Presentation on “Effect Of Renewable Energy On Grid”

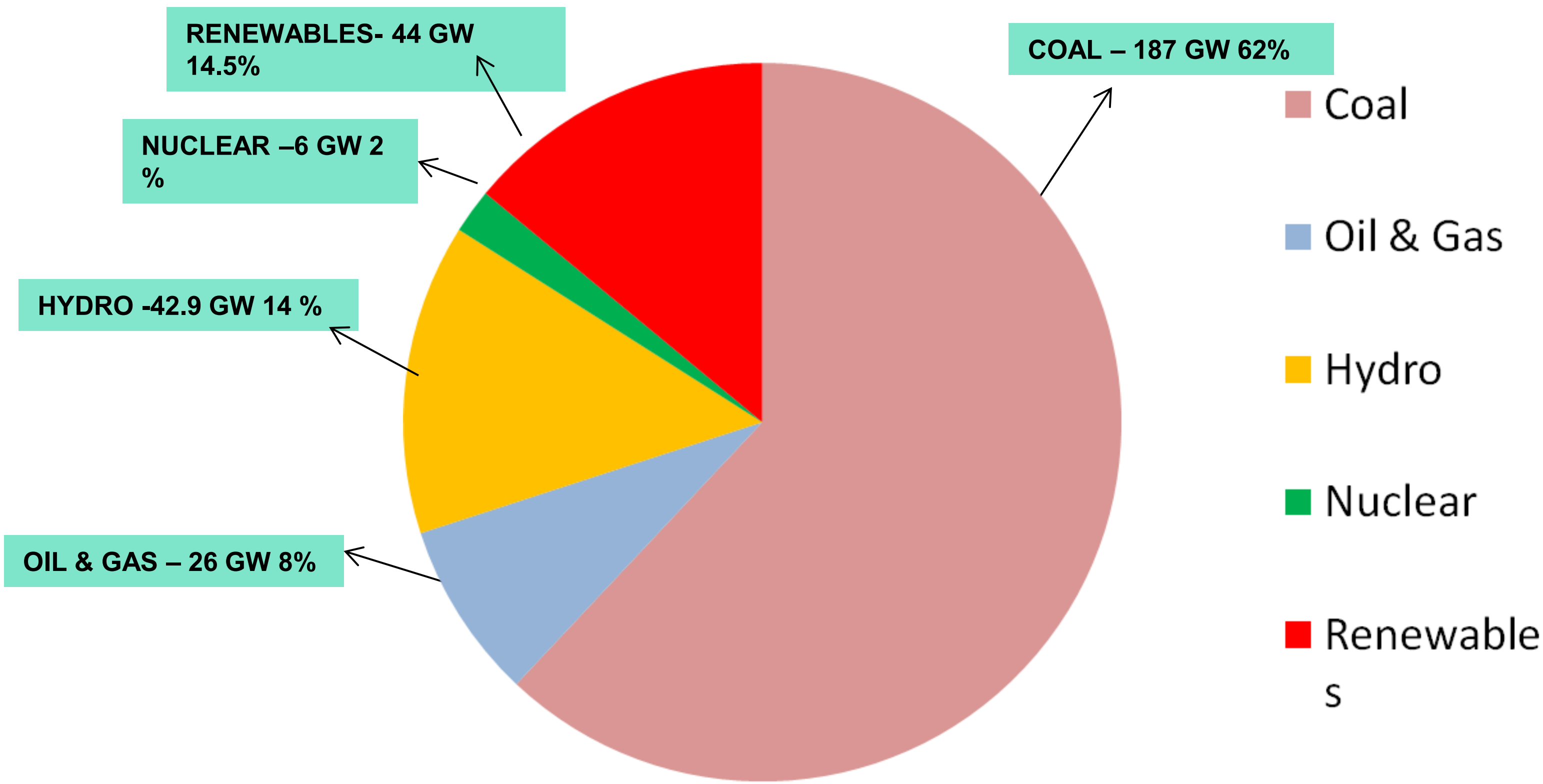
By Subhajit Ghosh, General Manager(OS),NTPC Limited

Indian Power Sector

- **India is aiming at ;**
  - **24x 7 Power for all**
  - **Affordability of Power**
  - **Environment Friendly Power**
  - **Energy Security**

India is blessed with availability of coal, Sunshine, Wind & water.

India : Installed capacity

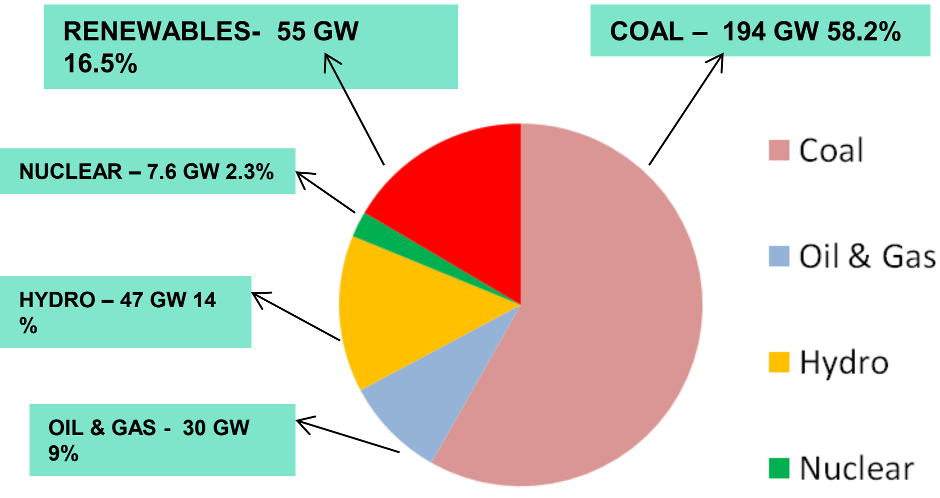


Total Installed Capacity as on 31.08.2016 : 305 GW

Source: CEA

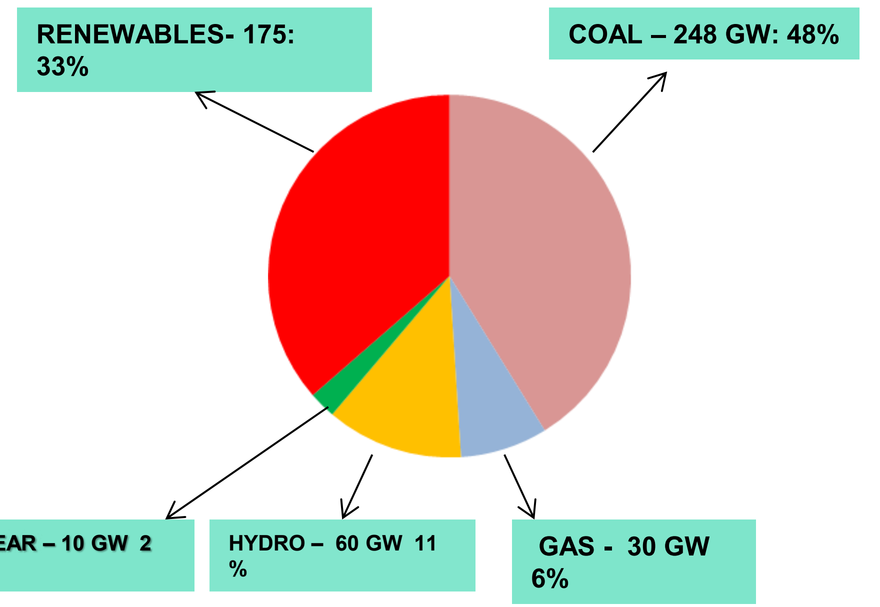
India : Likely Installed capacity (Projected)

