framatome

Nuclear Power Plant Flexible Operations

Adapt electricity production to an intermittent market demand

Get a full range of customizable & proven solutions with numerous references to fulfill grid requirements and maximize profitable operations.

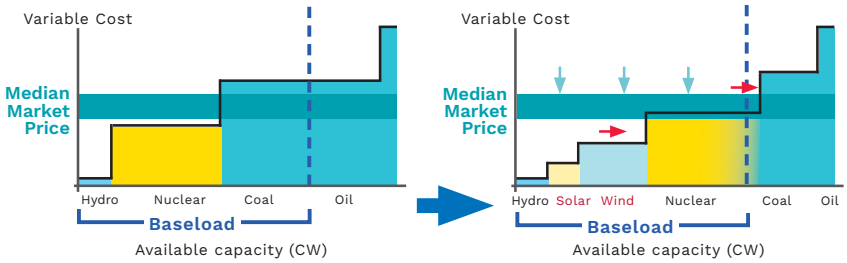
Challenge

Most NPPs are currently optimized for Base Load Operation. They are challenged economically by:

- existing and planned growth of intermittent renewables
- effects of new energy policies
- strong competition from low priced carbon energy

These pressures lead to low or even negative electricity spot market prices in some grids.

Grid stabilization needs are undergoing a harmonization process. To accommodate evolving future grid demands and maintain economic profitability, all NPPs can benefit from adding flexible operations capabilities.



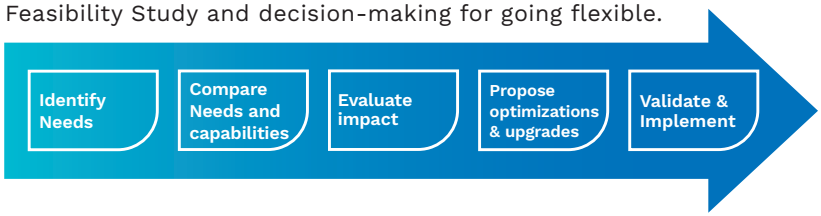
Solution

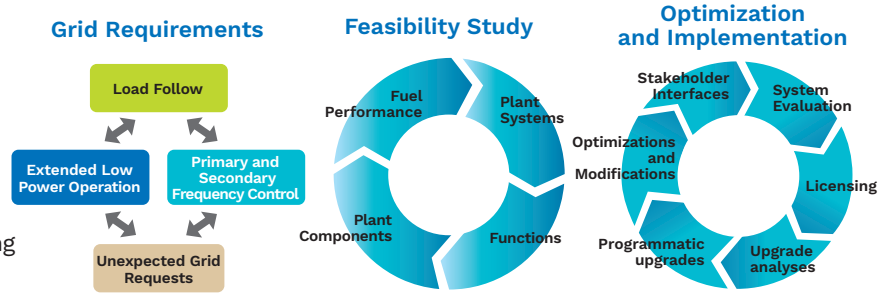
Framatome global approach is based on overall experience from reliable, safe and profitable flexible operations of NPPs in France and Germany over many decades.

- **Feasibility study "from the Reactor Core to the Grid"**
  Studies range from manually controlled load ramps to fully automated flexible operation. The feasibility study provides recommendations for plant optimizations and analyses upgrade options.
- **Optimization and implementation packages "from Low to High flexibility Demand"**
  Tailored solution based on full range of capabilities such as in-core monitoring, I&C, aging & maintenance management, codes & methods and fuel design.

Modular approach

Feasibility Study and decision-making for going flexible.





Customer benefits

Grid requirements

- Fulfill the obligatory grid requirements
- Better flexible performance than coal/oil and comparable to combined gas plant

Revenue

- Increase revenue by paid dispatch and by higher paid ancillary services
- Minimize carbon taxes (replacement of old fossil fired plants ability to produce ancillary services)
- Minimize production during periods of low/negative prices
- Increase the net value of the plant and limit industrial risks

Operating & Maintenance

- Optimize NPP costs for flexible operations "from the Reactor Core to the Grid"
- Optimize fuel resources, economics and refueling outage schedule
- Optimize maintenance means during outages (small fleet)
- Pellet Clad Interact monitoring minimizes the risk of fuel failures
- Full automatic mode with limitation of risks and transients impacts

