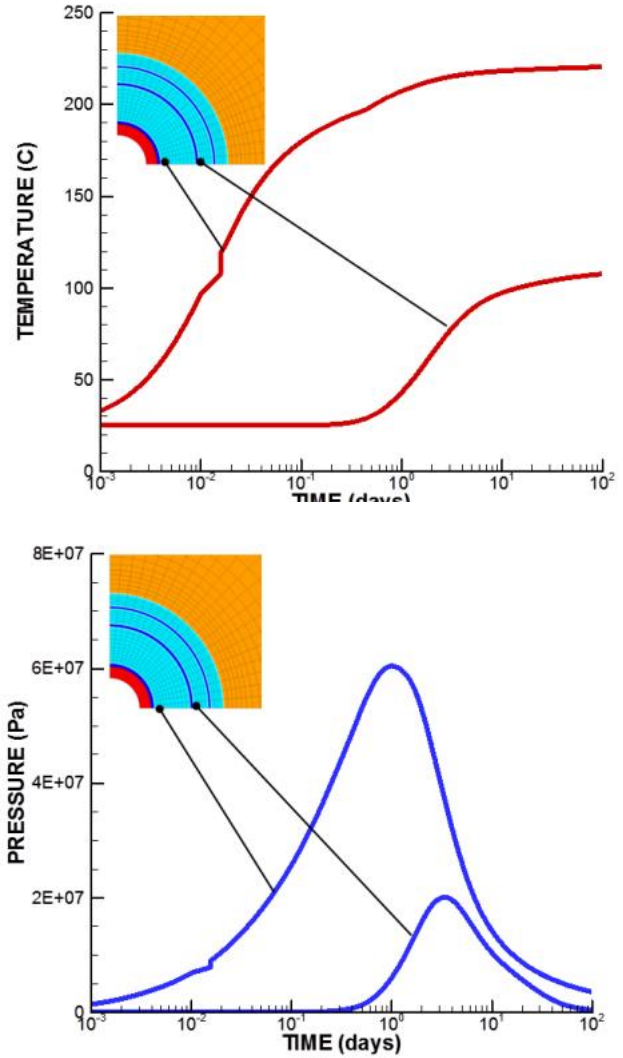
- Traditional hydrothermal plants were designed for baseload operation.
- Flexible geothermal can complement intermittent renewables, reducing curtailment & improving reliability
- However, it requires advanced reservoir modeling & control systems.



Modern control systems & reservoir management techniques enable variable modes

Flexible-mode Operation Resource Challenges

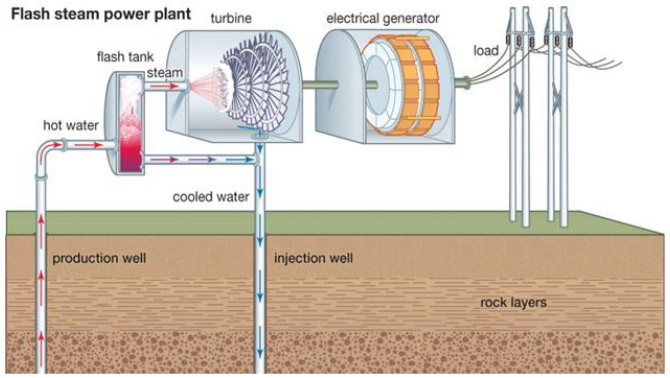
- Complex mechanical & chemical stress changes requiring optimized design & operational strategies to minimize risks and costs
- Flexible-Mode Operation
  - Thermal stress on wellbore: daily cycling causes expansion/shrinkage of casing & cement, leading to fatigue & potential failure
  - Scaling & corrosion: pressure & temperature fluctuations exacerbate mineral precipitation (carbonates, sulfides, silica) & corrosion
  - Reservoir impacts: cold-water injection creates large ΔT, affecting fracture-matrix heat exchange and long-term thermal stability.