Fuel Mix at the end of XIIth Plan



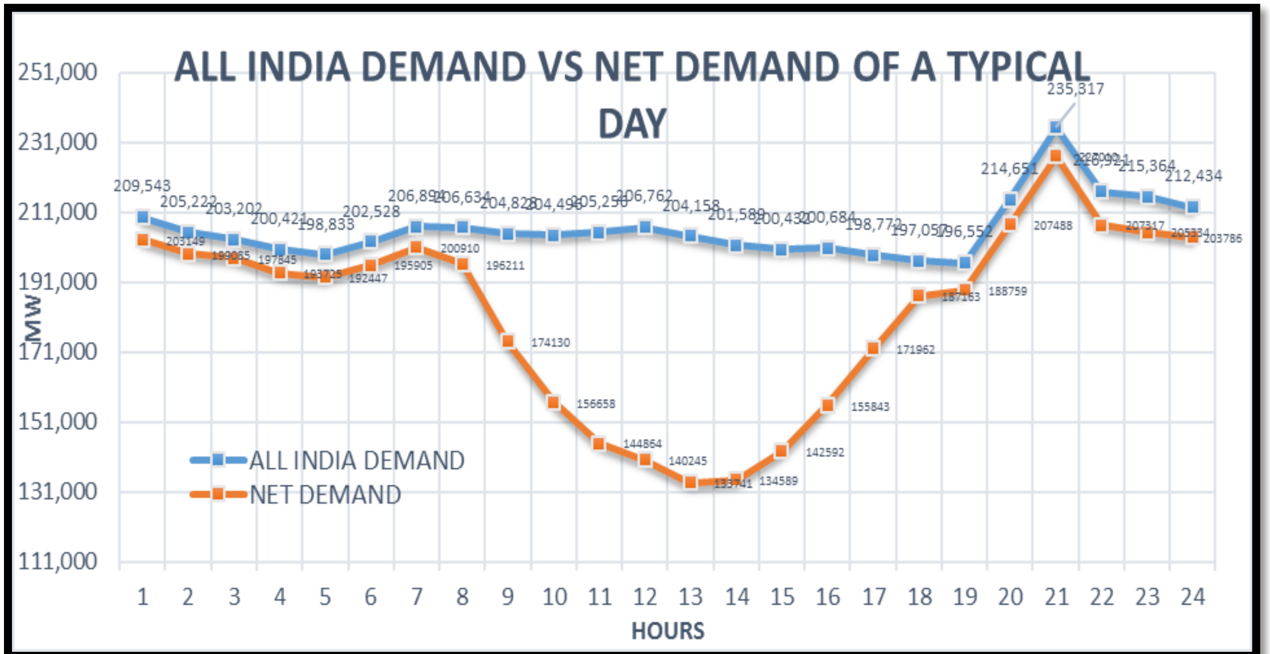
Projected Capacity on 31.03.17 : 333 GW

Fuel Mix at the end of XIIIth Plan



Projected Capacity on 31.03.22 : 523 GW

Future Load Generation Scenario: Duck Curve



- ➢Wide gap w.r.t. the belly of the duck curve indicates commensurate reduction in other sources of generation..
- ➢Steep rise in demand at the neck needs to be matched with corresponding generation..

?

In the Indian context , what would be the complementing source?

Need of the hour is :

-Stable Low Load Operation

-Improving Ramping Rate

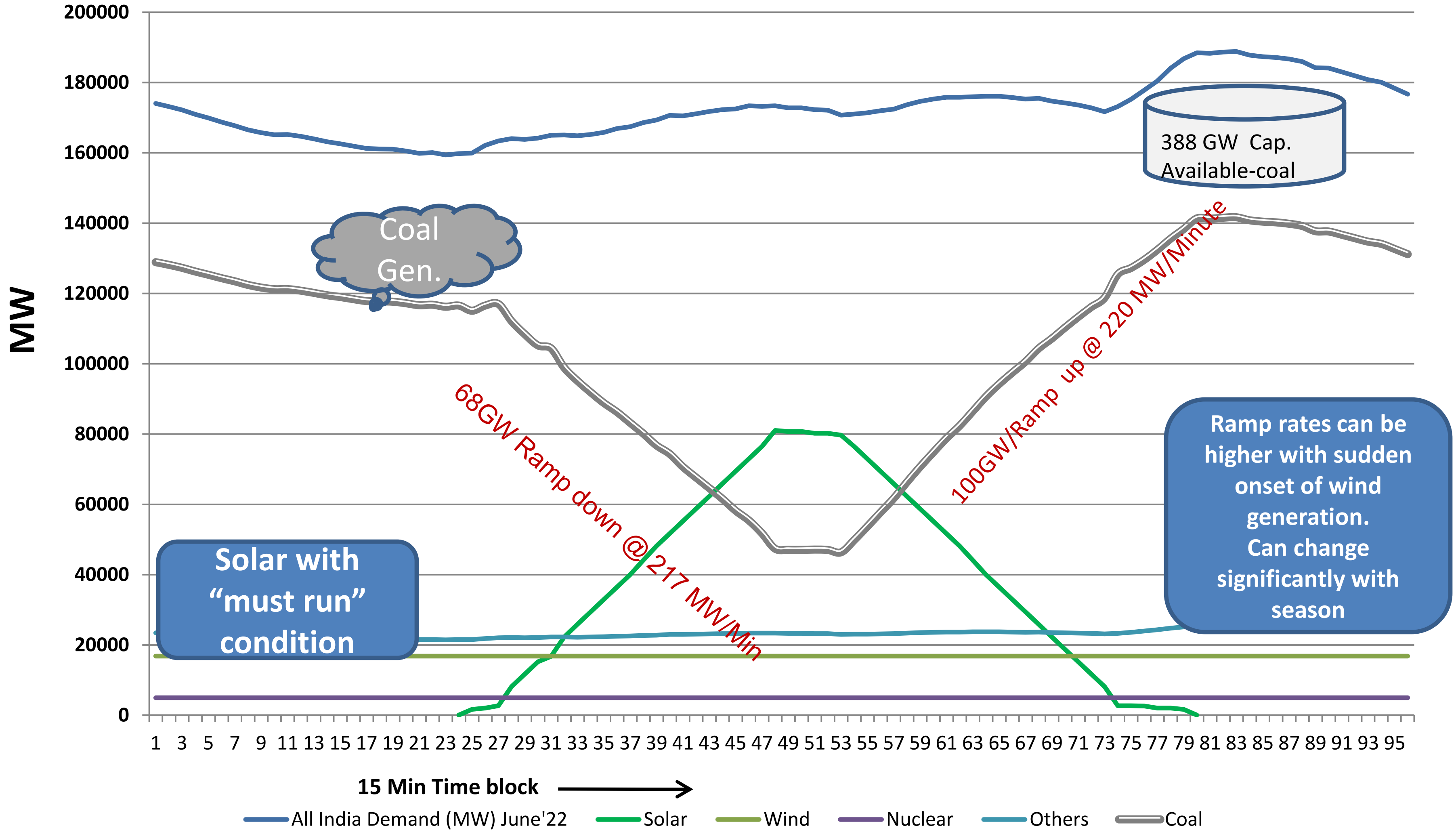
-Reduced House Load Operation (without Oil Support)

