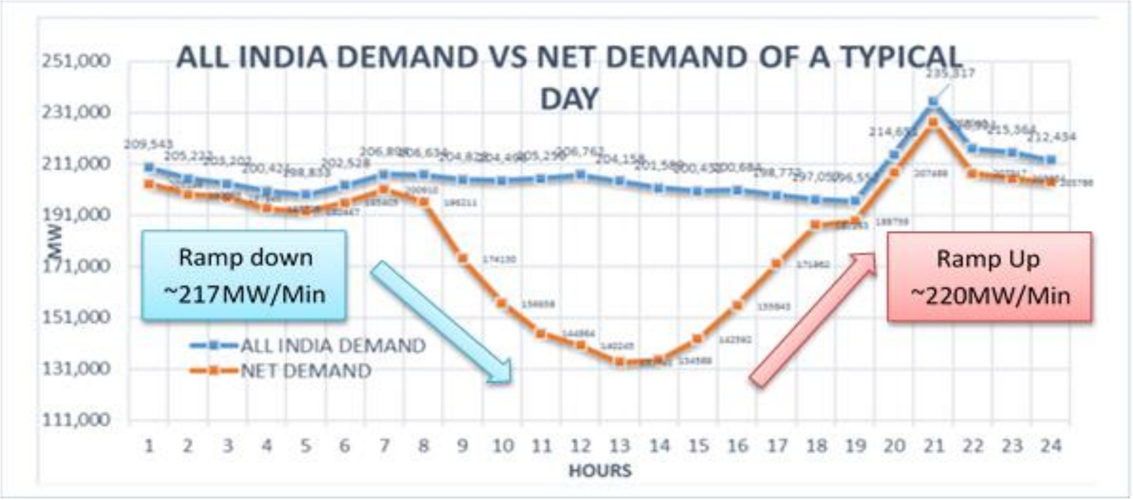
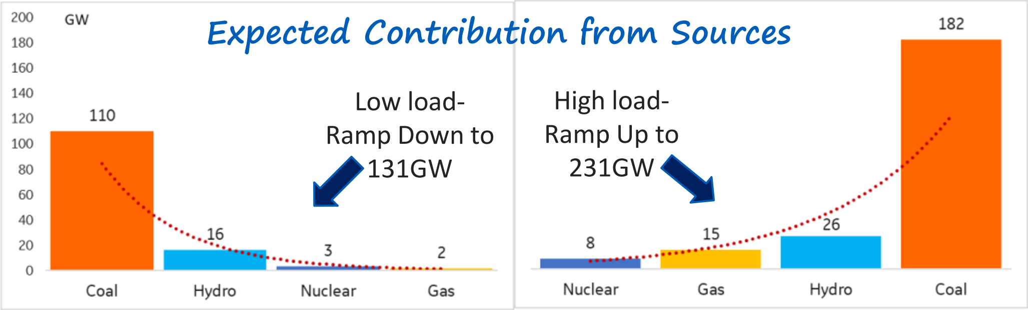
Using Conventional Coal Fired Plants for Large Scale Integration of Wind & Solar

Chinmoy Mohanty, GE Power

Flexible Power Projected Net Load Curve -2022 & Options





Options to support flexibility

- ***Gas*** - Low fuel gas availability; potential use of ~14GW of stranded asset for RE integration
- ***Hydro***-Limited Pump Storage <5GW. Constraints of water availability, downstream constraints & Agriculture needs etc.
- ***Nuclear*** - Limited capacities
- ***Coal*** - Expected & need to support ~70% of flex needs and most economical option
- ***Battery*** - Good source, however no short term scale and economic viability

Limited & inadequate flex support Options – Coal must support max. flexibility needs

Flexibilisation of Coal Plants

Flexibility Recommendation

Supercritical/ Ultra SC - 660 to 800 MW

- ✓ **Baseload operation** - install only near the mines
- ✓ **Need based Flexing** – plants away from mines potential candidates

1

Sub Critical (Reheat) – 200 to 600 MW

- ✓ **Efficiency upgrade** on units with age > 25-30 years and low variable costs/ close to mines – will be competitive
- ✓ **Flexibilise** the fleet with higher variable costs - Low Load Operation (40% to 25%)
- ✓ **Improve part load efficiency** where sustained operation in 60 to 80% load range is foreseen