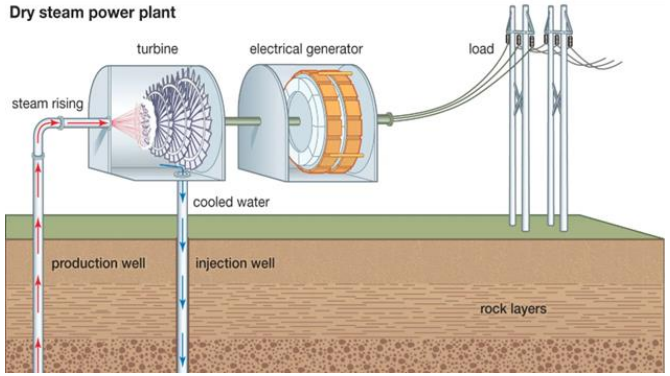


Rutqvist et al., 2021

Geothermal Power Plant Main Challenges

- H_2S content detrimental for steam turbine and corrosion
- Minimal actuation due H_2S deposition
  - Fully open operation of critical valves/actuators
- Traditionally minimal load following capability
  - Similarity with other assets years ago: Boiler, CCGT, Power-to-gas-to-Power, etc.





Control Strategies can help enable load following operation (minimizing abrupt changes in wellbores & reservoir)

How did control enable load following in traditional assets?

- **Optimize Performance**
  - Ensures optimal performance and reliability of critical manipulated and process variables
- **Automation**
  - Supports Flexibility
  - Mature systems adapt to changing operational demands and regulatory requirements
- **Enhances Operational Efficiency**
  - Mature C&I systems improve process control and reduce downtime
- **Reduces Risk**
  - Advanced C&I systems mitigate operational risks and enhance safety

White Paper - Control System Maturity Trajectory for Cost-Effective Flexible Operation of Power Generating Plants

Advanced Control Evaluation and Plant Implementation

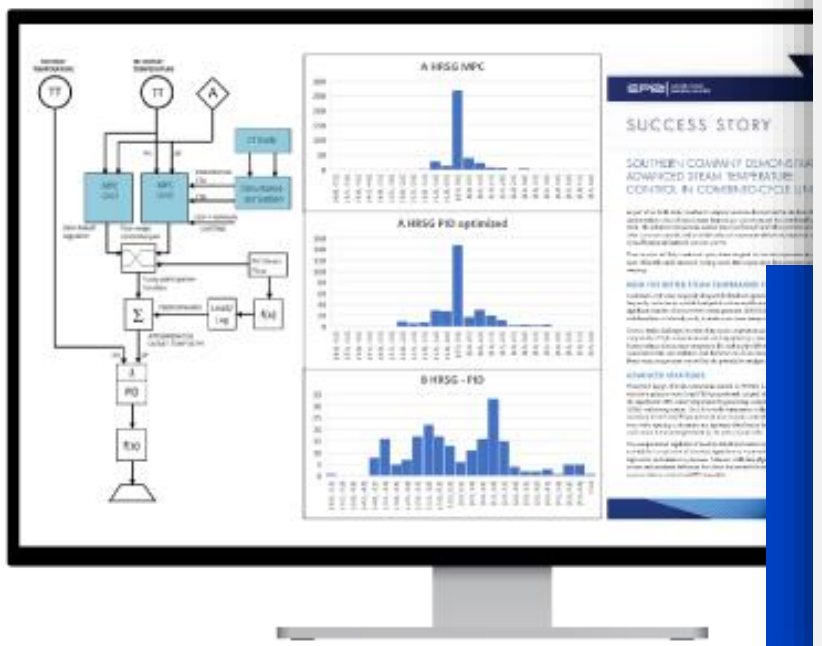
Project Objectives

- Evaluate Control Strategies and their effect on Flexible operations
- Demonstrate Improved Plant Flexibility through Improved Controls

Project Value

- Reduced O&M
  - Reduced Thermal Stress
  - Reduced Actuator Activity
  - Reduced Saturation Events
- Improved Performance
  - Faster Ramping
  - Improved Start-up Performance
  - Increased Steam cycle Efficiency