-Reduce effect on the life of equipment and systems due to cyclic loading

-Efficient Operation

Anticipated Indian Scenario in 2022

with 100 GW Solar & 60 GW Wind



Complementing the gap

- **Considering the limited availability of Gas generation,Hydro potential and storage system, Grid balancing appears to be difficult without substantial coal based generation**
- **<u>Coal based generation shall complement the gap</u> and continue to be the major source of reliable power for safe and stable operation of grid…till we have proper storage solution.**
- **Base load plants will have to Ramp up/down and shutdown/startup with greater frequency.**

Future Scenario for Thermal Generation

From Baseload towards Flexible/backup generation and Ancillary Service provider.

Thermal generators need to adjust to the "new rules of the game" by

- Providing new Ancillary services and
- Improving Environmental performance,
- Improving Efficiency,
- Improving Flexibility and
- Remaining Competitive & Sustainable.

Future Scenario for Thermal Generation

- Power sector is undergoing radical change.
- Electricity customers are becoming *Producers and* system is going to witness a rapid increase in renewables with low variable cost.

Future of Thermal Generation:

Thermal power has entered a period of fundamental change but the sector's evolving existence is crucial for India's electricity stability as a key pillar of the future energy system.

- *Who will compensate* ***Electric Supply during low -RE period****?*

- ***System Stability:*** Key element for system Security particularly in times of sudden and unexpected generation loss or network fault.

- Who will provide vital system services such as ***inertial response or fast frequency power recovery (Primary Control)*** that help stabilize the power network.

Challenges for Conventional Generation:

Technical Challenges:

❖**Cyclic operation / Load Ramping capabilities of machines of different age and technology will pose difficulties in dealing with the impact of RE generation variation.**

❖***Frequent variation in loading of machine, would affect the residual life of machine. This may lead to***

- ***increase in number of break downs of equipments,***
- ***tube leakage,***
- ***line leakages,***
- ***fatigue, creep etc. with impact on R&M cost of machines.***

❖***Part load operation would adversely impact the Heat Rate, SOC and APC.***

❖***Cheap Gas availability is a key issue in providing high ramping Services from Gas fired plants.***

Challenges for Conventional Generation:

Mitigating Measures:

- **Flexible reserve identification: Relatively newer Non-Pit Head station machines to be included.**

- **Retrofitting of plants for technical flexibility: Retrofitting of old plants would be beneficial for the improvement of fast and efficient delivery of control reserves. Techno-economic aspects of such retrofit may be explored.**

- **Set up of new flexible power plants: Specification for new conventional power plants should have a set of very high flexibilities standard for both Sub and Super-critical plants.**

Challenges for Conventional Generation:

Commercial Challenges:

- **Cost of startup fuels,**
- **Auxiliary power Consumption,**
- **O&M / R&M expenses,**
- **Poor efficiency & heat rate etc.**

The above will increase the cost of generation and affect merit order position in the highly competitive power market.

Mitigating Measures:

- **Generators need to consider cycling cost of such deployment. Such Services should be properly priced.**

Flexible Operation

Practices already adopted in NTPC

- Forecasting of renewable generation
- DSM(Deviation Settlement Mechanism)
- Ancillary Services regulation
- Sliding Pressure operation for part load optimisation
- Primary Control (RGMO/FGMO)
- Maintenance Scheduling

Practices under way of implementation

- AGC pilot Project
- Power Trading
- Specs included for design of future plants for two shift operation
- Study of engineering and economic impact of cycling through international consultant

Way Forward

- Gas based capacity for reasons of low schedule ,cannot effectively contribute towards balancing the grid, even though they have a high ramp rate.
- Limited capacity of Hydro and pumped storage power plants also poses limitation towards grid balancing.
- Considering the availability of resource for Gas generation & Hydro potential, Grid balancing appears to be difficult without adequate thermal generation.
- Therefore, thermal generation shall continue to be the major source of reliable power.

Way Forward

- Effective operation of modern Coal plants can take care of Grid imbalance to a large extent which in turn gives Reliability, Sustainability & Affordability
- Looking into this aspect, NTPC has already ventured into world class Thermal generation technology by way of inducting Super Critical units.
- Planning for adoption of Advanced Ultra Super Critical technology is under way with a pilot project by 2020.
- All these efforts shall lead to cutting down of Carbon foot print to a large extent.

Way Forward contd….

- **Market Options**
  - Time of day Tariff/Demand side management in line with RE generation
  - Market based compensations for cycling cost

- **Learning from experience of RE rich International power generators/grid managers**.

- **GERMAN EXPERIENCE .**

- **GERMANY IS HAVING MAXIMUM RENEWABLE PENETRATION**

POWER SECTOR SCENARIO IN GERMANY

- PRESENT INSTALLED CAPACITY 198 GW CONSISTING OF
- 11 GW NUCLEAR.
- 50 GW COAL AND LIGNITE.
- GAS 28 GW.
- OTHER 10 GW.
- SOLAR 38 GW .
- WIND 45 GW.
- BIO MASS 10 GW.
- HYDRO 6 GW.