2

Sub Critical (Non Reheat) < 200 MW

- ✓ **Cyclic Operation** – daily/ weekly start stop; Partial emission control; Run in flex mode and phase out – End of Life approach
- ✓ **Implement Digital** to ensure asset healthiness and safety while running in Cyclic mode
- ✓ **Phase out the very inefficient** ones and replace by SC/ USC smaller frames where load flexibility is desired

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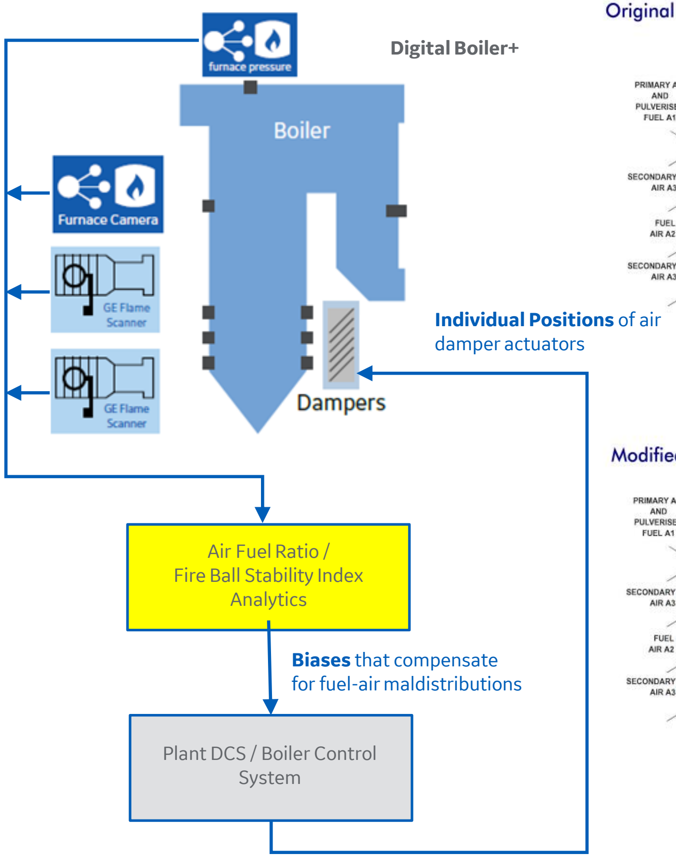
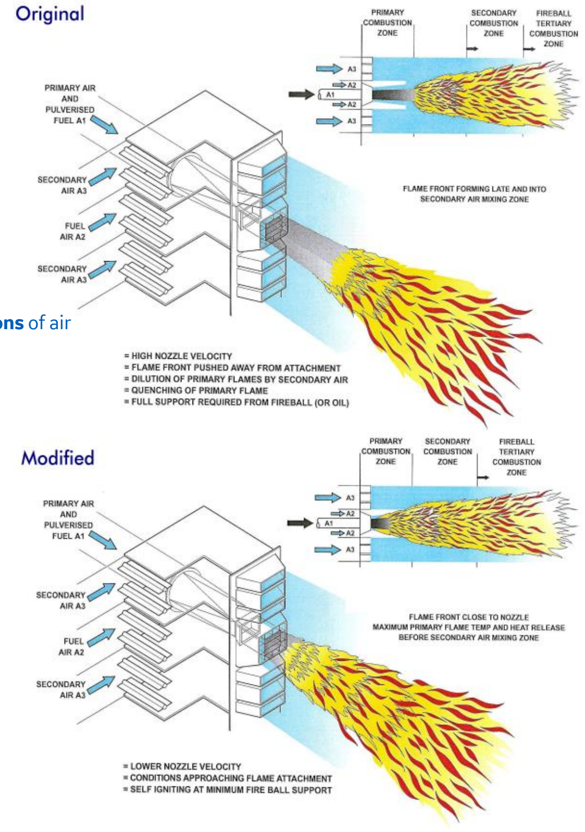
Boiler Flexibility





Bottleneck:

Flame instability caused by low firing rate and fuel-air maldistribution

Burner Upgrade and Digital Boiler+:

Burner re-design to provide local region of stability.

Advanced sensors provide finer information about flame stability and detect combustion imbalances – and balances in real time,

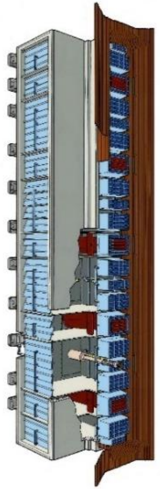
Generates Fire Ball Stability Index and Global Flame Stability Index with analytics

automates air distribution and adjusts excess air flow to ensure flame stability

Lowers minimum load as long as the flame is stable and no other limitations.

