Operational Flexibility of Large Turbine Generators

a message to

our industry from …

Electric Machinery Committee Task Force ….

Robert Thornton-Jones	**Brush Electrical Machines**
John Yagielski	**GE Power**
Lon Montgomery	**Siemens Energy**

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Electric Machinery Committee Task Force ….

“Coordination of Grid Codes and Generator Standards: Consequences of Diverse Grid Code Requirements on Synchronous Machine Design and Standards”

Operational Flexibility of Large Turbine Generators

- IEEE Task Force Members include Generator Owners, Manufacturers, TSOs, Regulators & Consultants, …
- … who are to prepare a report recommending improvements and harmonisations to:
  - 1. Generator Standards IEC60034 & IEEE C50.13.
  - 2. Grid Codes

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Chavdar	Ivanov	Matthias	Baechle
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Leo	Lima	Uwe	Seeger
Les	Hajagos	William	Bloethe

Operational Flexibility of Large Turbine Generators

CONCLUSION:

Cigré, IEC & IEEE must cooperatively pursue describing required attributes of desired operational flexibility … to include:

- duty cycles (start-stops, MW-MVAR load cycles)
- weighted average efficiency

Operational Flexibility of Large Turbine Generators

Operational Flexibility Attributes being discussed:

- Voltage-frequency operating ranges and durations
- Reactive power capability
- Generator short-circuit ratio (SCR)
- Rate of Change of Frequency (RoCoF) withstand capability
- Fault ride through
- Excitation voltage ceiling factor
- Auto-reclosing
- Power output as function of frequency

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See presentations by Luis Rouco & John Yagielski

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Added Topics

- **duty cycles**
- **weighted average efficiency**

Operational Flexibility of Large Turbine Generators

Operational Flexibility Attributes being discussed:

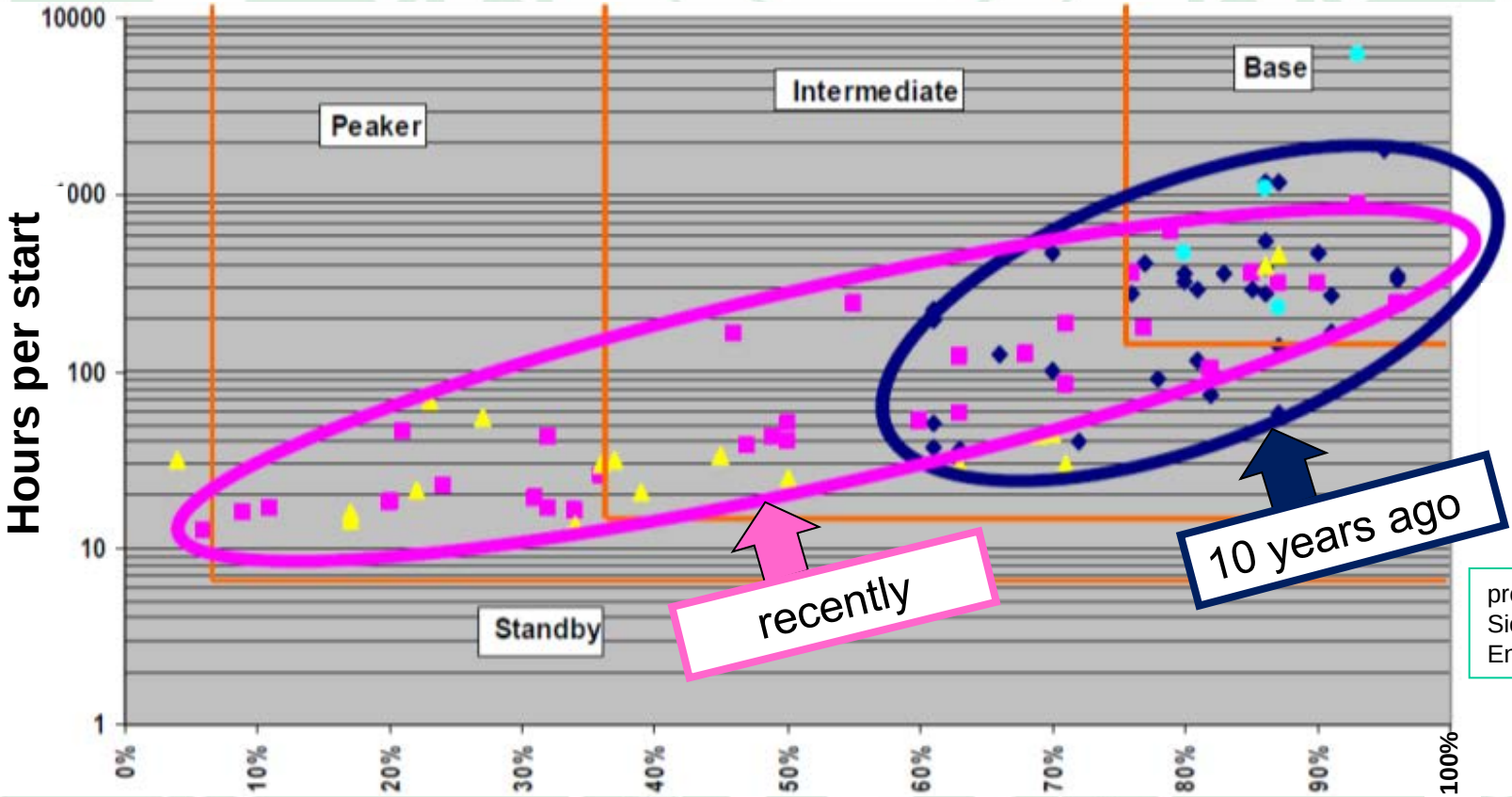
- **duty cycles**

Operational Flexibility of Large Turbine Generators

TREND

increasing flexibility

standby ← peak ← intermediate ← base load (ISO)