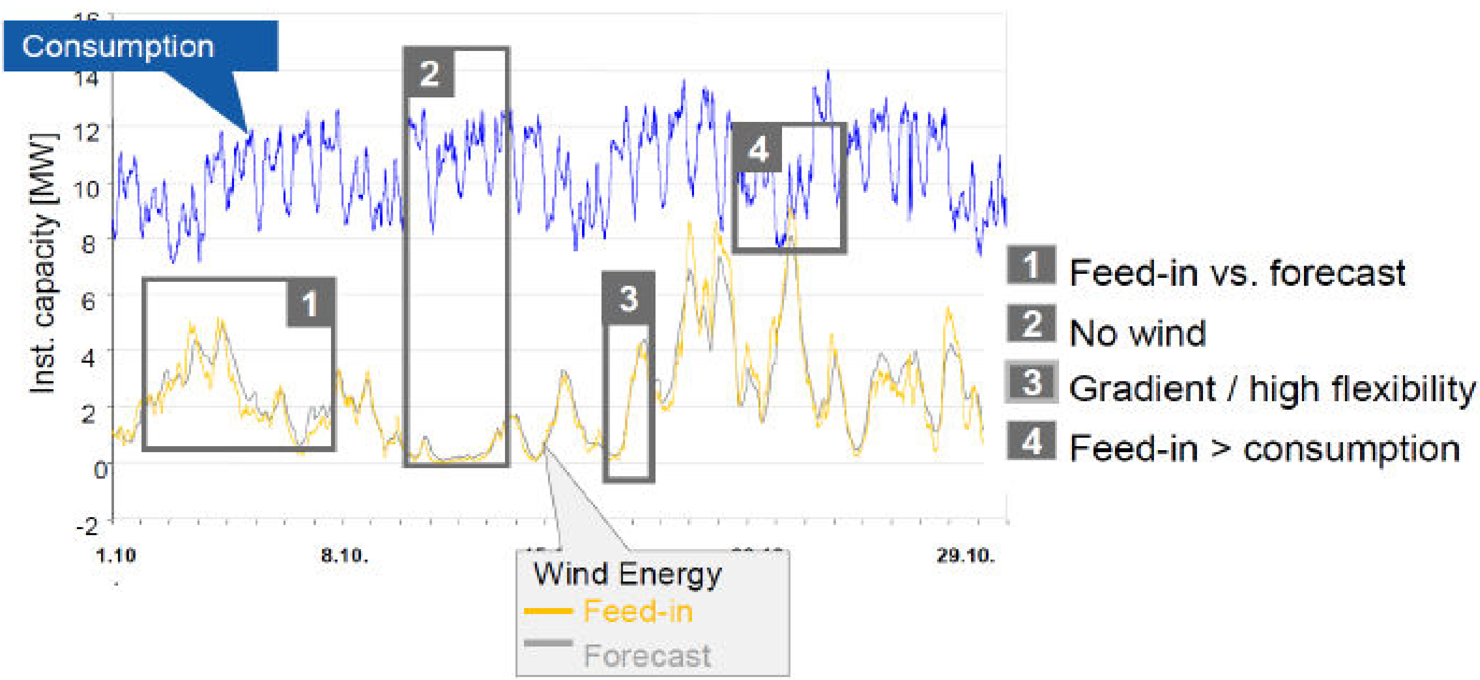
GOVERNMENT POLICY IN GERMANY

- 80 % DE CARBONIZATION BY 2050.
- CLOSURE OF NUCLEAR POWER BY 2022.
- GOVERNMENT IS ENCOURAGING ESTABLISHMENT OF RENEWABLE POWER PLANTS BY MEANS OF
- DISPATCH ORDER PRIORITY.
- FIRST CONSUMPTION.
- SUBSIDY.

PROBLEM DUE TO INJECTION OF RENEWABLE POWER IN THE GRID AND ITS EFFECT

- RENEWABLE GENERATION IS HIGHLY VARIABLE IN NATURE
- DUE TO THIS WIDE FLUCTUATION IS TAKING PLACE IN THE GRID

Load profile October 2015



GRID

- THE SYSTEM BALANCE IS CONTINUOUSLY VARYING.

- THE INERTIA OF ALL ROTATING MASSES OF SYNCHRONOUS GENERATOR IN THE INTERCONNECTED POWER SYSTEM ENSURES INSTANTANEOUS SYSTEM BALANCE.

- FOR SUBSTANTIAL DEVIATION FROM THE SET GRID FREQUENCY (50 HZ) IS BALANCED BY TSO'S BY ACTIVATING CONTROL

GRID STABILIZATION

- SUBSTANTIAL DEVIATION FROM THE SET GRID FREQUENCY (50HZ) IS BALANCED BY TSO'S BY ACTIVATING CONTROL RESERVE.

- TSO PROVIDES BALANCING SERVICES BASED ON MARKET BASED PROCUREMENT OF CONTROL RESERVE.

- THE UNITS PROVIDING CONTROL POWER ARE SUBJECTED TO HAVING TECHNICAL PRE-QUALIFICATION FOR PROVIDING SUCH SERVICE.

- CONTROL RESERVES IS TENDERED BY PREQUALIFIED BIDDERS.

	PCR	SCR	TCR
tender period	weekly	weekly	daily
tender time	as a rule on Tuesdays (W-1)	as a rule on Wednesdays (W-1)	as a rule Mo-Fri, 10 a.m.
product time-slice	none (total week)	peak: Mo-Fri, 8 a.m. to 8 p.m., without public holiday off-peak: residual period	6 x 4 blocks of hour
product differentiation	none (symmetric product)	positive / negative SCRL	positive / negative TCR
minimum bid amount	1 MW	5 MW	5 MW (submission of bid for a block of max. 25 MW possible)
increment of bid	1 MW	1 MW	1 MW
call for tender	capacity price merit-order	energy price merit-order	energy price merit-order
remuneration	pay-as-bid (capacity price)	pay-as-bid (capacity price and energy price)	pay-as-bid (capacity price and energy price)

Fig.4.3: Main product characteristics of control-reserve qualities tendered in Germany

