Flexible Operation - Challenges for Thermal Power Plants

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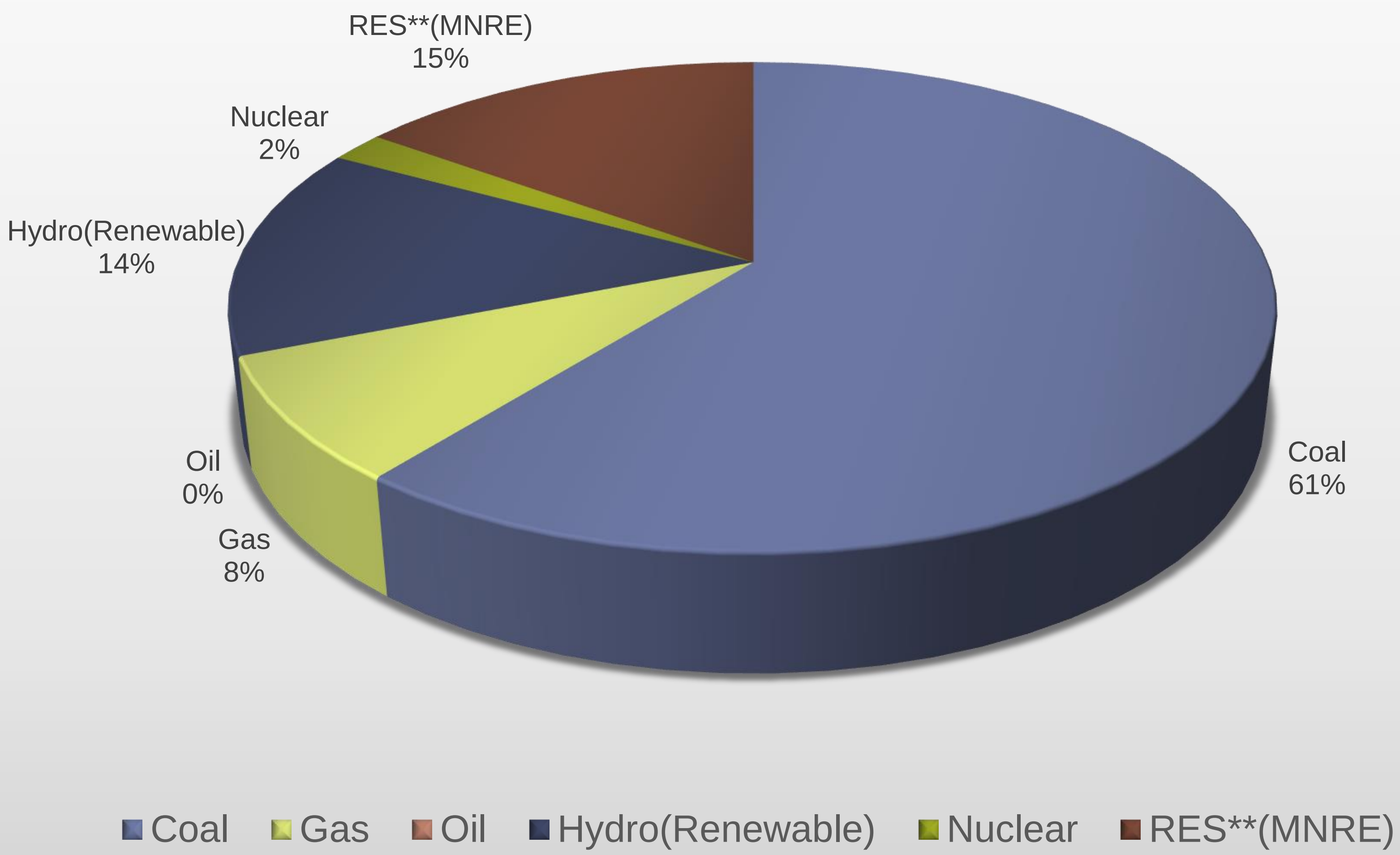