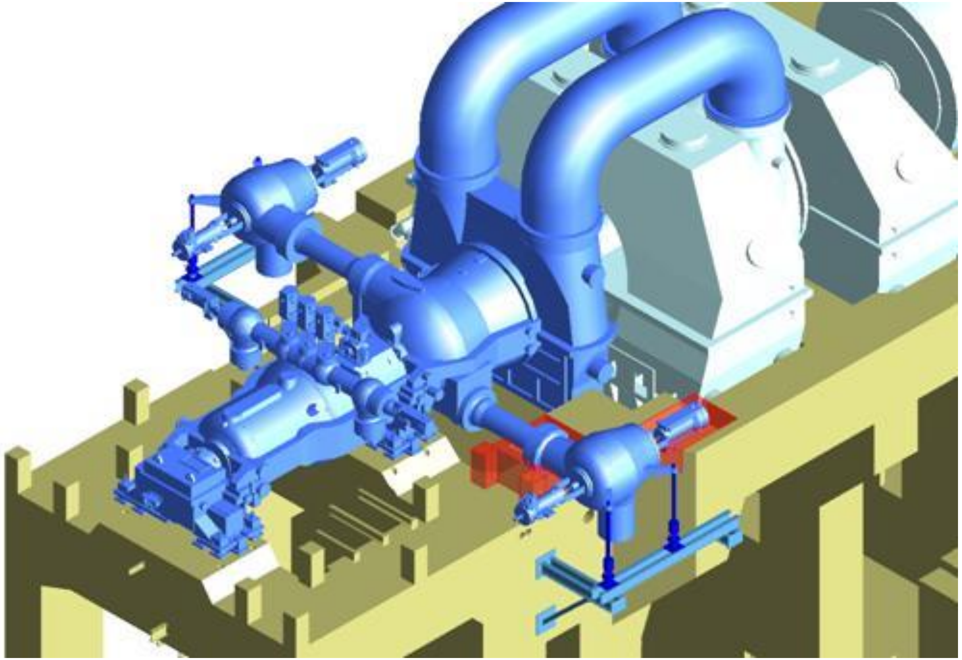
Boiler Flexibility

Enable	Monitor	Analyze/ Enhance	Control
• Re-tipping windbox. • Replace air, auxiliary OFA, and SOFA tips • Boiler protection • High turndown flame scanners that provide fuel-air balancing information	• Flame instability • Global Fireball Stability Index • Avoid safety trips, emissions violations • Reduce support energy use	• Low Excess Air mode optimizing combustion. • Improves efficiency by reducing sensible losses • Low Load Stability mode ensures stability of the combustion process	• produce locally stabilized flame front when air and fuel in proportion • Real Time Controls use Neural Nets, Model Predictive to improve performance



Stability	Very good	Good	Deteriorated	Dangerous	Failed	Lost Flame
Instability	<10%	~15%	>30%	>50%	>70%	100%
Operator info						
Operation Issue	n.a.	n.a.	Bad coal, issues	Unburned coal accumulation	Serious issue	Lost flame - boiler trip required
Stability State Description	Support not needed	Normal operation	Required support	DANGER of EXPLOSION	Boiler overloaded	Lost flame - boiler trip required
Action	Stop Support	n.a.	START of oil/gas burners	Blocking of Oil / gas burners	Master Fuel Trip	Master Fuel Trip
Customer Benefit	SAVING$ of gas / oil	SAVING$ of gas / oil	KEPT OPERATION, RELIABILITY	BOILER PROTECTION from damages		Boiler protection

Steam Turbine Solutions for Extended Lifetime & Higher Flexibility - Mature Aged fleet < 25-30 years



- ✓ **Pitheads** – These units will continue to enjoy a better merit in SCED. Only payback should not be the criteria. Upgradation with Shaftline retrofit (HP Module + IP Module + LP Inner Block + Valves and Control System with auxiliaries) for performance improvement beyond original design.
- ✓ **Efficiency Upgrades + Flex** – Payback for those where without upgrade the units does not remain competitive in merit. Upgradation with Shaftline retrofit for performance improvement with better part load design. Use Weighted average methodology for THR evaluation

Case Study – GSECL Ukai 4 & Wanakbori 3

The R&M was envisaged to implement the option of replacing the Steam Turbine modules with state of art high efficiency design as against the earlier practice of need based in-kind replacement of components.