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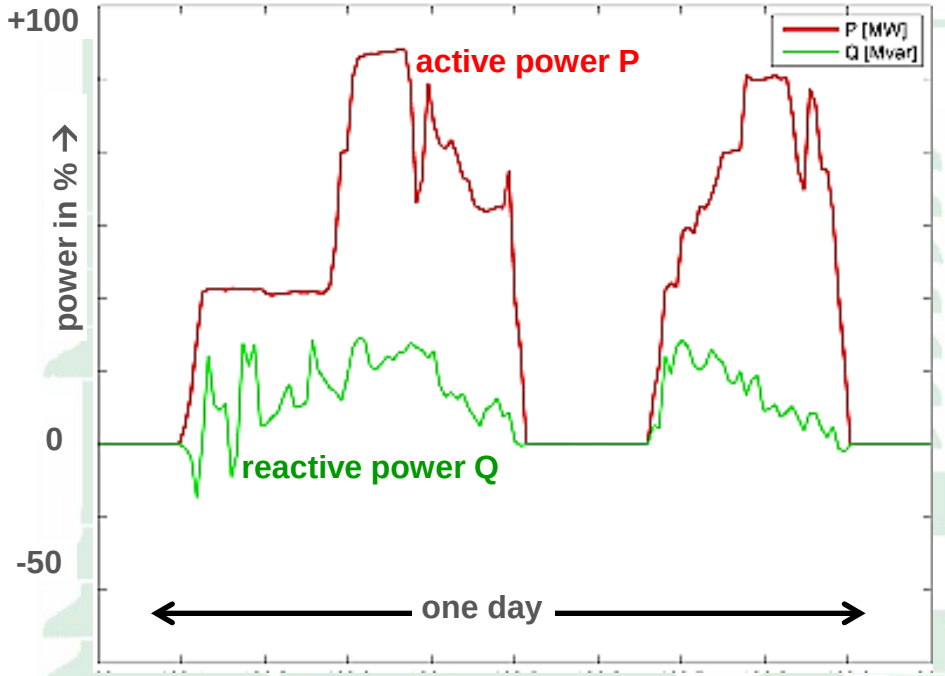
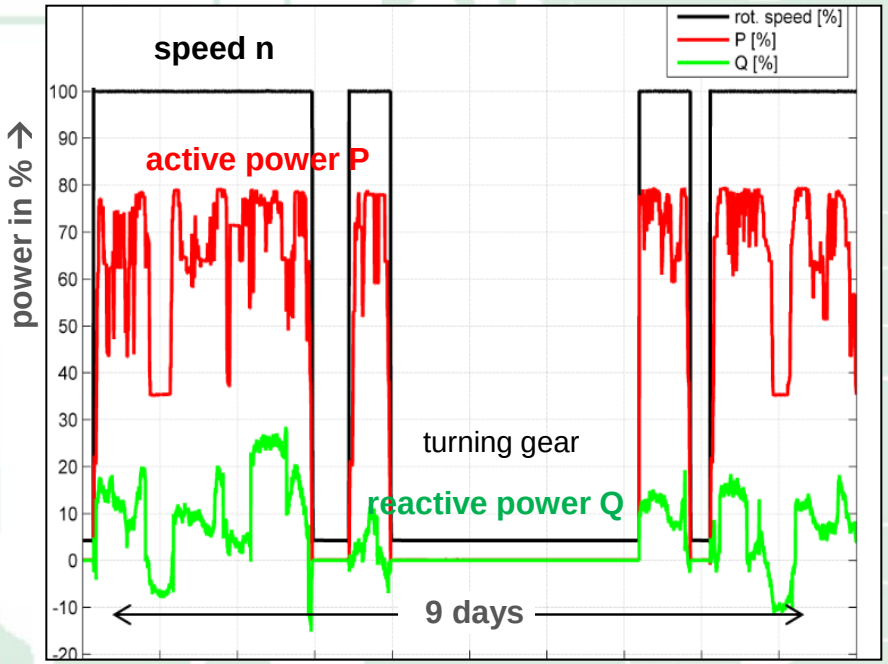
Operational Flexibility of Large Turbine Generators

Changing speed & MW-MVAR in typical daily grid demand profile





- Several start-stops / day & week depending on renewable energy production
- Fast & frequent steps in MW to balance weather dependent renewable energy
- Continuous MVAR variation to stabilize fluctuating grid conditions

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Operational Flexibility of Large Turbine Generators

Excerpt about duty cycles from IEC 60034-1 …

4.1 Declaration of duty

It is the responsibility of the purchaser to declare the duty. The purchaser may describe the duty by one of the following:

a) numerically, where the load does not vary or where it varies in a known manner

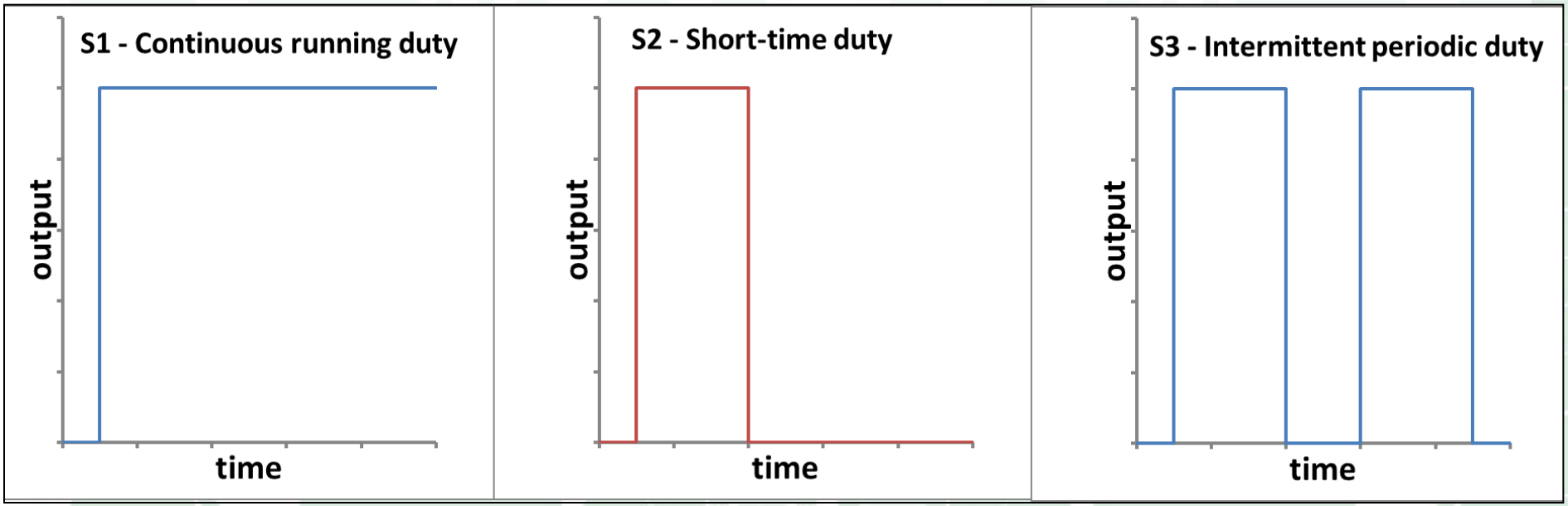
b) as a time sequence graph of the variable quantities

c) by selecting one of the duty types S1 to S10 that is no less onerous than the expected duty.