Reporting and Technology Transfer

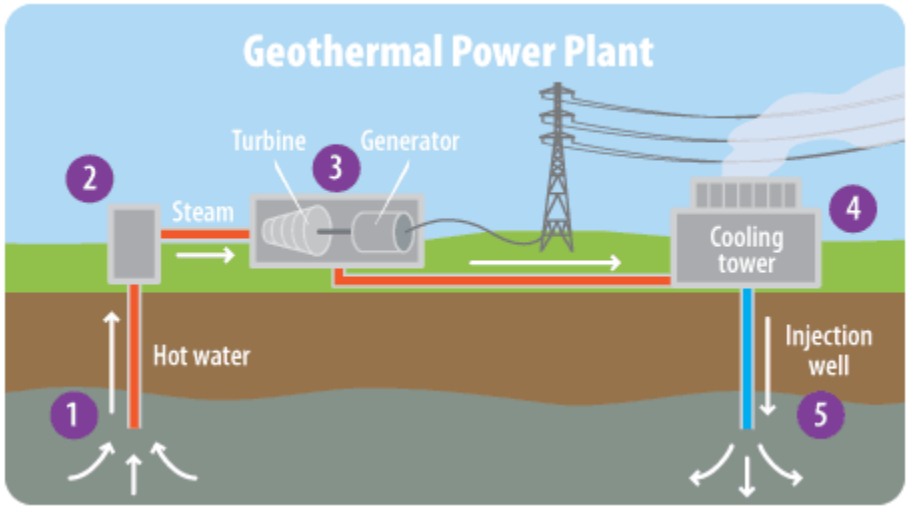


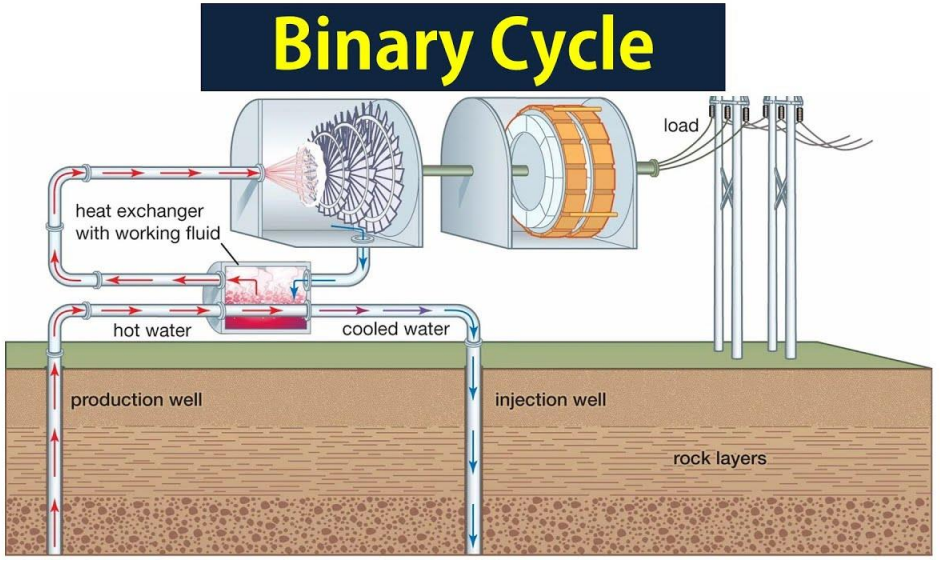
> *This project established a clear roadmap for implementing advanced steam temperature control strategies to improve generation flexibility and asset health of combined-cycle units across the power industry.*
>
> - Southern Company

- Success Story: Advanced Control Demonstration (3002017735)