Shaftline retrofit with advanced technology ensured high performance gain and minimizing O&M and spares spend. Scope of Work

- Shaftline Retrofit (HP, IP Module replacement, LP only internals changed, Outer casing retained)
- Hydraulic system incl. actuators and piping.
- Turbine control & protection.
- Auxiliaries Upgrades.
- Dismantling / Installation/ Commissioning/ Performance Test

GSECL Benefits realised

- ✓ **14.43%** improvement in Turbine Heat Rate
- ✓ **5.3%** improvement in Thermal Efficiency of the unit
- ✓ Annual savings in **coal consumption** is 0.102 Million MT and 0.128 Million MT at Ukai # 4 and Wanakbori # 3 respectively.
- ✓ **Reduced CO2 emissions** of 0.165 Million MT and 0.192 Million MT at Ukai # 4 and Wanakbori # 3 respectively
- ✓ Reduction in start-up time.
- ✓ Safe & Reliable Operation
- ✓ Instantaneously five percent (5%) extra load can be generated if there is grid requirement.
- ✓ Unit lifecycle extended by 20 years

PARTICULARS	UKAI - 4		WANAKBORI - 3	
	BEFORE R & M	AFTER R & M	BEFORE R & M	AFTER R & M
Capacity (MW)	200	200	210	210
Boiler Efficiency (%)	83%	87.32%	83%	87.32%
Turbine Heat Rate (kcal/kwh)	2265	1939	2265	1950
Unit Heat Rate (kcal/kwh)	2721	2320	2718	2320
Variable Cost (Rs/unit)	**3.28**	**2.88**	**3.62**	**3.10**
Coal Factor (kg/kwh)	0.680	0.597	**0.678**	**0.580**
Coal Cons (MT/Hr.)	136	119	**142**	**122**
Per Year Coal Consumption at 70% PLF (MT)	**833,952**	**732,160**	**873,074**	**744,831**
Per year saving in Coal Consumption (MT)	**101,792**		**128,243**	
Landed Cost of Coal	**Rs 4350/MT**		**Rs 4865/MT**	
Saving in Fuel Cost PA	**Rs 44.28 Crore**		**Rs 62.39 Crore**	

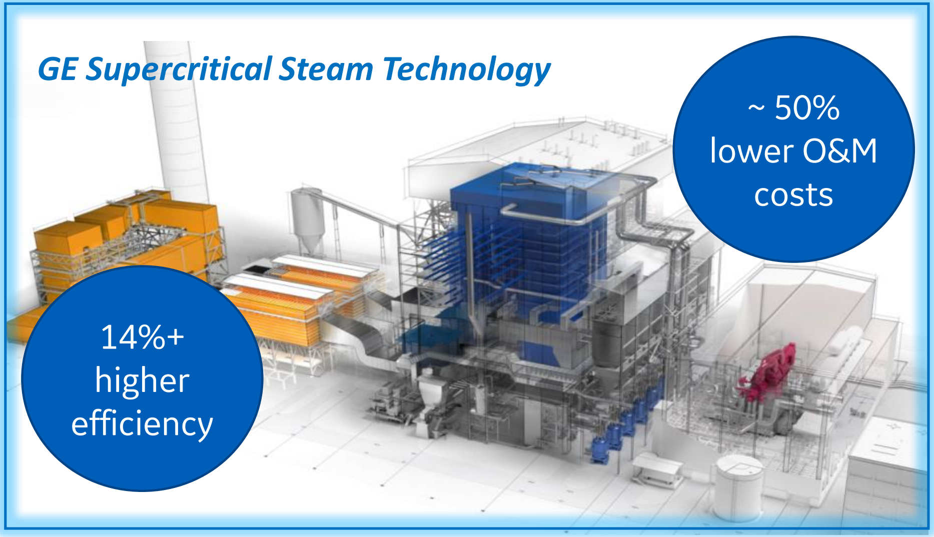
Boiler R&M done by GSECL

Best in class 210 MW machine in India now – better than 500/ 600 MWs in efficiency

Recommendations on Smaller Units (Non RH)

✓ Replace the existing older < 200 MW units with a 150/ 350 MW supercritical unit configurations