Operational Flexibility of Large Turbine Generators

Excerpt about duty cycles from IEC 60034-1 …

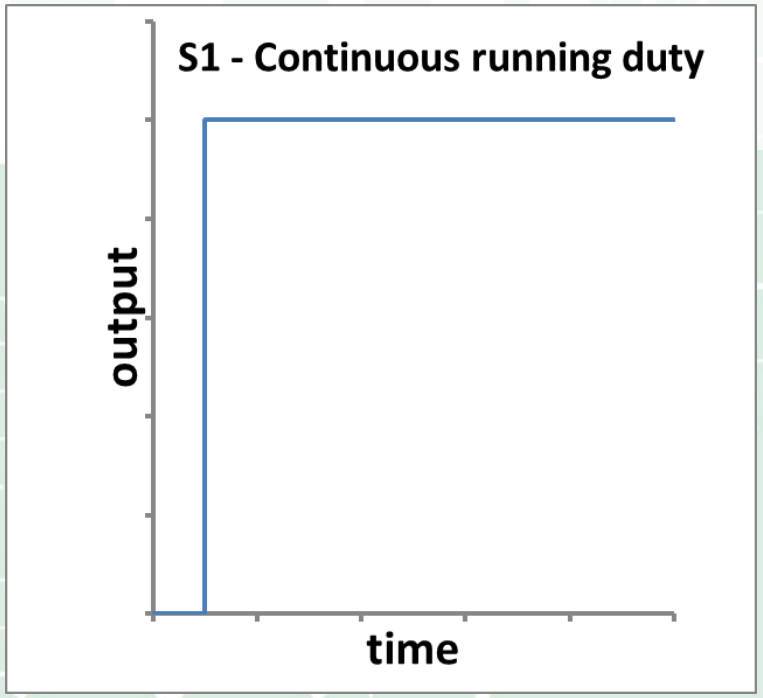
c) by selecting one of the duty types S1 to S10 that is no less onerous than the expected duty …..



Operational Flexibility of Large Turbine Generators

Excerpt about duty cycles from IEC 60034-1 …

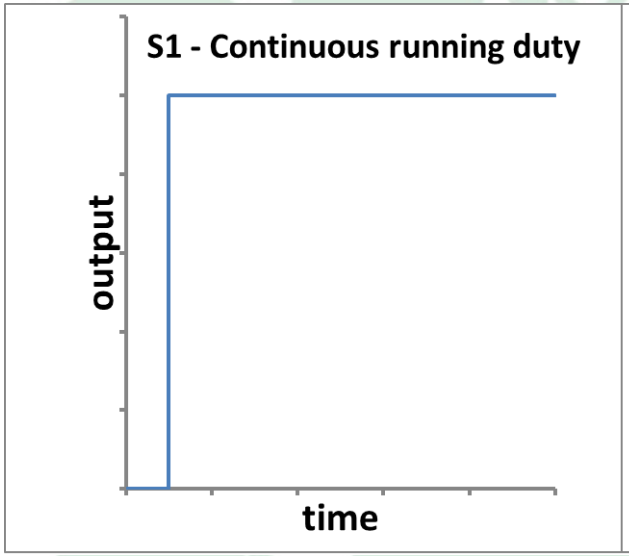
Where the purchaser does not declare a duty, the manufacturer shall assume that duty type S1 (continuous running duty) applies.

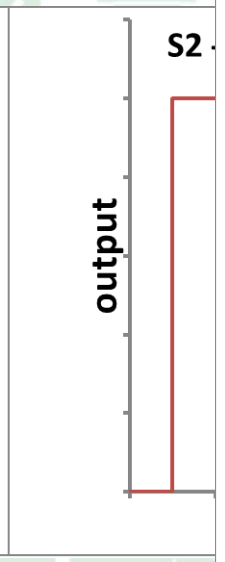


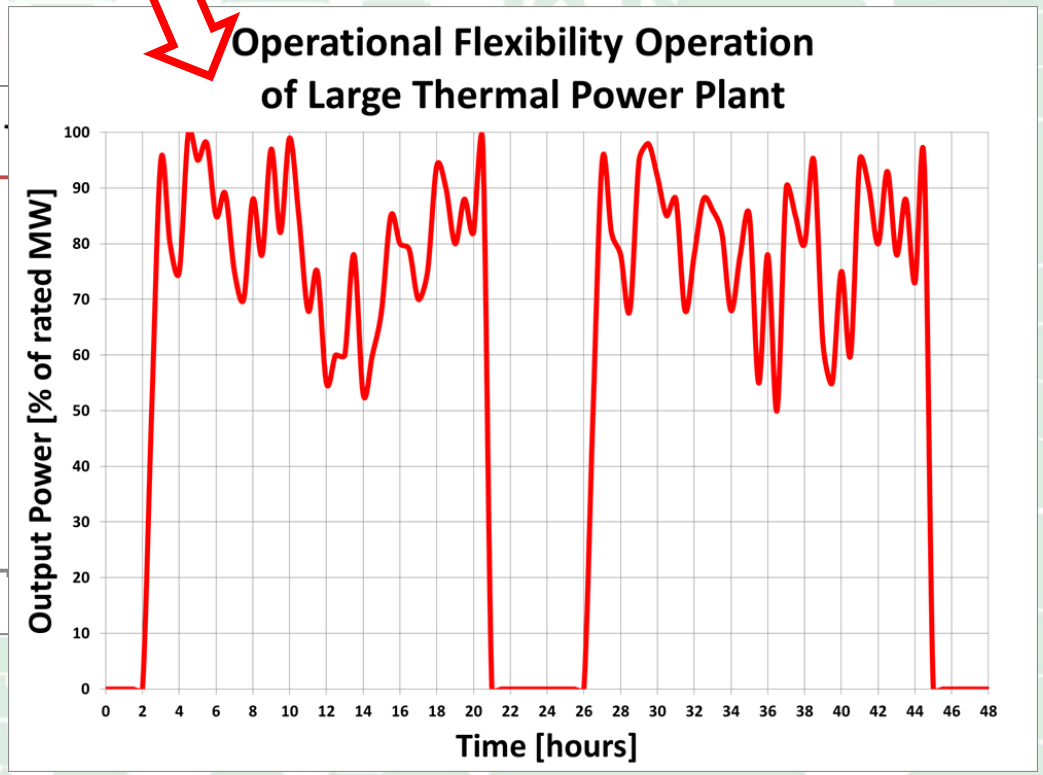
Operational Flexibility of Large Turbine Generators

Excerpt about duty cycles from IEC 60034-1 …

b) as a time sequence graph of the variable quantities ….. perhaps something like this ….

