

framatome

Flexible in Operation

Increase safety and profitability
Framatome's world-wide solution

CORP MKG – T. GAIN
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Framatome Confidential



Future of nuclear energy is
flexible
... reasons why

In the 80's and now



- ❖ Automatic
- ❖ Energy efficient
- ❖ Reliable
- ❖ Stable
- ❖ Faster - quicker
- ❖ Safer

... and profitable



Our understanding of your electricity market

- ❖ Climate-neutral long-term strategy for energy
- ❖ Share of weather-dependent vs. conventional energies
- ❖ Grid demand variations
- ❖ Balancing energy market (bidding for positive and negative)
- ❖ Harmonization of the EU market through the new European platforms

Problem is not to produce enough electricity, but if (a) electricity will be available when needed, and (b) production of energy is variable so as to use the source as an energy balancing resource

- ❖ Low price of electricity
- ❖ Investments significant business risk
- ❖ Uncertainty about electricity market trends
- ❖ Difficulties building new power plants

Problem is not to erect new power stations, but to design and operate facilities in the most financially flexible way able to accommodate for future energy market evolutions and needs

Why encourage flexibility in nuclear power generation

		Nuclear	Solar/wind	Hydro	Fossil
Grid	Base load	+	-	↑↓	+
	Stability – Peak demand	+ (*)	-	+	+
	Load follow	+ (*)	-	+	+

Give two solutions in the mix for flexibility with low carbon

Anticipate climate changes (less streamflow)

*: all designs of fleet not equipped with FLEX-OPS at Framatome

- Considering grid stability
- Considering climate changes
 - drastic reduction of fossil energies
 - Modification of river flows
- Considering alternative solutions for changes in energy policies

⇒ Nuclear is therefore a viable option, if performances are similar to fossil plants

Why make nuclear power production flexible

Flexible nuclear power can be more profitable than new natural gas/hydro plants to meet grid variations when...

- Intending to extend the lifetime of your nuclear power plants to 60 years
- The usage factor of the fleet is difficult to estimate (due to market uncertainty), putting your ROI at risk

Thus, there is a need to “industrialize” the flexibility of your nuclear power fleet to adapt to the market variations, optimize outages and maximize the ROI of your plants

⇒ **FLEX-OPS** can ensure the ROI of your investments in your nuclear power fleet

- Difficult to obtain permit for new hydro plant
- CO₂ emissions for new gas plants (R&D to reduce emissions but with strong impact on costs)
- Cost of nuclear power is less dependent on unpredictable fuel prices than natural gas power
- Price of natural gas is not predictable at mid / long term

On the other hand, the costs of nuclear power is more predictable and more stable

Nuclear is ready now to provide power balancing services and frequency control



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... however what about technical and financial risks

Flexible operation: performances target and achievements

Power plant type	Time to start	Maximal load variation within 30 s	Load range	Maximum load ramp
Gas turbine	10-20 mn	20-30 %	0 – 100 %	20 % / mn
Combined cycle gas	30-60 mn	10-20 %	0 – 100 %	5-10 % / mn
Coal plant	1-10 hours	5-10 %	0 – 100 %	1-5 % / mn
PWR designed for base load	2 h to 2 days	--/--	--/--	0,2% / mn
PWR GENII designed for Tertiary Reserve	2 h to 2 days	1 %	50-100 %	2 % / mn
PWR GENIII – III+ designed for Tertiary Reserve	2 h to 2 days	3-5 %	50-100 %	3 % / mn
All PWR with Framatome's solution	2 h to 2 days	5 %	30-100 %	5 % / mn (qualified up to 14%)



Fully Automatic Load Follow Control applicable to all reactors reaches European GENIII+ target for load follow operation, better than coal and comparable to combined cycle gas plants

NPP Flexible Operations: potential impacts

Control issues

- BoP and BNI I&C incl. control rod maneuvering program - automated reactivity management (Boron / Dilution) - axial power distribution control - Xe transient management
- Pressurizer level and pressure control channels
- Human Machine Interface

Life-time issues

- Wear e.g. control rod system wear
- Fatigue
- Flow-accelerated corrosion
- Vibrations (secondary side during part load)
- Impact on Design Transients File