- Dismantle existing BTG and build new 150 MW BTG with supercritical parameters
- > 14% + improvement in unit efficiency
- Reduction in O&M expenses
- Fully emission compliant – implement WFGD/ NiD to address SPM and SOx simultaneously within given space**



Comparison	Typical Non RH Unit	Proposed SC Unit
Area required		80 acres**
Output	~ 100 MW	**150/350 MW**
Efficiency	~ 26%	**> 40%**
Aux Power	> 12%	**~ 5.5%**
Lead Time		Dismantling + 34 months
Emissions	NOx, SOx and SPM need retrofitting	New BTG emissions compliant
Flexibility	Not flexible in design	**Flexible in design**

** space availability to be confirmed

RDK 8 – The Most Efficient Coal Fired Unit in the World

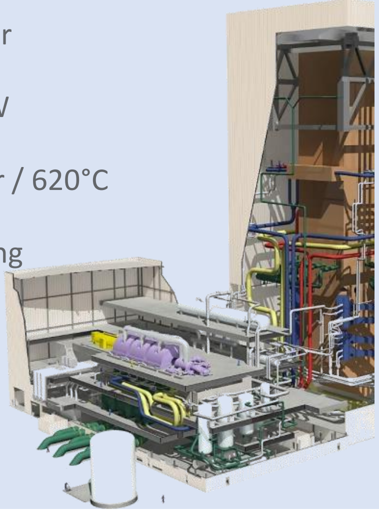
47.5% WORLD'S BEST STEAM PLANT EFFICIENCY

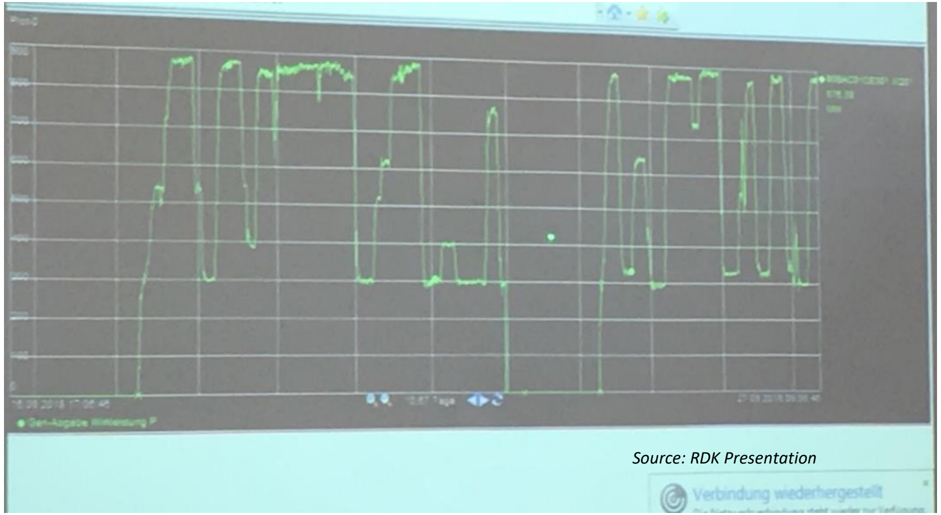
40% CO_2 EMISSIONS REDUCTION

275K TONS OF COAL SAVED PER YEAR

Ultra-supercritical plant with district heating

Boiler :	GE Tower type USC boiler
Turbine:	GE ST-D1050, 1×912 MW
Steam:	275 bar / 600°C & 62 bar / 620°C
Extraction:	220 MWth district heating
Customer:	ENBW Kraftwerke AG
Location:	Karlsruhe, Germany
Net efficiency:	**47.5%**





Source: RDK Presentation

- Inbuilt SCR, Wet FGD and ESP to contain emissions to 100/110/10 mg/Nm3 for NOx/ SOx/ Dust respectively
- RDK has hybrid cooling
- RDK operates in pure market mode. Now have 4500 hrs as against planned 6-7000 hours.