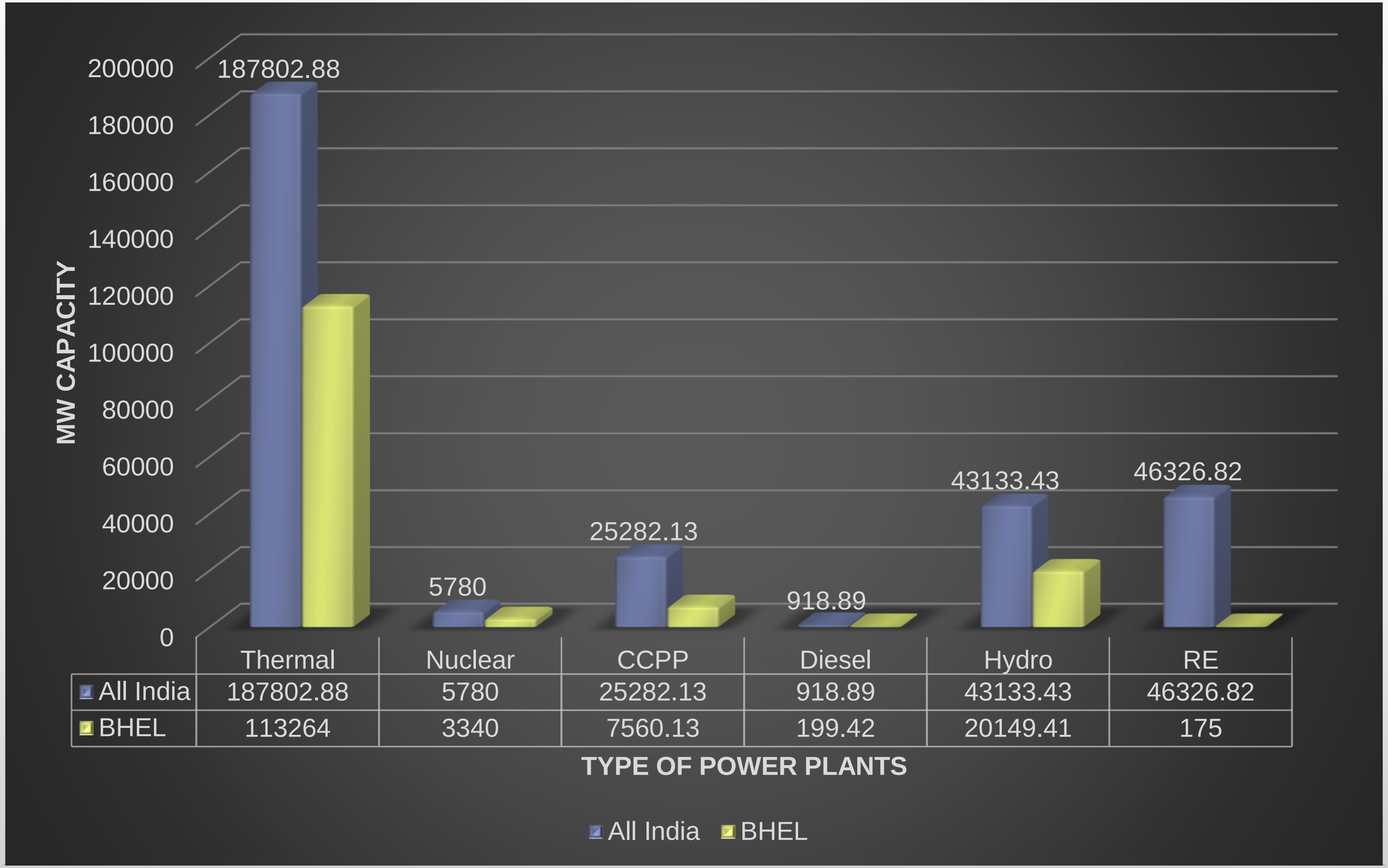
Total Installed Capacity of India (309244MW) As on 30.11.2016(Source: CEA and MNRE)