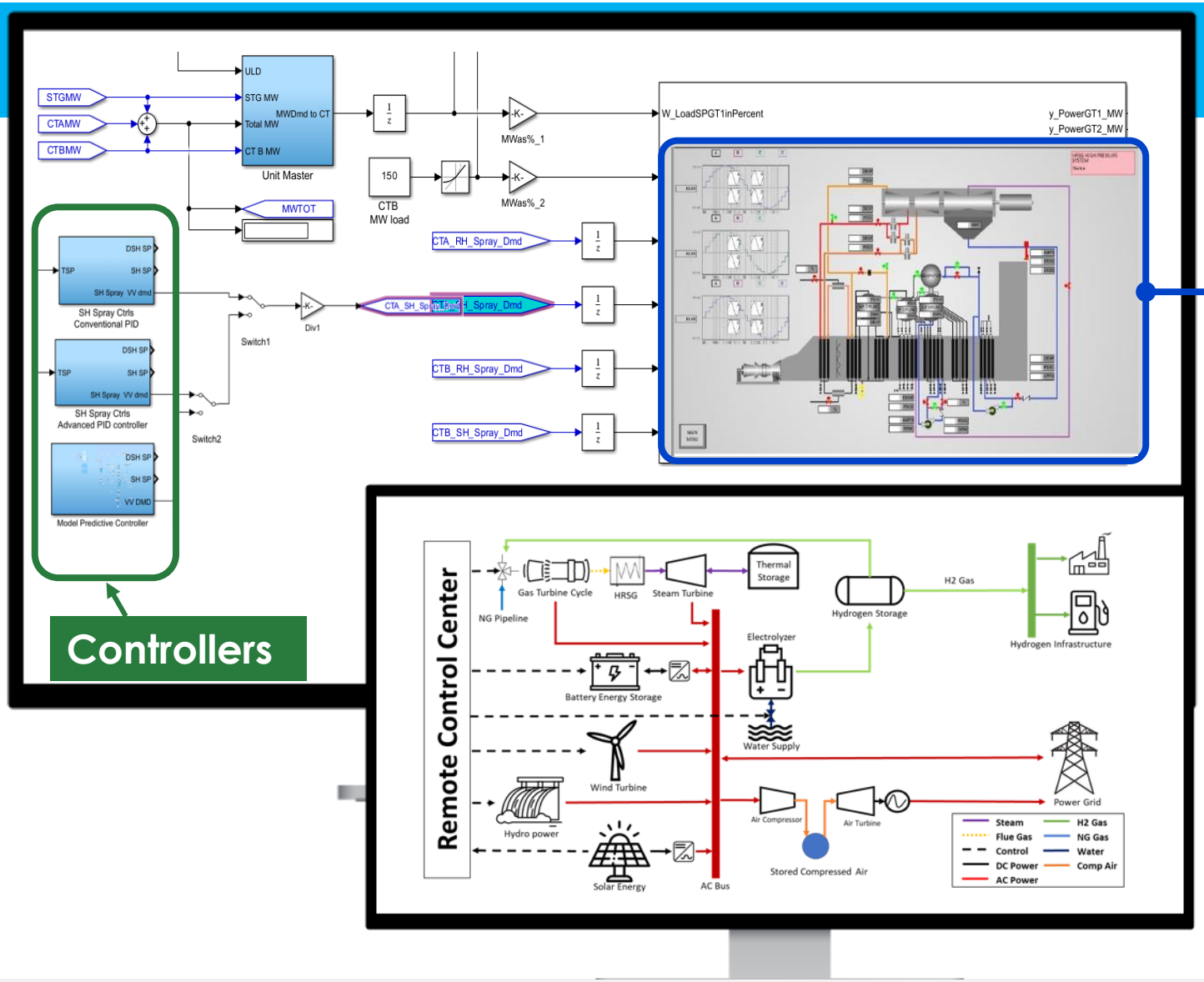
How can control enable load following in Geothermal?