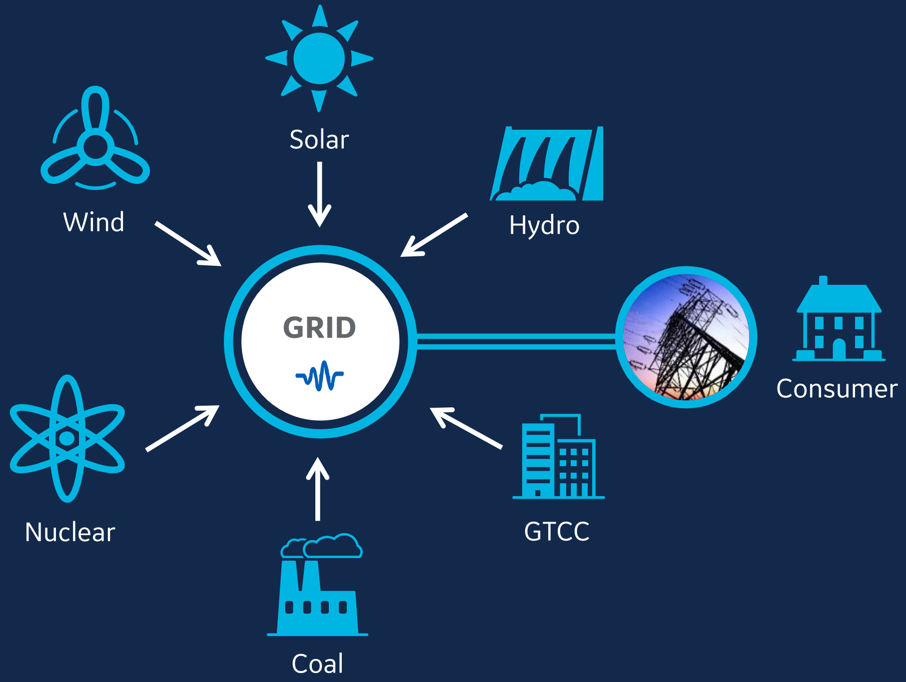
- Annually 50 to 60 start/ stops - shutdown every weekend.
- Minimum load about 20% possible and critical in avoiding start/stop and supporting high RE generation period in weekdays
- Design ramp rate of 5% but actual close to 1% as higher ramps not needed by grid operator.

One of the most efficient power plant in the world – working on flexible operations with low technical minimum

Reactive Power Management

Utilizing Retired / Retiring units by converting to Synchronous Condenser

Addressing rising needs for grid performance enhancement



Synchronous Condensers addressing market needs

Evolving electricity mix

- Increasing renewable share
- Thermal plant retirements
- Long HVDC transmission lines
- Transit markets

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- Shrinking inertia
- Reduced short circuit strength
- Decreased dynamic reactive power reserves
- Grid System instability

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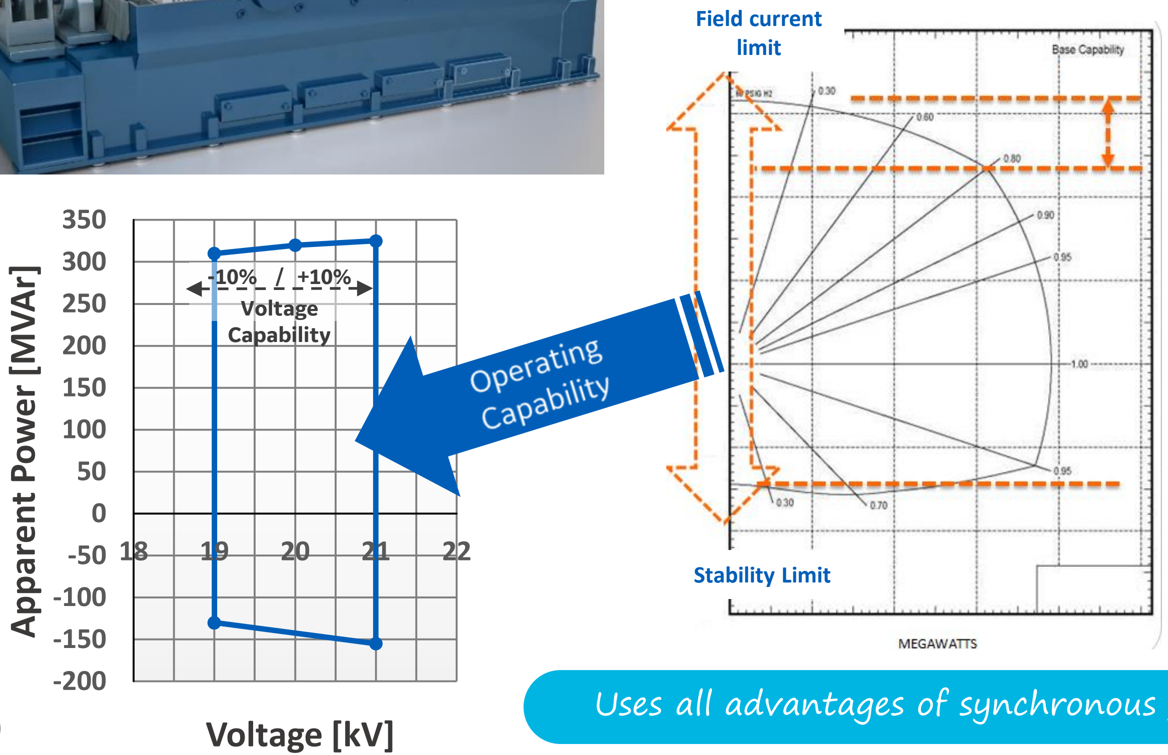
Market Requirements