Crediting of potential available flexible operation capability

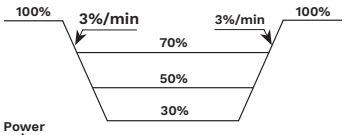
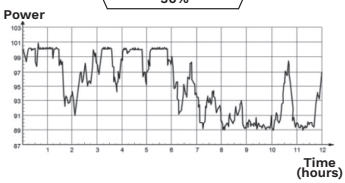
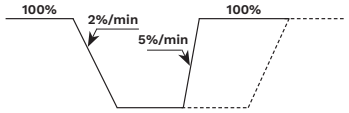
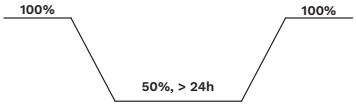
- Identify real design capabilities in detail
- Improve reliability and safety
- Take into account the plant life time (and License Extension) aging

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

Technical information

All types of flexible operations required by the grid can be implemented, from semi manual to fully automated mode, singly and combined.

Framatome has experience to specify best capability mix based on specific customer needs owing to unique & proven solutions.

Potential Grid Requirements	Example	Potential NPP Operation Modes
Adaptation to daily demand variation		**Load Follow (LF)** • Low power period: power level, duration • Power range rate (slope): slow, fast • Load Schedule
Adaptation to real-time frequency variation		**Frequency Control (FC)** • Primary (PFC): automatic (amplitude, slope) • Secondary (SFC): remote control (amplitude slope) • Possible superimposition of PFC and SFC
Adaptation to Grid disturbances		**Follow unexpected grid requests:** • Ramps (amplitude, slope) • Instantaneous return to full power (slope) • House Load Operation
Adaptation to longer term forecasted demand		**Extended Low Power Operation (ELPO)** • Reduce the power level during significant periods (number of occurrences, duration)

Key Figures

The scenario is based on a typical plant with the following characteristics

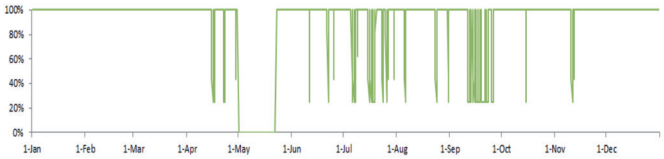
Capacity	MWe	1,065
Efficiency	%	33 %
Maximum remaining lifetime as T0	years	32
Annual load factor	%	94 %
Outage duration	days	22
Outage start date		1-May

Selected hourly price profile characteristics

Maximum price	USD	163
Minimum price	USD	-57
Average price	USD	20
Share of hours with negative prices	%	3.8 %
Average price when negative	USD	-8
Longest period with negative prices	hours	36
Median price	USD	21
Standard deviation		12

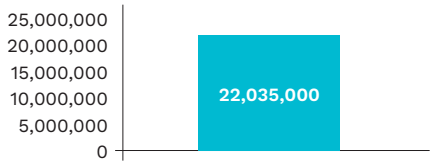
→ **Hourly Load factor with the benefits of flexibility is simulated**

Hourly Load Factor with Planned Flexible Operation (including outage if any)



→ **Total NPV* is calculated for the remaining years of Operation**

NPV* Delta with Business as Usual ($)



*Net Present Value

References

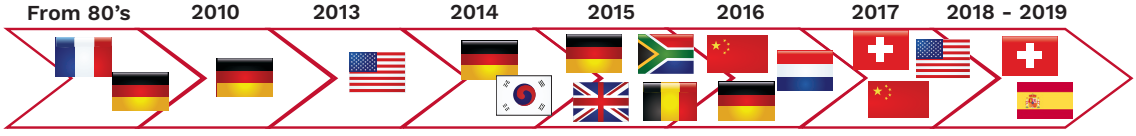
Since the 1970's, Framatome has supplied nearly 100 NPPs with flexible operation capabilities.
Framatome has also upgraded various existing designs to improve upon their flexibility.

Of these NPPs, most operate in flexible mode in a safe, profitable and reliable manner.
In France, 58 EDF plants have used flexible operation since 1984 and have accumulated hundreds of years of favorable operating experience.

In Germany, more than a decade from 4 plants operating at fully automated mode.
Such mode is available for all types of reactors and enables new profitable price models in some countries.

Fuel power maneuvering guidelines have been developed based on extensive testing and analyses that ensure safe and reliable performance during all flexible operations modes.

Industry leader with decades of experience



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