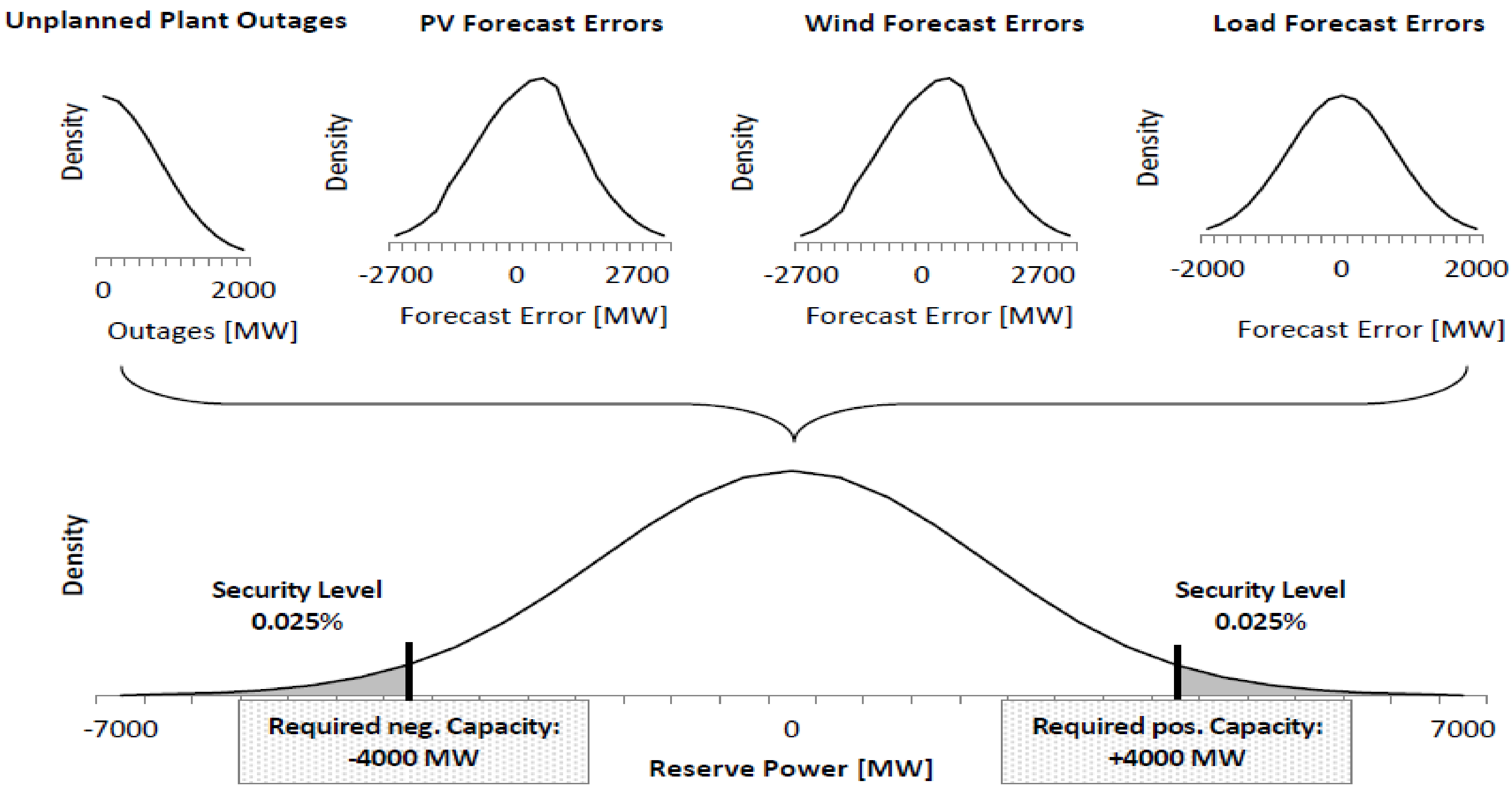


Figure 3. Probabilistic approach for ex-ante determination of requiring capacity of $SC^{+/-}$ and $TC^{+/-}$

CONTROL RESERVES

- THERE ARE THREE TYPES OF CONTROL RESERVES

- **PRIMARY CONTROL RESERVE:**
- STABILIZES NETWORK FREQUENCY AS FAST AS POSSIBLE.
- ACTIVATED AUTOMATICALLY BY NETWORK FREQUENCY IN A NON-SELECTIVE MANNER FROM TOTAL INTERCONNECTED SYSTEM.
- PCR IS DESIGNED AS PROPORTIONAL REGULATOR.
- PCR HAS TO BE REALIZED WITHIN 30 SECONDS.

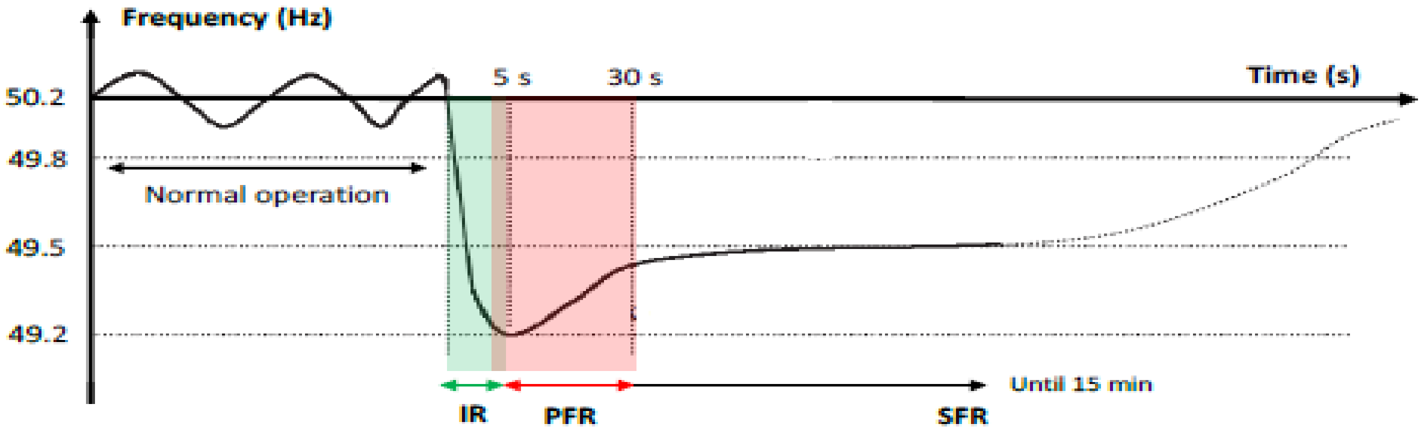
CONTROL RESERVES

- **SECONDARY CONTROL RESERVE:**

- AUTOMATICALLY ACTIVATED BY LOAD – FREQUENCY CONTROLLER. THE DEPLOYMENT IS ON MERIT ORDER BASIS.
- IT REPLACES PCR.
- DEPLOYMENT OF SCR IS TIME SENSITIVE PROCESS.
- IN GERMANY ALLOWED MAXIMUM LEAD TIME IS 5 MINUTES.

- **TERTIARY CONTROL RESERVE:**
- IN CASE OF LONG LASTING SYSTEM BALANCE FAILURE, TCR IS ACTIVATED
- DEPLOYMENT TIME WITHIN 15 MINUTES.
- TCR IS NOT ACTIVATED AUTOMATICALLY.
- IN GERMANY , TCR IS ACTIVATED USING MERIT ORDER LIST SERVER

Figure 1. Time frames involved in the system frequency response.