- Reactive power and voltage support
- Short circuit strength
- System inertia

What is a Synchronous Condenser?



VARS are critical

- **Maintain** voltage stability
- **Provide** ability to transfer power flows efficiently

Synchronous Condensers

use

Standard Generator Tech

provide

dynamic reactive power performance

- Increased short circuit power
- High response to power system fluctuations
- Overload capability
- Inertia
- High reliability

Uses all advantages of synchronous generators

Thermal Storage

Utilizing Retired / Retiring units by converting to AMSES

GE's Suite of Various Storage Technologies

Thermal Storage

What its good at

- Large scale storage >100 MW, >8 hrs
- No geographic constraints
- Very low marginal costs to increase number of storage hours

Downsides

- Lower round trip efficiency
- Higher initial CAPEX

Pumped Storage

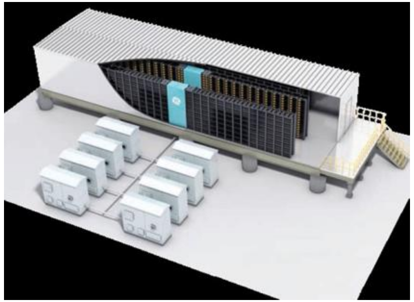
What its good at

- Bulk storage large time periods
- Ancillary services
- Long life time
- Good round trip efficiencies