- **Advanced Control**
  - Predict changes in load and steam production
  - Optimize steam flow adjusting valve, flow to ejectors, bypass valves, etc.
- **Optimizing Auxiliary Systems**
  - Cooling water pumps and gas ejectors can be adjusted based on plant load, rather than running constantly at full capacity
  - Wellhead flow control valves can maintain stable pressure for the plant's separator
- **Major Benefits**
  - Smooth load ramp up and down to match grid demand while maintaining stability
  - Reduces plant own energy consumption





Research Opportunities



Thermal

- Traditional Thermal
- Combined Cycle

Renewable

- Wind, Solar, Hydro

Hybrid

- Battery and Thermal Storage
- H_2 Gen and Storage

Geothermal

- Controls steam flow, pumps, ejectors
- Geothermal + Solar
- Geothermal + Long duration energy storage

Water Treatment

- Flexibility
- CCGT
- Geo-thermal water and steam treatment

Research Opportunities - Innovative Cycle Configurations

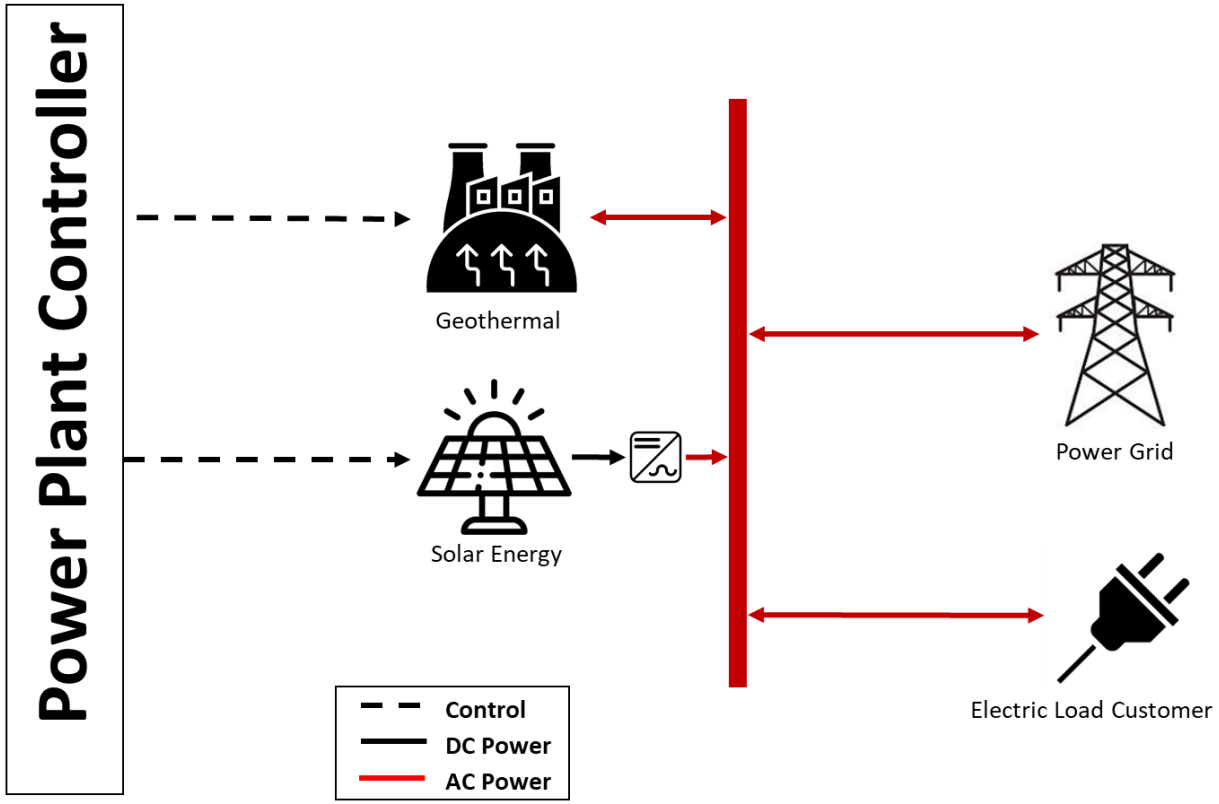
Key Benefits

Efficiency and Reliability

- Solar panels perform best during warmer and sunny months
- Geothermal most efficient during colder months
- Daily variation (need smooth ramping to minimize well damage)