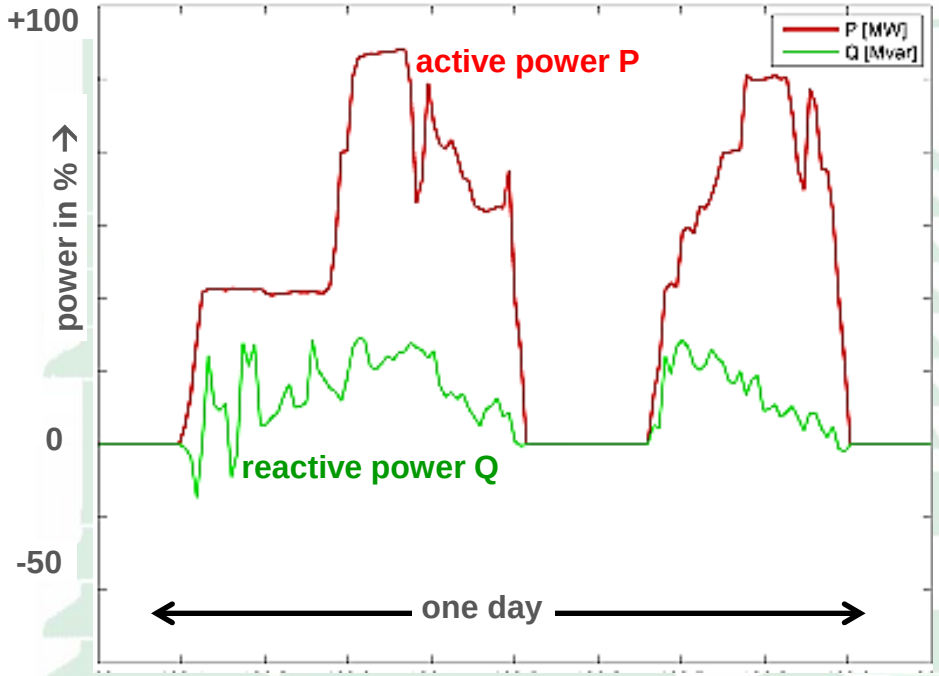


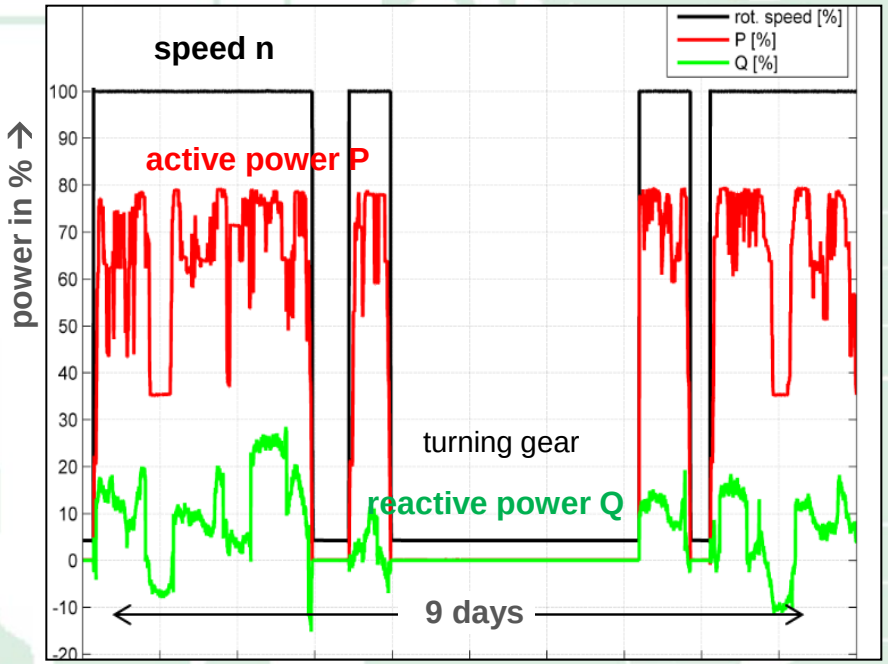




Operational Flexibility of Large Turbine Generators

Changing speed & MW-MVAR in typical daily grid demand profile





- Several start-stops / day & week depending on renewable energy production
- Fast & frequent steps in MW to balance weather dependent renewable energy
- Continuous MVAR variation to stabilize fluctuating grid conditions

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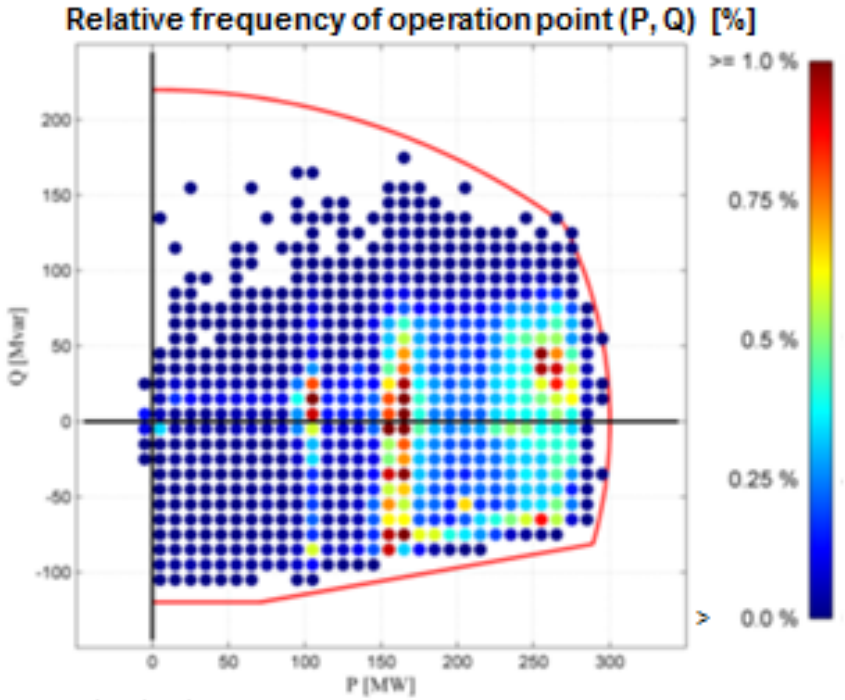
Operational Flexibility of Large Turbine Generators