Chemistry issues

- Primary side - Boric Acid/ Alkalisiation management (pH-value) and treatment
- Secondary side - BOP optimizations (pH -value), SG (cleaning strategy)

Fuel Behavior and transition analysis

- Neutronic and TM Justifications
- Power maneuvering guidelines (PCI)
- Optimization of Fuel management strategies
- Fuel transition global package, if required

Safety analyses

- 3D power and burn up distributions
- Impact on the Safety Analyses Report (Events; Core and NSSS initial conditions before accidents)

Technical specifications

- Plant operating conditions
- Operational technical specifications
- Other current documentation

Training issues

- Operator training
- Simulator

- ⇒ Framatome has a solution for each of potential customer's concern, developed in a profitable way
- ⇒ Critical success factors include defining only what is essential in terms of flexibility
- ⇒ Offer a full range of customized solutions with a single point of accountability to maximize profit and improve safety

Flexible operation: Value Drivers & Value Proposition

Electricity market	Availability / Operation / Maintenance		Asset management
Better flexible performance than coal/oil and comparable to combined gas plants	Transients impacts mitigation: Xe monitoring	Automatic modes: improve reactivity management and maneuverability	Plant life time and aging monitoring
Minimize production for low/negative prices: low power operation	Less LCOs and SCRAMs	Identify real design capabilities in detail	Mitigation of fatigue and vibrations
Fulfill the obligatory grid requirements:	Pellet Clad Interact monitoring minimizes the risk of fuel failures	Improve Reliability and Safety: DNB/LOCA margins and PCI monitoring	Optimize fuel resources, economics and refueling outage schedule
Increase output net power	Less boron (recycling), less wastes	Easier and safer operation: mitigates human failures	Increase the net value of the plant and limit industrial risks
Increase revenue by paid dispatch and by higher paid ancillary services	Optimize maintenance means during outages (small fleet)		

Value propositions:

- Fulfill grid operator requirements
- Maximize plants' performances and profitability
- Easier to operate with higher performances
- Fuel economies



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... Framatome has the solution tailored to meet
your needs

Only Framatome worldwide considered and implemented all phases of the projects



- 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
- Countries with flexible nuclear reactors all experienced grid-specific profitable economical models
- Such mode is available for all types of reactors and enables economies in OPEX, long term asset, no carbon
- In all countries with Framatome's flexible operation projects implemented, feed back is beyond increase, stable price, increased reliability, and new profitable price models in some countries expectations
- Fuel power maneuvering guidelines have been developed based on extensive testing and analyses that ensure safe and reliable performance during all flexible operation modes
- Project tailored to customers needs and dimensionned in accordance with existing economical model
- If the flexibility is required, Framatome has a customer-tailored solution

Summary

YOUR CHALLENGE

Most nuclear plants are designed or currently optimized for base load operations

Evolution of the grid and market share., climate changes

New drivers for customers:

- Flexibility in the grid
- Long-term asset and profitability

Solution limited by the design, operation modes and organization impacts:
solution adapted to the customer

OUR SOLUTION

Our solution is unique, we offer the complete scope and are able to adapt to customers' needs:

- Applicable to all types of reactors
- Customizable following operator's needs from full automated embedded solution to limited-to-design solution
- Covering all the plant's scope "from the Reactor Core to the Grid", including all safety systems and logics"
- Adapted to aging monitoring, lifetime extension, fuel economy, safety improvement ...

YOUR BENEFITS

- Better flexible performance than coal/oil and comparable to combined gas plants
- Minimize carbon taxes (replacement of old fossil fire 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
- Optimize fuel resources, economics and refueling outage schedule
- Optimize maintenance means during outages (small fleet)
- PCI monitoring leads to less or prevents fuel leaks

Summary

FRAMATOME together with EDF has the complete know-how and experience with respect to flexible operation mode

- design new NPPs including advanced fully automatic I&C
- optimize and upgrade existing NPPs
- fuel development and transition

Our overall technical expertise covers “from Reactor Core to the Grid”

Our Mission is to make NPP a valuable asset for balancing of today’s Grid in each required flexible mode:

- Load Follow
- Primary and Secondary frequency Control
- Unexpected Grid Requests
- ELPO



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... questions

with Dr Tatiana Salnikova – Framatome GmbH