Downsides

- Needs suitable geography
- Requires transmission capacity to remote locations

Li-Battery Storage



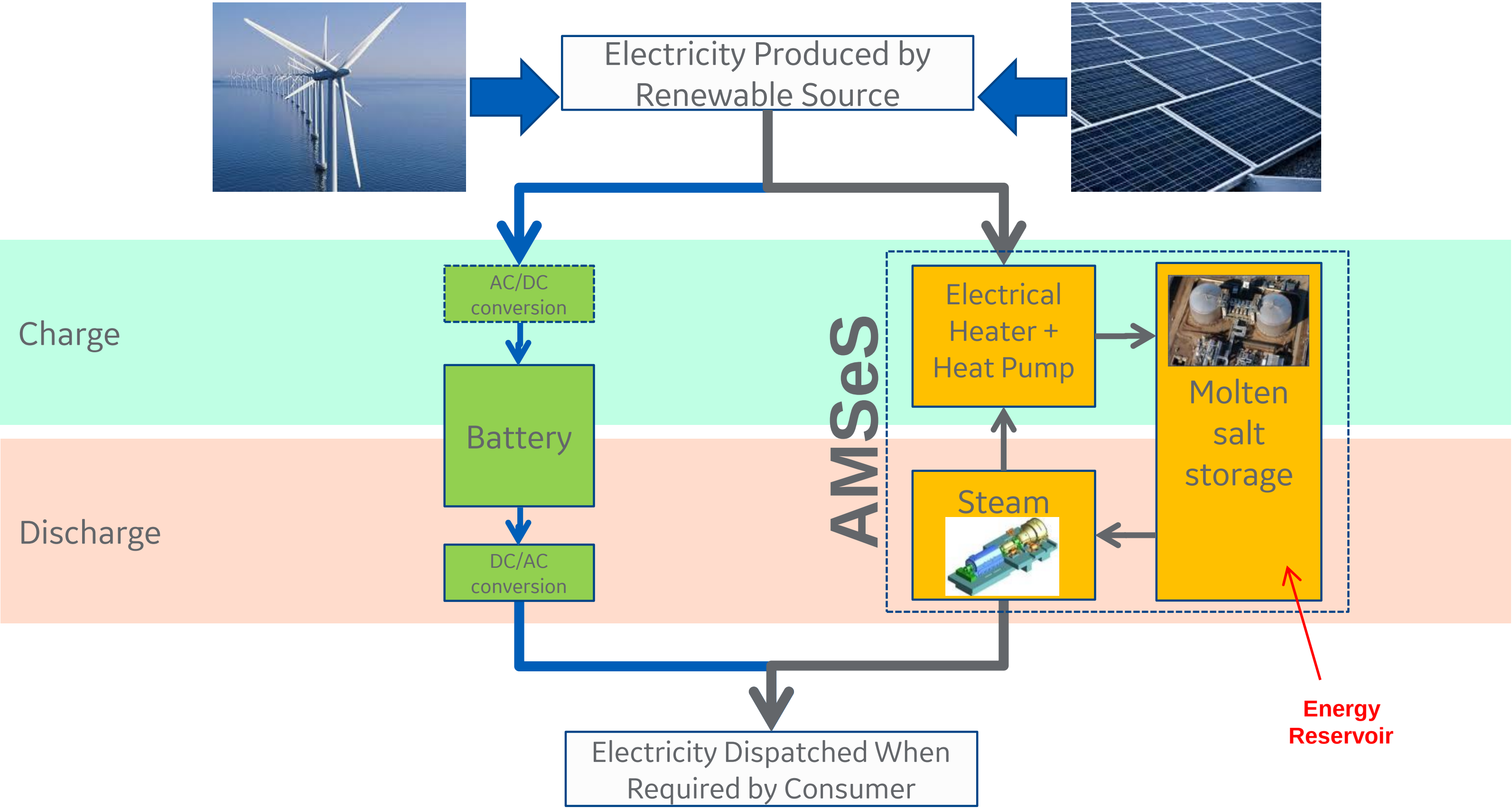
What its good at

- All kinds of fast responses
- High round trip efficiency >80%
- Modular to achieve variable scale

Downsides

- Cost – scale manufacturing with EVs
- Low lifetime – multiple stack replacements over lifetime

Electricity Storage – The Thermal Option



Peak Power Storage

Peak Power Storage – GE Offering

Why Storage

Overload Capability without violation of approved firing rate limit

Increase of primary and secondary load control

Reduction of start-up costs (oil consumption)

Why water

Water is most cost effective for Temp. < 200°C

Direct Integration in water/steam cycle enables high gradients (Reaction time <30 s)

Proven Technology (District heating storage, fireless steam -locomotive)

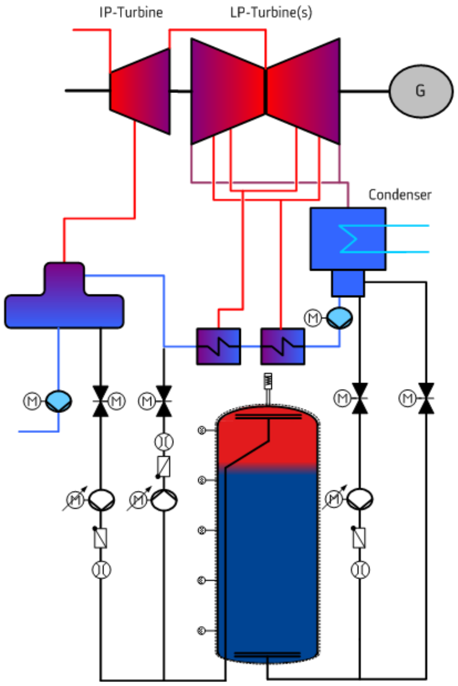
Peak Power Storage – GE Offering

Motivation

- Increase Peak Power Capacity
- Decrease minimum load
- Provide secondary control range
- Use of thermal heat storage

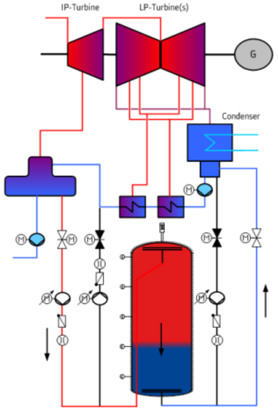
Performance:

- 3-5% load increase / de-crease at maximum load possible



Charge Storage

- Cold condensate is heated in the LP heaters and stored in water tanks
- Heating requires additional extraction steam, electrical output is reduced



Discharge Storage

- LP heaters are bypassed
- Stored hot condensate is pumped to the deaerator
- Reduced steam extraction, increase of electrical output