Operational Flexibility Attributes being discussed:

- **weighted average efficiency**

Operational Flexibility of Large Turbine Generators

One specific generator



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- High number of start-stop cycles
- Operation in whole released capability range (& infrequently at rated load)
- High share of reactive power for grid stabilization
- Full use of under-excitation capability because of capacitive grid demands

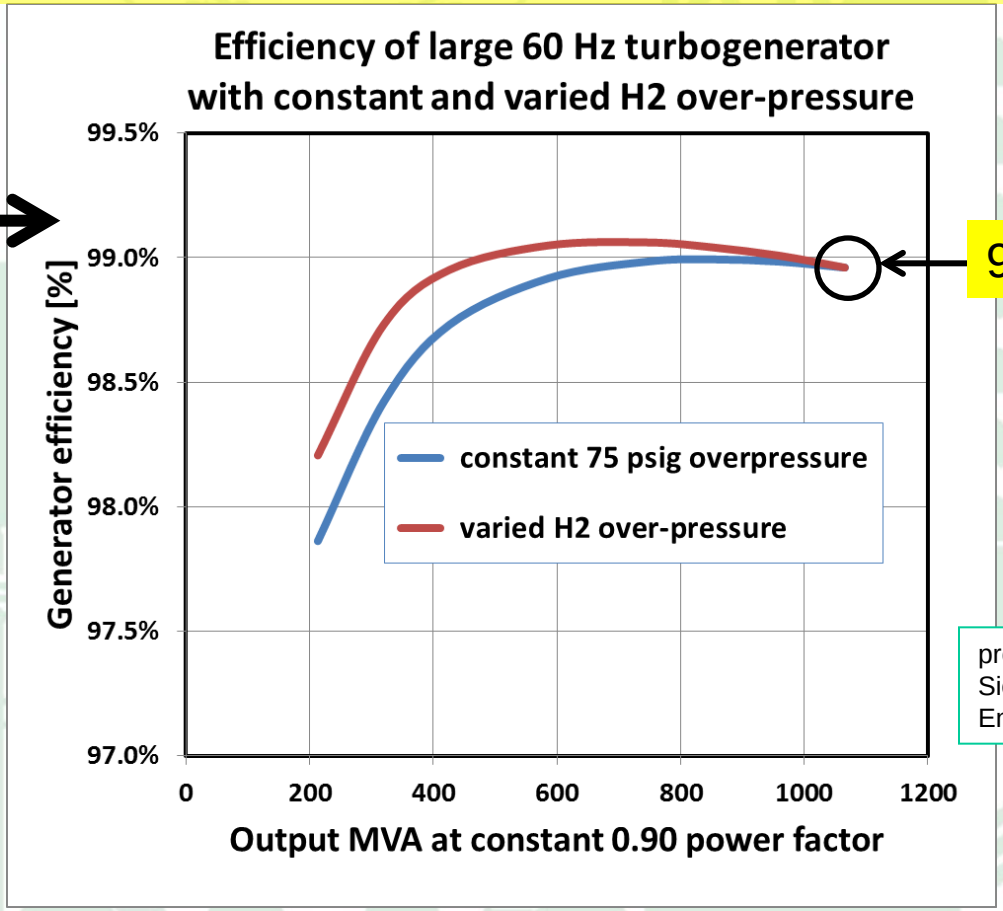
Increased demand on highly flexible load operation of conventional power plants

Operational Flexibility of Large Turbine Generators

Possibility for flexible operation to increase efficiency:

- **Variable operation with fixed H2 over-pressure**
- **Variable operation with varied H2 over-pressure**

lower part load losses with varied H2 overpressure



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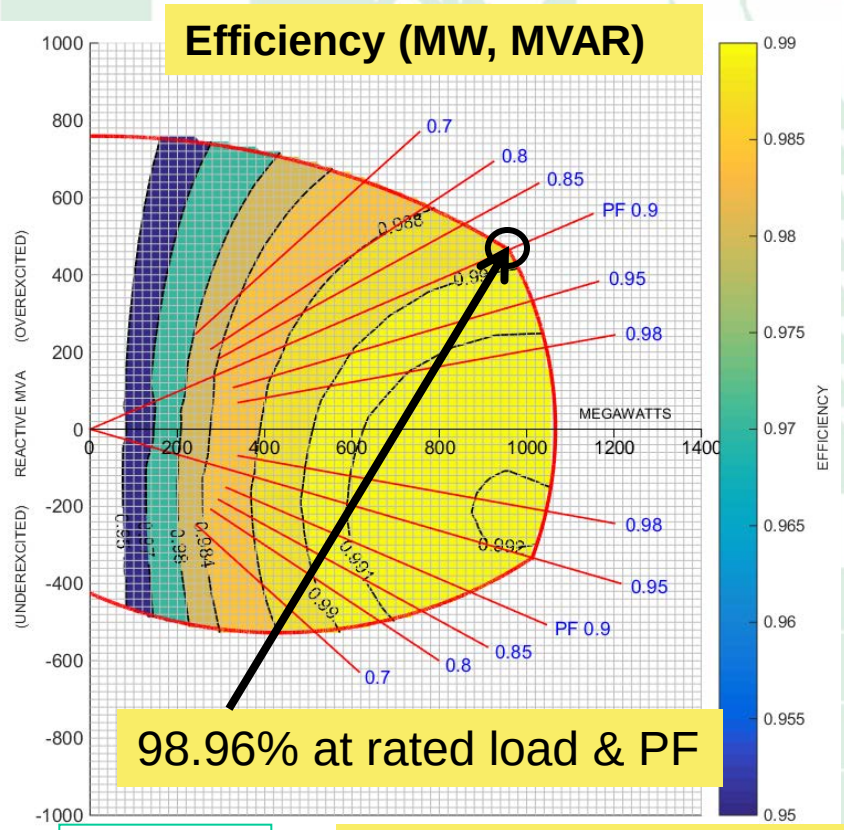
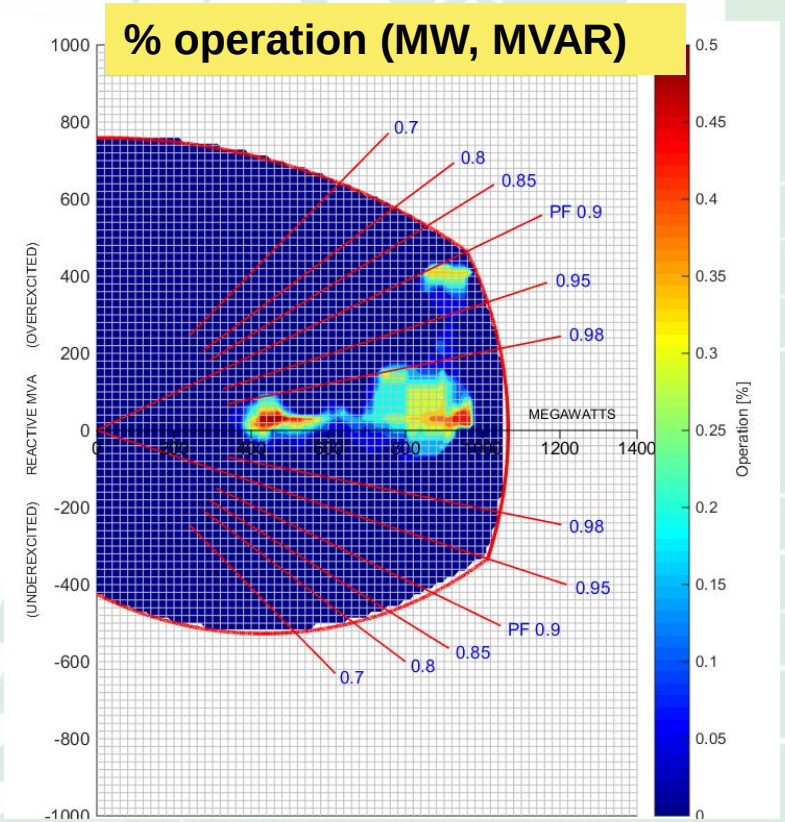
Operational Flexibility of Large Turbine Generators

