framatome

OAPS

Operator Assistance Predictive System

Agile, real-time plant operator aid to facilitate safe, flexible operation of nuclear power plants
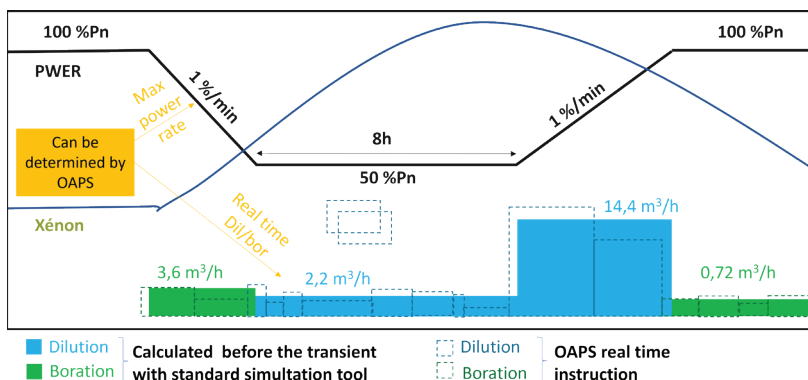
Challenge

Increased variable renewable energy production and market regulations that favor renewable energy, along with aggressive carbon neutrality goals challenge nuclear plant operators to employ flexible operations of the plants in their fleets. Currently, fossil plants are the first choice to provide flexible generation, costing more and putting owners at the mercy of volatile fossil fuel costs and potential low/negative electricity pricing. Flexible nuclear plant operation requires complex calculations and planning that are burdensome and risky. Relying on their fossil plants also puts owners at risk of not meeting their carbon reduction goals.

Nuclear power plants must become more flexible, even those designed for baseload production.
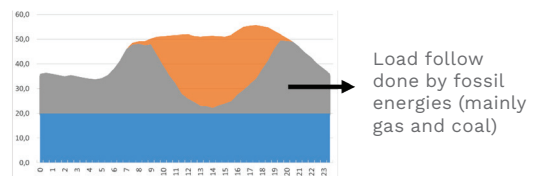
Solution

Framatome Operator Assistance Predictive System (OAPS) is a predictive operator aid that supports operators with real-time guidance for safe, flexible operation of their nuclear plants. The system acts like a "GPS" for reactor core control to eliminate operator burden during transients with no core control modification. It allows the increase in renewable penetration while maintaining grid stability and reducing carbon emissions, and makes nuclear the profitable, preferred alternative to gas for load follow.

Typical day without nuclear flexibility

Load follow done by fossil energies (mainly gas and coal)

Typical day with nuclear flexibility

Load follow done by nuclear instead of fossil energies

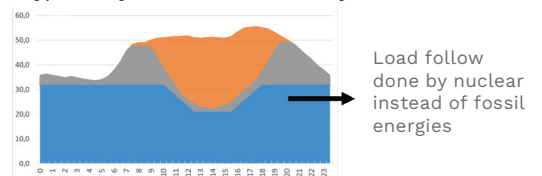### Current standard load follow in mode A (AO ≈AOref strategy)