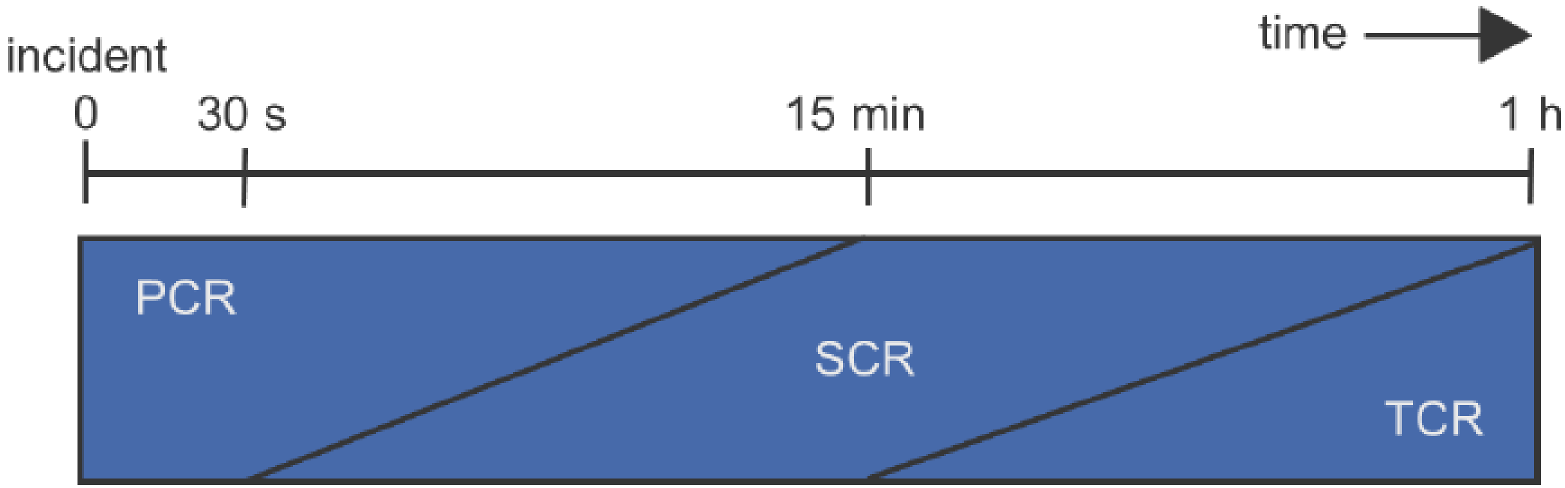


Fig. 3.2: *Three-step control concept in the Continental European interconnected system*

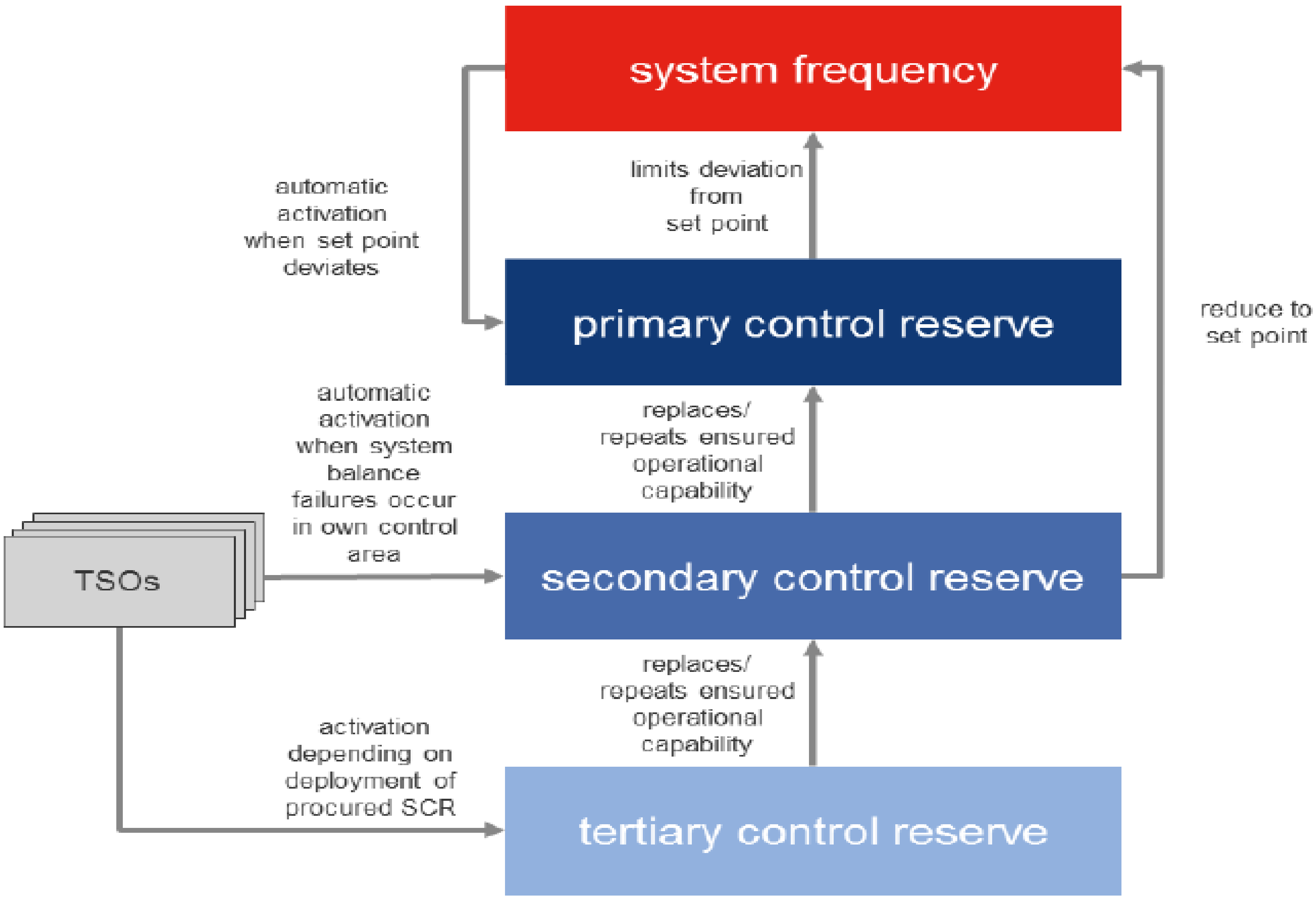


Fig. 3.1: Overview: Application and responsibilities of different qualities of reserve