Environmental sustainability

- Complimentary operation with other assets
- CO_2 reduction



Research Opportunities - Innovative Cycle Configurations

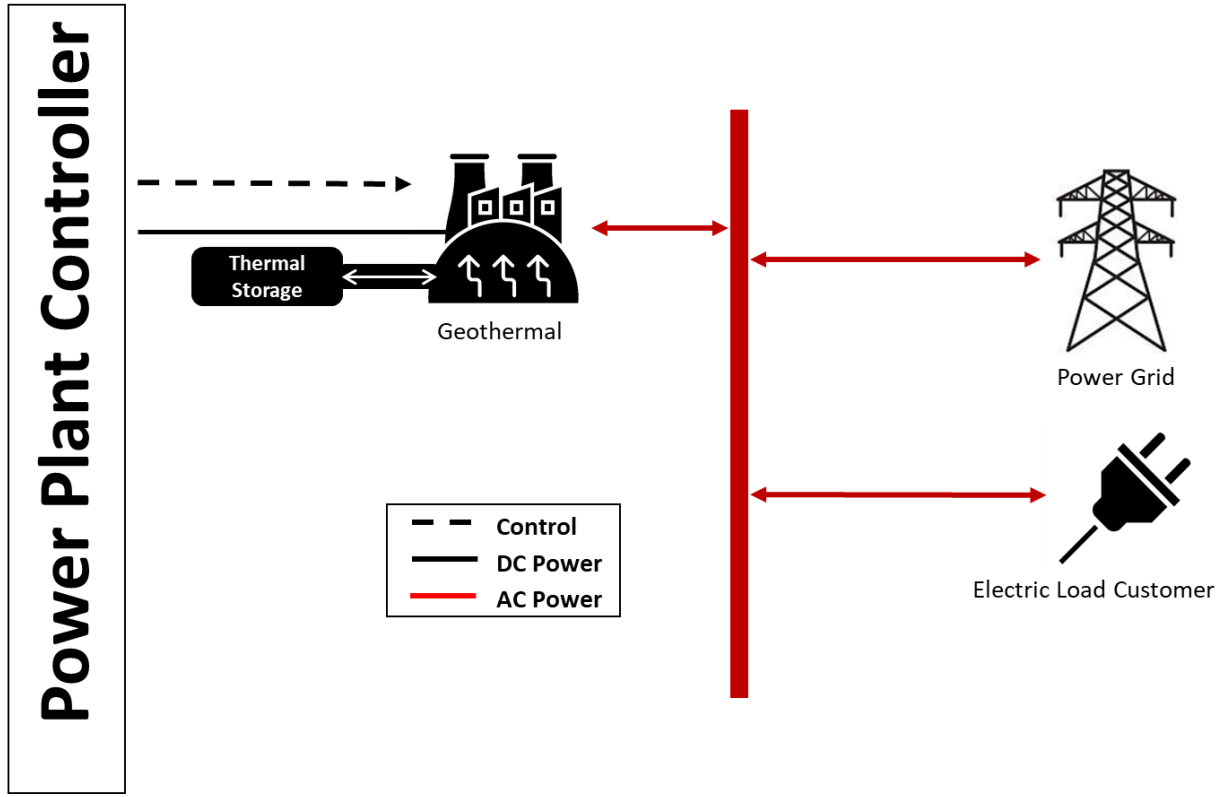
Key Benefits

Efficiency and Reliability

- Heat storage and reuse when needed to generate steam and power
- Geothermal is available 24/7 but heat can be stored for peaking demand to accelerate picking power generation
- Geothermal most efficient during colder months but heat can be stored to be reused in other seasons

Environmental sustainability

- Complimentary operation with other assets
- CO_2 reduction



Summary

- In the changing energy landscape, digital transformation provides an enabling technology for improving the flexibility, performance & efficiency of essential grid-supporting generation assets
- Part of that transformation involves moving up the controls/automation maturity curve to ensure reliable, predictable and economic operation
- EPRI's research provides operational analysis, control design and implementation guidance, based on case study examples, member engagement and training to support industry's progression along the maturity pathway

Questions?