Despite accuracy of standard simulation tools (even with 3D neutronic model), operator must adjust dilution/boration during the transient which is tricky due to dilution/boration delay (> 15 min).
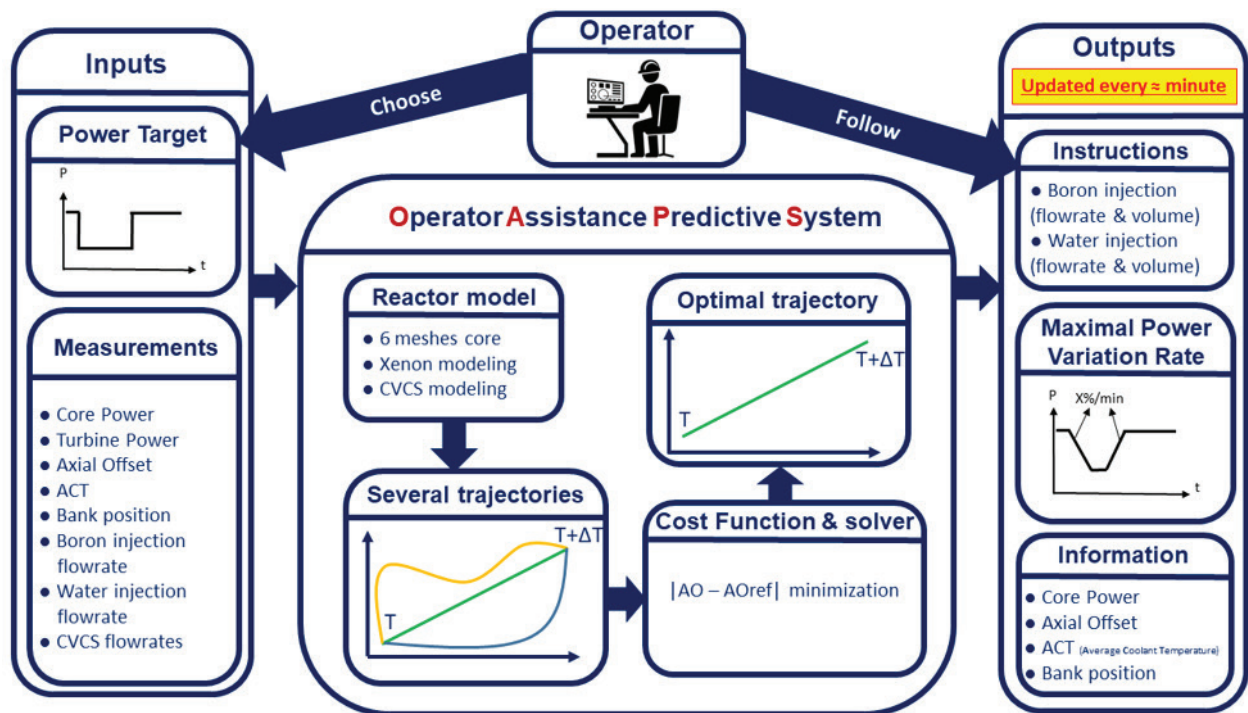
Customer benefits

Maximize nuclear power plant operations

- Maximizes fleet ROI by making nuclear the preferred alternative to gas for load follow

- Improves profitability due to less power production during low or negative pricing scenarios

- Optimizes renewables and nuclear generation to help reduce carbon emissions

- The OAPS solution is adaptable to any specific need in any reactor type or size

Ensure safe operation

- Minimizes boron consumption and effluent production with strictly necessary dose calculation resulting in additional savings

- Provides guidance during transients and baseload operation, reducing operator burden and reaction time

- Reduces risks of exceeding operating limits by keeping core characteristics within safe operating domain, and providing predictions of the evolution of key parameters (axial offset, Xenon) 24 hours in advance

Operator

Inputs — Choose → ← Follow — **Outputs**

Power Target — P / t

Operator Assistance Predictive System

Reactor model
- 6 meshes core
- Xenon modeling
- CVCS modeling

Several trajectories — T ... $T+\Delta T$

Optimal trajectory — T ... $T+\Delta T$

Cost Function & solver
$|AO - AOref|$ minimization

Measurements
- Core Power
- Turbine Power
- Axial Offset
- ACT
- Bank position
- Boron injection flowrate
- Water injection flowrate
- CVCS flowrates

Outputs

Updated every ≈ minute

Instructions
- Boron injection (flowrate & volume)
- Water injection (flowrate & volume)

Maximal Power Variation Rate — P / $X\%/min$ / t

Information
- Core Power
- Axial Offset
- ACT (Average Coolant Temperature)
- Bank position

Technical information

No core control modifications required.

Two main features as a GPS:
- Optimal trajectory:
  - An evolved optimization solver proposing the best strategy based on your needs and constraints: effluent minimization, maximum power variation, being as close as possible to the Axial Offset reference
  - 24 hours in advance predictions of core key parameters: Axial Offset, Xenon, bank position, temperature, chemical condition
- Real time commands:
  - A rapid calculation time allows for continuous recommendation and prediction even in the event of unexpected occurrences such as urgent grid requests or reactor contingencies
  - Accurate boron/water injection or control rod insertion recommendation with a stability of the command allowed by the Model Predictive Control system developed

Examples of use cases where OAPS provides substantial added value include:
- Optimization of effluents
- Flexible operations and load follow
- Extended low power operation (ELPO)

OAPS provides:
- The ability to react to any unexpected events to keep Axial Offset (AO) within a tight band during transients and baseload operations
- Optimized, accurate boration, dilution and other parameters to reach power targets while minimizing effluents production
- Enhanced maneuvering with real-time guidance to reduce operator burden and risk

Key Figures

2,400 I&C professionals at **21** sites in **10** countries.

Framatome has more than **30** years experience helping customers achieve flexible operations of their nuclear plants.

References

I&C flexible operation solutions already installed on the following PWRs:
- Germany (4)
- Switzerland (1)
- Spain (1)

Can be installed on any PWR:
- Without core control modification (for manual mode)
- With core control modification (for automatic mode)

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