Table 1: Types of control power

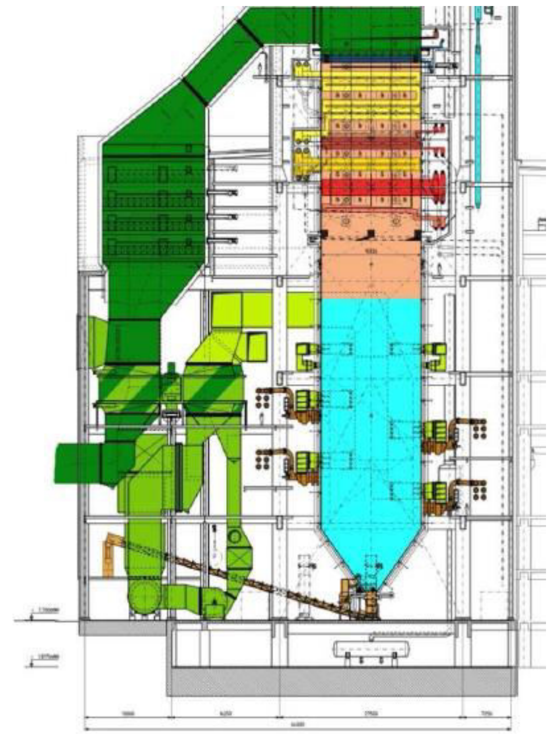
	Primary Control	Secondary Control	Tertiary Control (Minute Reserve)
Response Time	30 s (100%), direct (continuously)	5 min (100%), direct (continuously)	7-15 min (100%), director schedule
System	UCTE	Control area	Control area
Control Variable	Frequency deviation from 50 Hz (UCTE system)	Balance of the control area; Frequency deviation	Amount of $SC^{+/-}$ activated
Activation	Based on local frequency measurement	Centralized (TSO); active call through IT	Centralized (TSO); active call through phone / IT
Suppliers (typically)	Synchronized generators, (industrial consumers)	Synchronized generators, stand-by hydro plants, large consumers	Synchronized and fast-starting stand-by generators, large consumers
Reserved Capacity (see section 3)	3000 MW in UCTE (600 MW in Germany)	Decided by TSO (2500 MW in Germany)	Decided by TSO (2500 MW in Germany)

PROBLEM DUE TO INJECTION OF RENEWABLE POWER IN THE GRID AND ITS EFFECT

- SHARP REDUCTION IN THE ENERGY CHARGES IN BULK MARKET .
- MORE AND MORE THERMAL POWER PLANTS ARE PARTICIPATING IN LOAD FREQUENCY CONTROL MARKET AND THERE BY STABILIZING THE GRID.
- FLEXIBILIZATION OF COAL FIRED PLANTS FOR PROVIDING ATTRACTIVE CONTROL ENERGY THROUGH MARKET.

ADAPTATION OF THERMAL POWER PLANTS IN GERMANY

- **FLEXIBILIZATION OF 2X800 MW MOORBURG POWER PLANT**



- THE PLANT WAS DESIGNED AS A BASE LOAD PLANT WITH A CORRESPONDING NUMBER OF START-UP AND LOAD CHANGE RATE.
- TO ADOPT CHANGED CIRCUMSTANCES IN THE GERMAN ELECTRICITY MARKET - SIGNIFICANT FLEXIBILIZATION IN THE POWER PLANT CARRIED OUT IN CO OPERATION WITH **VATTENFALL** THROUGH A PACKAGE OF MEASURES CALLED **MOORFLEX.**
- **CHANGES IN EXISTING CURVES, MARGIN, CONTROL LOOPS SETTINGS ARE DONE BY OEM**

ADAPTATION OF THERMAL POWER PLANTS IN GERMANY

MOOR FLEX MEASURES:

- THE NUMBER OF COLD, WARM AND HOT START-UP HAS BEEN INCREASED COMPARED TO THE ORIGINAL DESIGN

- COLD START UP 20 PER YEAR (ORIGINALLY 2)
- WARM START UP 30 PER YEAR (ORIGINALLY 5)
- HOT START UP 10 PER YEAR (ORIGINALLY 10)

- IN ADDITION TO START-UP PROCEDURE A LOAD CYCLE OF 26 PERCENT TO 103 PERCENT BOILER LOAD HAS BEEN CONSIDERED

- LOAD CHANGES 26-103 % 300 PER YEAR
- LOAD CHANGES 40-103 % 150 PER YEAR
- LOAD CHANGE BETWEEN 40 AND 103% HAS BEEN ENABLED AS 21 MIN
- UNIT RAMP RATE 3% / MIN = APPROXIMATELY 26 MW/MIN (ORIGINALLY 2% /MIN)

FLEXIBILIZATION

- **DESIGN REQUIREMENT OF THERMAL POWER PLANT**
  DYNAMIC

- HIGH OPERATIONAL GRADIENT (LOAD CHANGE SPEEDS)
- SHORT START-UP MINIMUM AND NOMINAL LOAD
- SHORT MINIMUM DOWNTIME.

- **OPERATIONAL**

- HIGH STARTING NUMBER AND LOAD CYCLES AT REDUCED LIFETIME CONSUMPTION
- LOWEST POSSIBLE MINIMUM LOAD AT HIGH EFFICIENCY
- UNIFORM, HIGH EFFICIENCY CURVE ACROSS THE LOAD

FLEXIBILIZATION

Design Specifications new Power Plants
Example: Westfalen

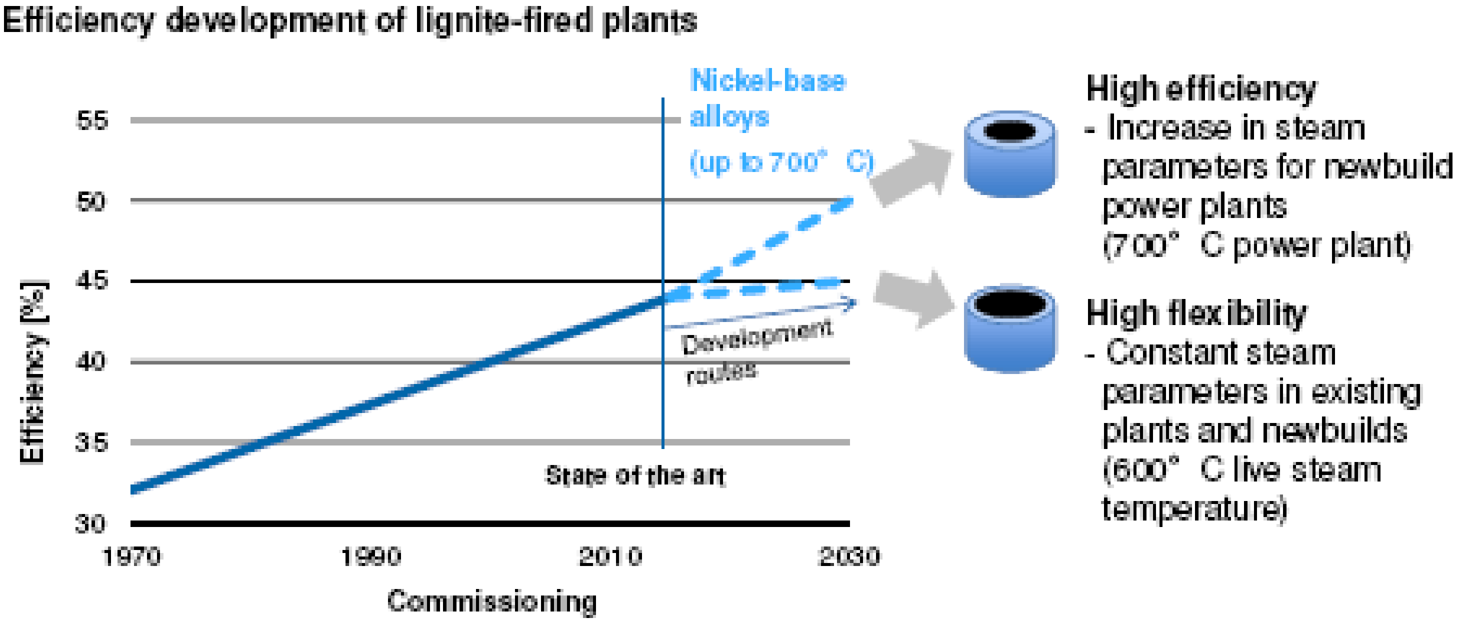
Operational Characteristics (Hard Coal, 800 MW)

