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# Advanced Load Following Control

## for Non-Baseload Operation of Pressurized Water Reactors

### Fully-automated advanced flexible load following reactor control offering major economic and operational benefits

## Challenge

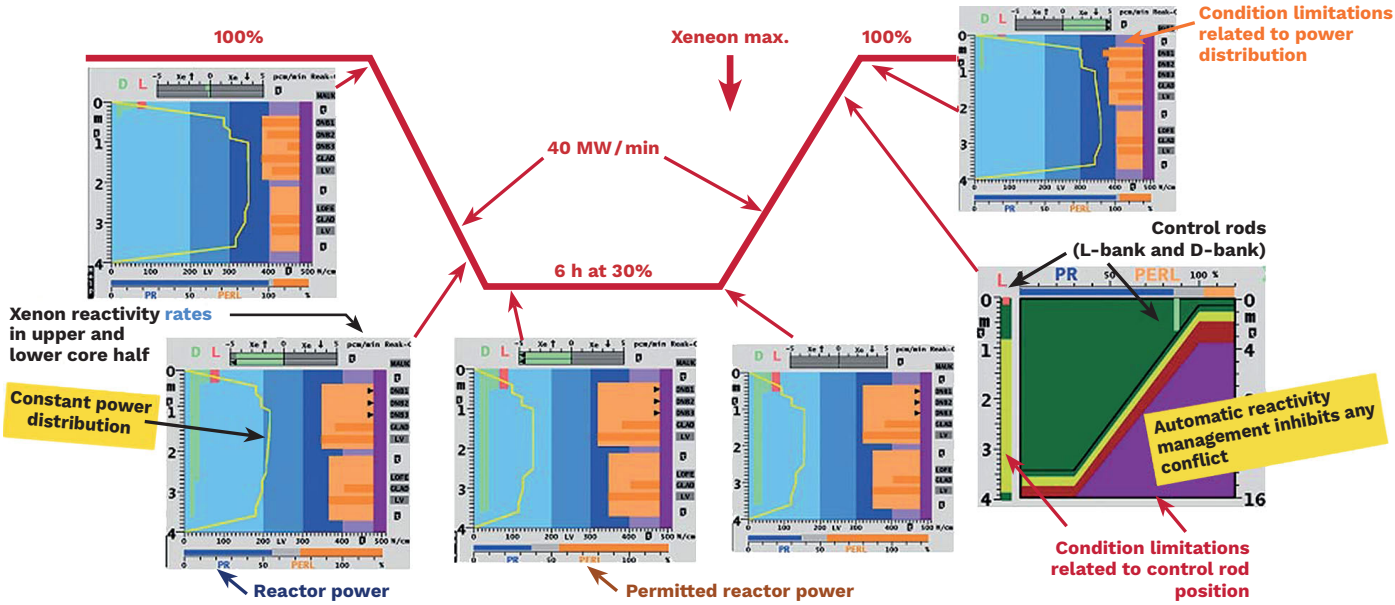
Increasingly volatile and decentralized renewable energy in the grid requires new operation modes for power system stability. Load dispatchers require balancing power to ensure a balance between generation and consumption of electrical energy at any given time and within the space of a few seconds. Various markets offer extremely attractive financial compensation for power producers providing this flexibility. However, common control systems in nuclear power plants (NPPs) are typically not flexible enough.

## Solution

The Advanced Load Following Control (ALFC) enables flexible non-baseload operation modes in pressurized water reactors (PWRs). These include load cycling, part-load operation, and primary or secondary frequency control according to the requirements of the grid. ALFC handles different core loading patterns and opens up possibilities for power uprates. Nuclear safety is enhanced thanks to automated boric acid / demineralized water mixing and transparent reactivity management not requiring manual support interventions.

## Customer benefits

- ALFC ensures fully automated flexible load following and does not require manual intervention.
- ALFC enables non-baseload operation modes (primary, secondary, tertiary).
- ALFC enhances nuclear safety.
- ALFC functions can be implemented in digital reactor control systems using a modular approach.
- ALFC offers a quick return on investment through attractive financial compensation for load following capabilities.




Constant power distribution during load following operation with ALFC

**Your performance**
is **our** everyday **commitment**

# Technical information

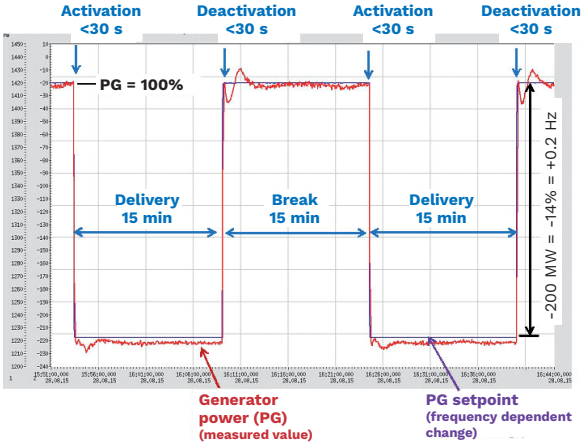
### ALFC reactor control system

- Ensures fully automated flexible load following operation without any manual intervention or intervention by the limitation system
- Enables load ramps at rates of up to 40 MW/min (3%/min, also with mixed oxide (MOX) equilibrium cores)
- Ensures frequency control with step-type load changes up to 14% in 30 s (“primary control”)
- Enables remote-controlled operation from load dispatcher (“secondary control” with no reaction time)
- Enables tertiary control mode (by telephone with 1 hour reaction time)
- Minimizes boric acid and demineralized water injection (mixture management)
- Can save on fuel assemblies due to possible extreme low-leakage core loadings

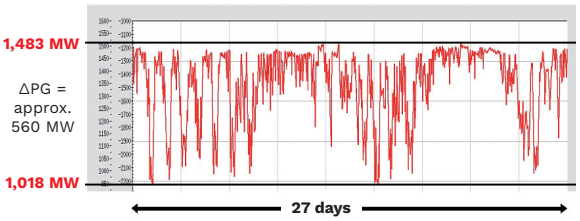
### Functionalities of ALFC

ALFC uses digital automation to improve process technology with regard to enhanced load flexibility such as:

- Exact boric acid/demineralized water mixing and reactivity management
- Adaptive filtering to reduce signal noise and operate with smaller margins
- Self-adaptation to fuel burnup-dependent power distribution changes
- Adaptation to shifting reactivity coefficients
  - for transparent automatic reactivity management by reactivity balancing
  - for better adaptation to changing core loads (low-leakage, MOX, increased enrichment)
- Xenon calculation for the power distribution controller and boric acid and demineralized water injection management




Primary frequency control with ALFC in a NPP




Remote secondary control: stochastic changes of generator power at a rate of 30 MW/min

## References

PWRs with ALFC technology:

- Germany (4)
- Switzerland (1)
- Netherlands (1 part-ALFC)



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