Weighted average efficiency with fixed H2 overpressure



X



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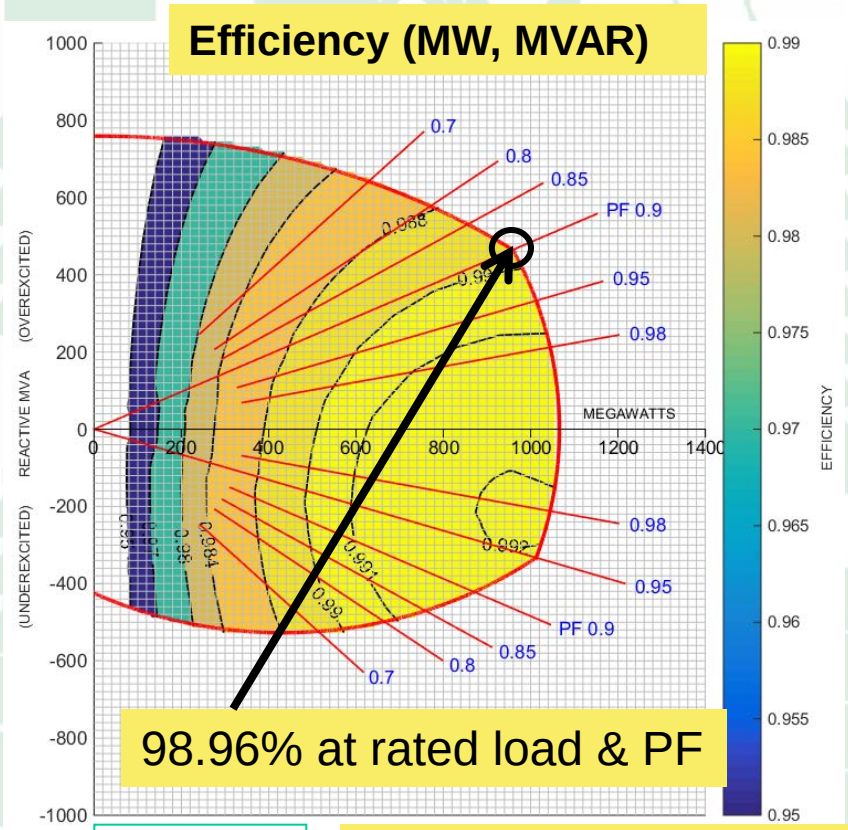
= 99.08% weighted average efficiency

Operational Flexibility of Large Turbine Generators

Weighted average efficiency with fixed H2 overpressure



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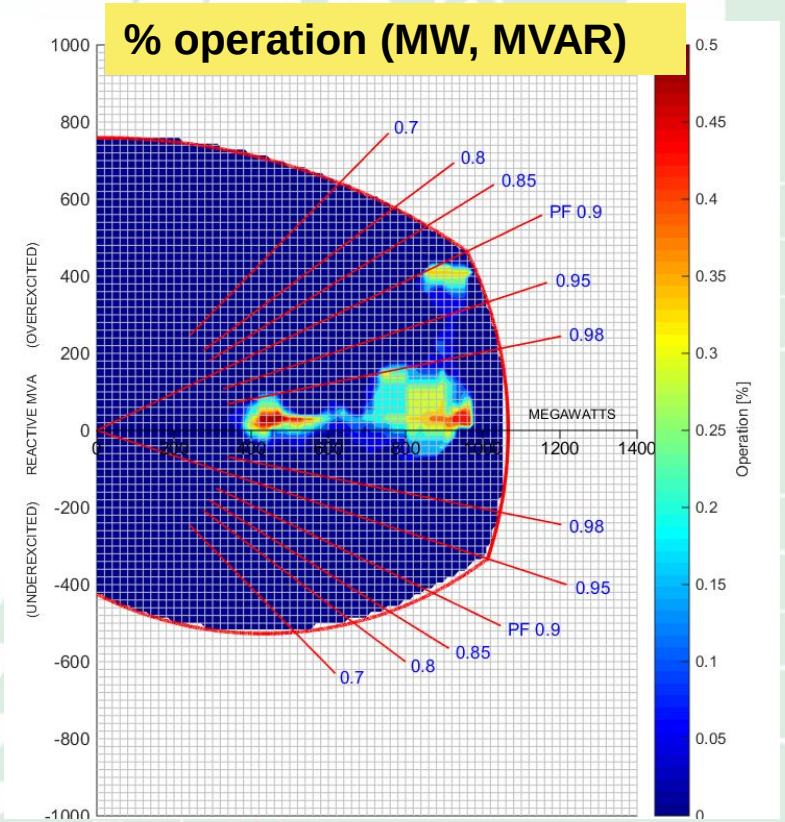