- Base and medium load
- Plant runs through in times of low demand
- Minimum load 25 - 30%, 7,500 operation hours per year

Operation Mode	Per year	40 years
Cold Starts	6	240
Warm Starts	42	1,680
Hot Starts	84	3,360
Load Cycles	1,200	48,000

FLEXIBILIZATION

New advanced Materials allow Increase in Flexibility or Efficiency



Use of nickel-base alloys depends on operating conditions of future power plants

STORAGE SOLUTION IN GERMANY IN RISING RENEWABLE AND FLUCTUATING FEED-IN

PRESENT STORAGE PLAN IN GERMANY :

- GERMANY IS PLANNING TO LAUNCH AROUND 4.2 MN ELECTRIC CAR (STORAGE POWER 4-6 KW/CAR) IN THE MARKET BY 2030 WHICH CAN BE CHARGED DURING OFF-PEAK HOURS.

OTHER STORAGE PLAN

- BATTERY STORAGE
- PUMP STORAGE
- HYDROGEN ELECTROLYSIS

STORAGE SOLUTION IN GERMANY IN RISING RENEWABLE AND FLUCTUATING FEED-IN

PRESENT STORAGE PLAN IN GERMANY

Investment in large battery systems to provide 90 MWel PC in total:

- Project costs in total: about 100 Mio. €
- No subsidies
- Erection at 6 STEAG sites in Germany using existing grid connections
- Containerized solution to have the option of relocation

Fast realization

- Start of erection April 2016
- Commercial operation of all units end of 2016

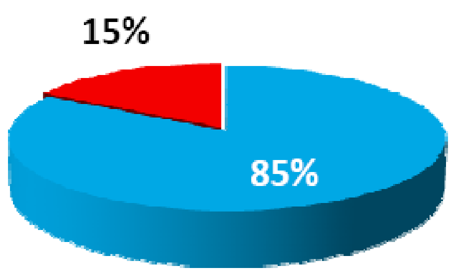
LOCATION IN GERMANY

A) LUNEN
B) HERNE
C) WALSUM
D) BEXBACH
E) FENNE
F) WEITHER

NTPC IN INDIAN POWER SECTOR SCENARIO AS ON 2016

Share of Installed Capacity (*as on June 30,2016)

*Rest of India 255940 MW
*NTPC (Group) 47178 MW



Fuel Mix	No. of Plants	Capacity (MW)	% Share
NTPC Owned			
Coal	18	35,085	74.29%
Gas/Liquid Fuel	7	4,017	8.51%
Hydro	1	800	1.69%
Solar	9	360	0.76%
Sub-total	35	40,262	85.25%
Owned by JVs and Subsidiaries			
Coal	8	4,999	10.58%
Gas	1	1,967	4.17%
Sub-total	9	6,966	14.75%
Total	44	47,228	100.00%

NTPC RENEWABLE ENERGY (SOLAR) CONTRIBUTION IN THE GRID = 360 MW AS ON JUNE, 2016

RENEWABLE ENERGY IN INDIA MASSIVE CAPACITY ADDITION PROGRAM

NTPC Renewable Plan: 10 GW by 2022 (Revised)

S.No	Projects (As on 2016)	Capacity (MW)
1	Under operation (9 Projects)	360
2	Recommended for award (1 Project)	125
3	Under Construction (2 Projects)	510
4	Under Tendering/Process (6 Projects)	2200
Total Solar PV Projects (18 nos)		3195 MW

TOWARDS FLEXIBILITY - AN OVERVIEW

- INDIAN GRID PROFILE TO BE STUDIED IN DETAILS DUE TO INJECTION OF LARGE AMOUNT OF RENEWABLE POWER. STUDIES MAY INCLUDE NUMBER OF **LOAD CYCLE PER DAY, PEAK LOAD DEMAND AND MINIMUM LOAD DEMAND** ETC.

- **DAY AHEAD WEATHER FORECASTING** .

- ESTIMATED **NUMBER OF CYCLE** MAY BE DECIDED PER DAY OR PER MONTH WHICH MAY BE A GUIDING FACTOR FOR MODIFICATION OF BASE LOAD EXISTING COAL BASED POWER PLANT OR NEWLY BUILT COAL BASED POWER PLANT.

TOWARDS FLEXIBILITY - AN OVERVIEW

AREAS OF IMPROVEMENT IN BOILERS :

- THE **MINIMUM TECHNICAL LIMIT** OF STEAM GENERATOR
- THE **RAMP UP AND RAMP DOWN** RATES
- NUMBER OF **STARTS AND STOPS**
- BOILER START-UP TIME DURING **COLD, WARM AND HOT**
- **NUMBER OF LOAD CYCLE** PER YEAR CONSIDERING A PLANT LIFE OF 25 YEAR.
- **MINIMUM TECHNICAL LOAD RUNNING TIME** IN HOURS PER YEAR.

TOWARDS FLEXIBILITY - AN OVERVIEW

ESTIMATION OF CYCLING COSTS :

- INCREASES IN MAINTENANCE AND OVERHAUL CAPITAL EXPENDITURES .

- FORCED OUTAGE EFFECTS, INCLUDING FORCED OUTAGE TIME, REPLACEMENT ENERGY, AND CAPACITY.

- COST OF INCREASED UNIT HEAT RATE, LONG-TERM EFFICIENCY LOSS AND EFFICIENCY AT LOW/VARIABLE LOADS.

- COST OF START-UP FUELS, AUXILIARY POWER, CHEMICALS AND ADDITIONAL MANPOWER REQUIRED FOR UNIT START-UP.

TOWARDS FLEXIBILITY - AN OVERVIEW

MODIFICATION TO O&M STRATEGIES DUE TO CYCLIC LOADING :

•O&M STRATEGIES FOR THE LONG, MEDIUM AND SHORT TERM SHALL BE STRUCTURED AS CYCLING LOADING GETS INTRODUCED OVER COMING YEARS.

•REFINEMENT OF OPERATIONAL PROCEDURES TO PREVENT AND MANAGE CYCLING RELATED FAILURES, REDUCTION IN START UP TIMES WITH MINIMUM PHYSICAL DAMAGE TO THE PLANT, MAXIMIZING HEAT RATE FOR SELECTED OPERATIONAL RANGE, MINIMIZING PLANNED OUTAGES ETC SHALL BE CONSIDERED AS AN AREA FOR IMPROVEMENT.

THANK YOU