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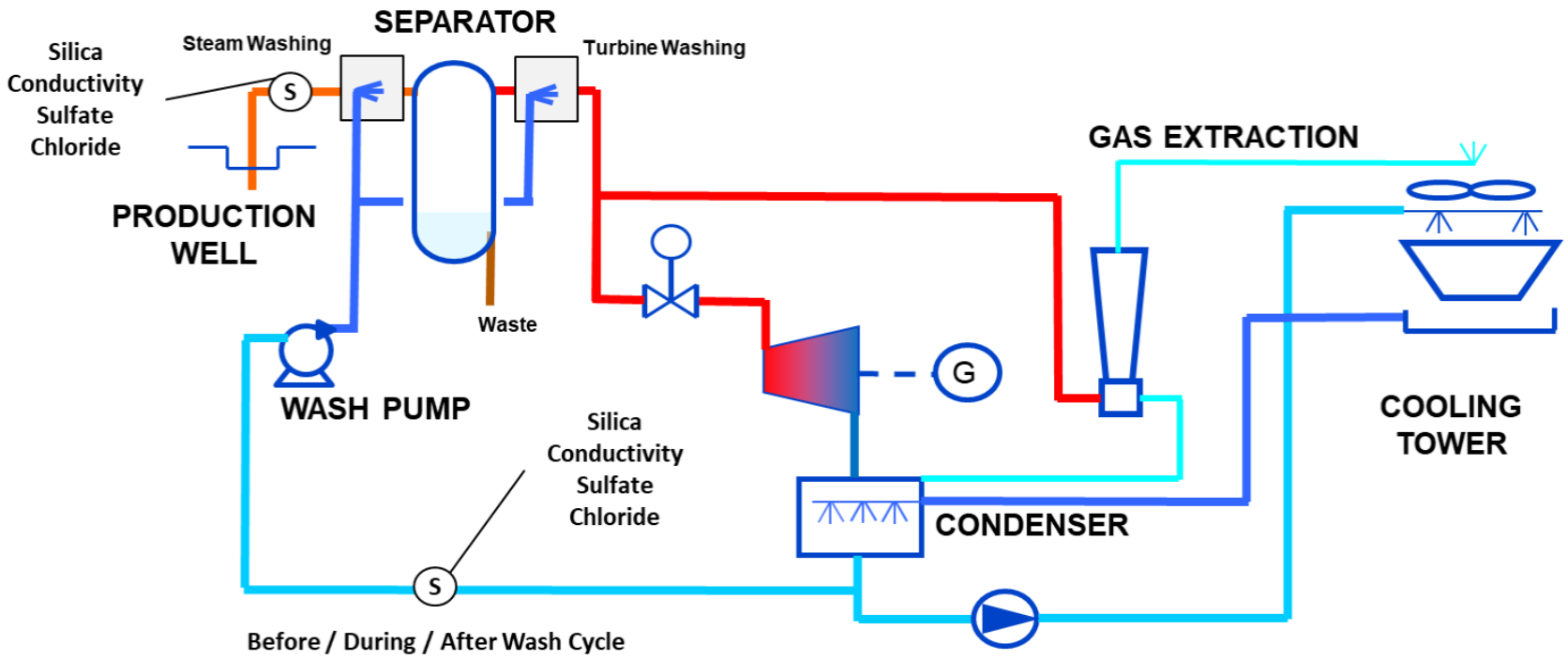
Water Treatment



- Online monitoring of at a minimum the conductivity on a continuous basis to see if this can enable optimization of the separator wash system operation
- Trending operating data (e.g. wash pump flow versus conductivities of wash water and wastewater from the separator) may identify operating parameters that can be adjusted to optimize performance of the separator
- Potential mechanical issues may be identified in the separator leading to less capture of contaminants in the waste