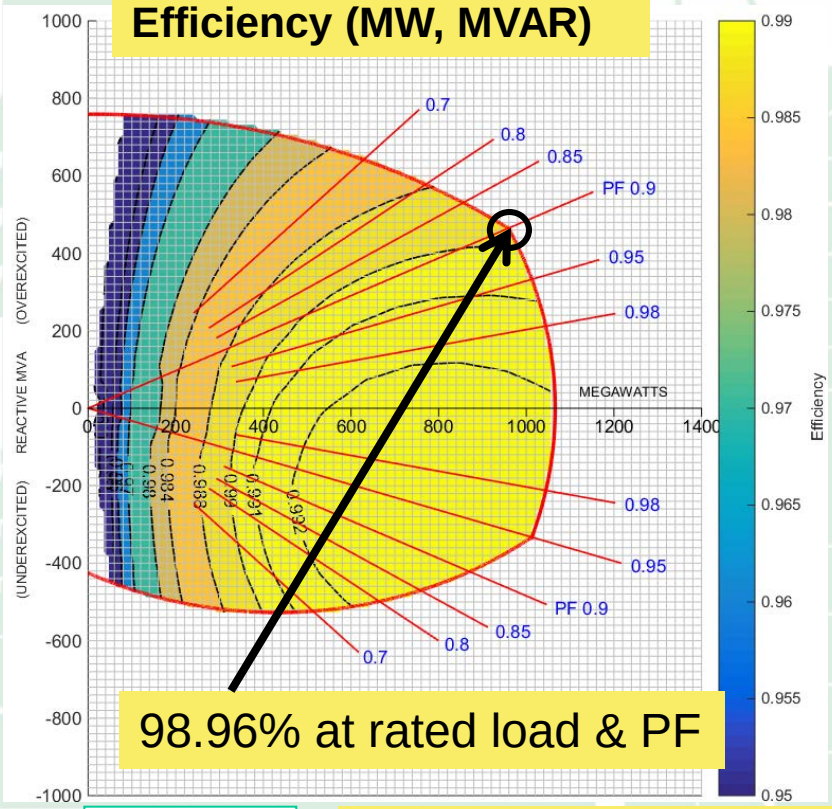
provided by Siemens Energy, Inc.

= 99.08% weighted average efficiency

Operational Flexibility of Large Turbine Generators

Weighted average efficiency with varied H2 overpressure

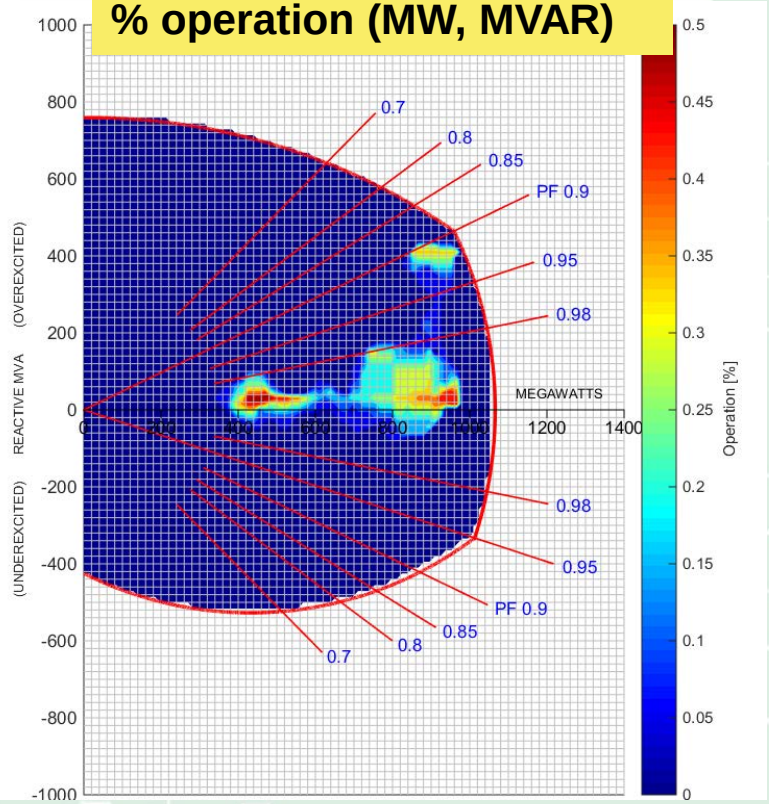
Efficiency (MW, MVAR)



98.96% at rated load & PF

X

% operation (MW, MVAR)



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= 99.17% weighted average efficiency

Operational Flexibility of Large Turbine Generators

Consider: Amend turbogenerator standards to allow specification of several operating points at which efficiency is to be quoted, with % weightings for each point by agreement

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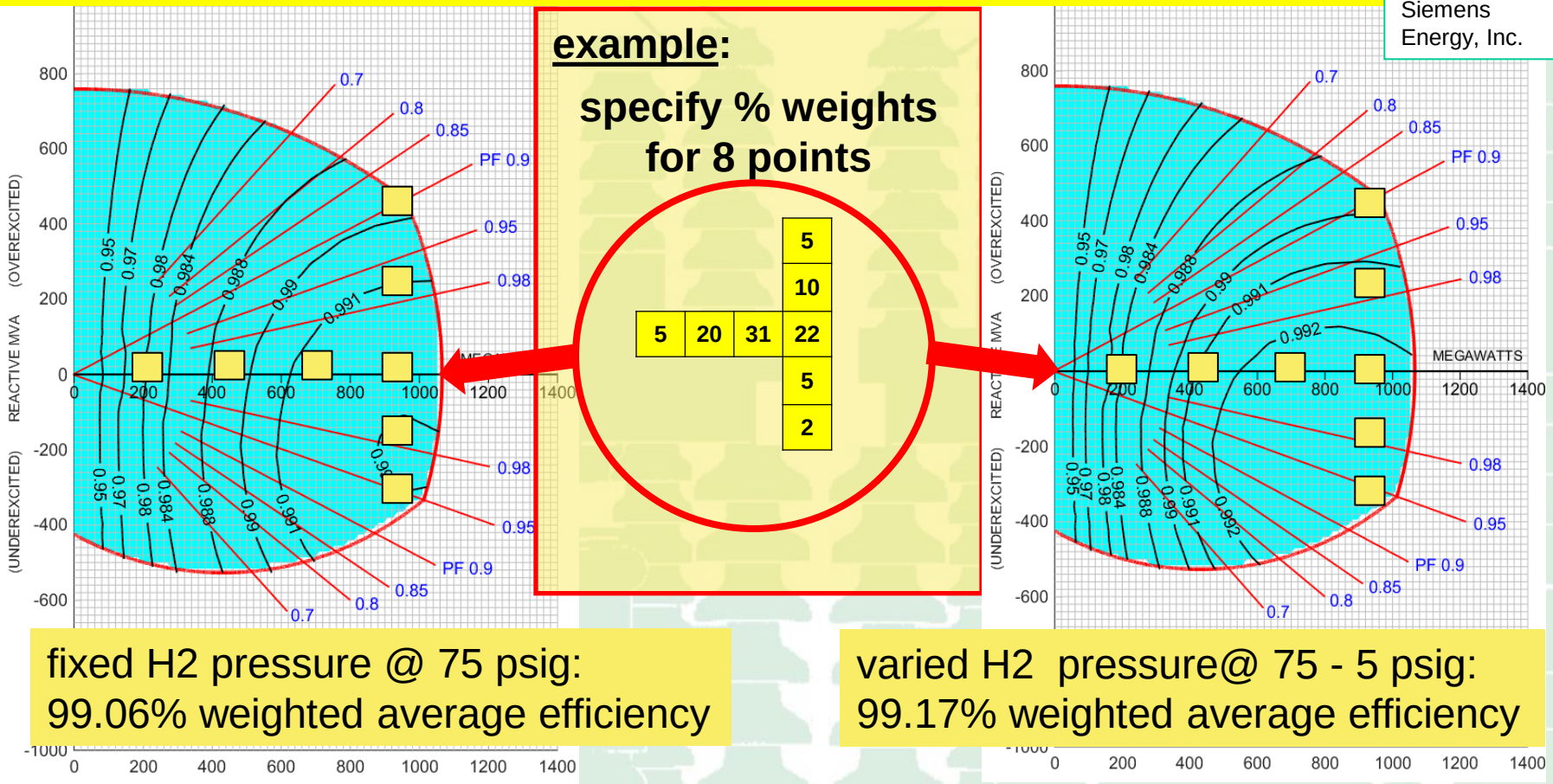

fixed H2 pressure @ 75 psig:
99.06% weighted average efficiency

varied H2 pressure@ 75 - 5 psig:
99.17% weighted average efficiency

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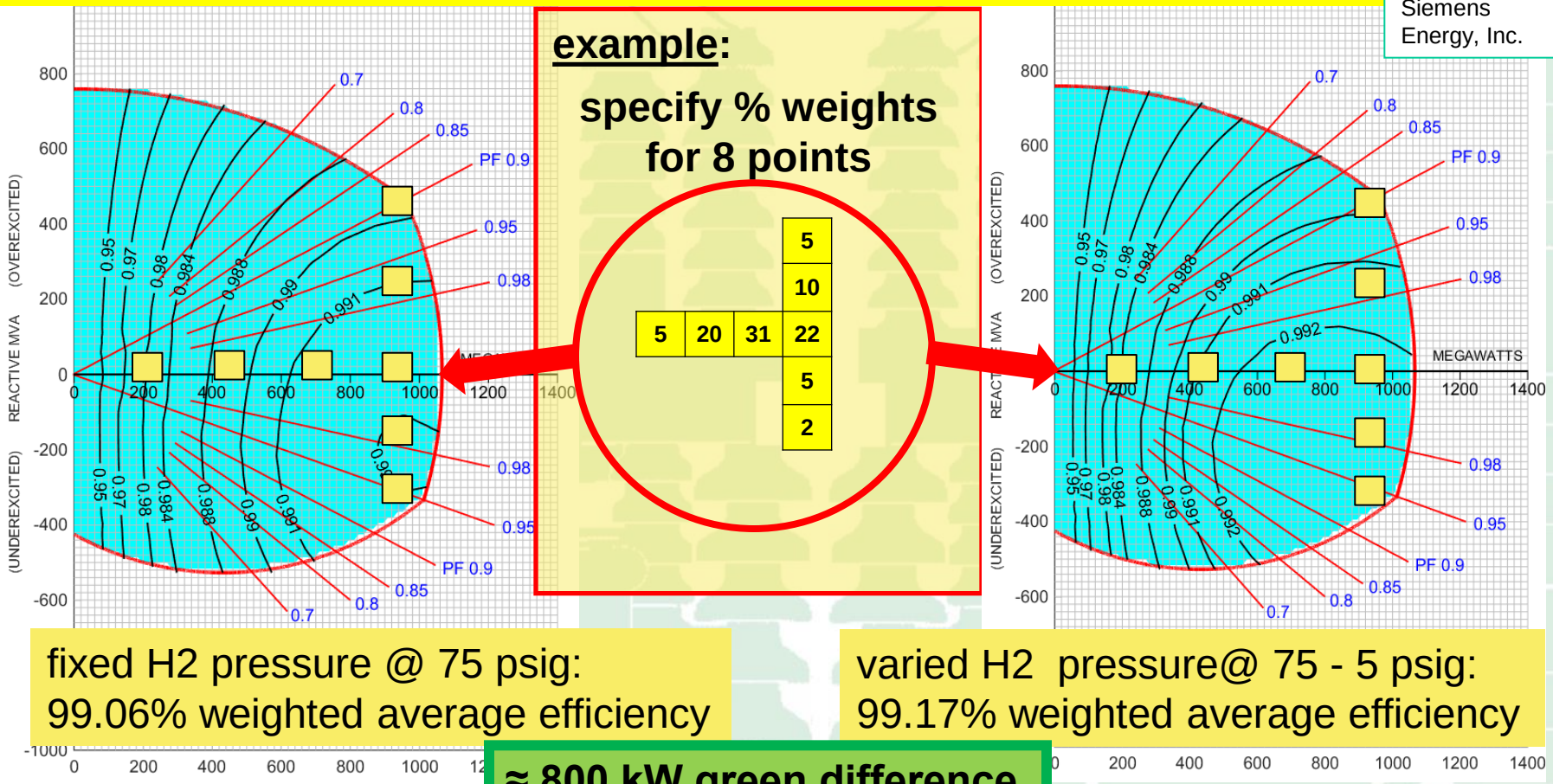

fixed H2 pressure @ 75 psig:
99.06% weighted average efficiency

varied H2 pressure@ 75 - 5 psig:
99.17% weighted average efficiency

≈ 800 kW green difference

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CONCLUSION:

Cigré, IEC & IEEE must cooperatively pursue describing required attributes of desired operational flexibility … to include:

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