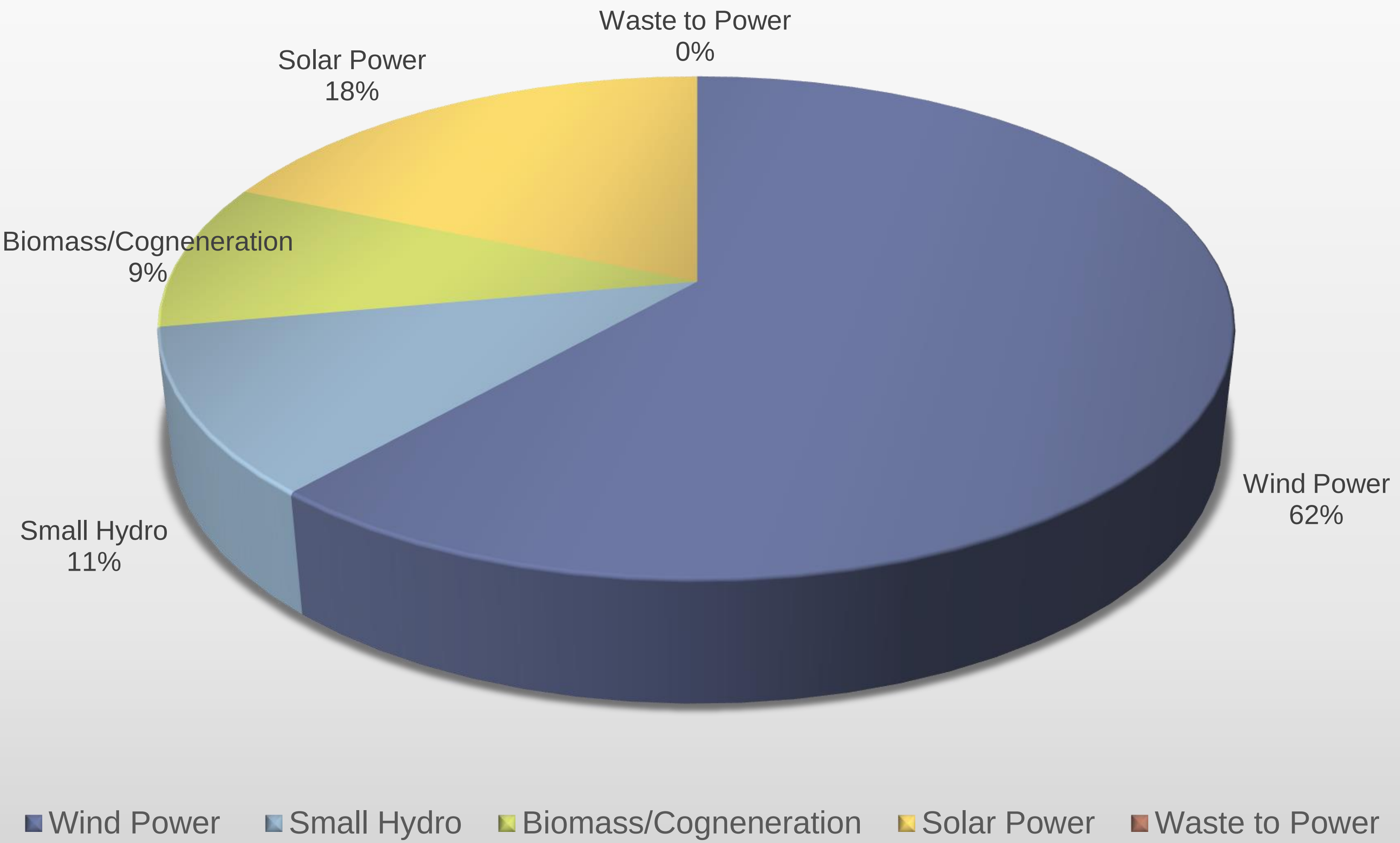


BHEL's Contribution In Indian Power Sector



	Thermal	Nuclear	CCPP	Diesel	Hydro	RE
All India	187802.88	5780	25282.13	918.89	43133.43	46326.82
BHEL	113264	3340	7560.13	199.42	20149.41	175

Indian Renewable Energy Sector (46326.82 MW)
Source: MNRE



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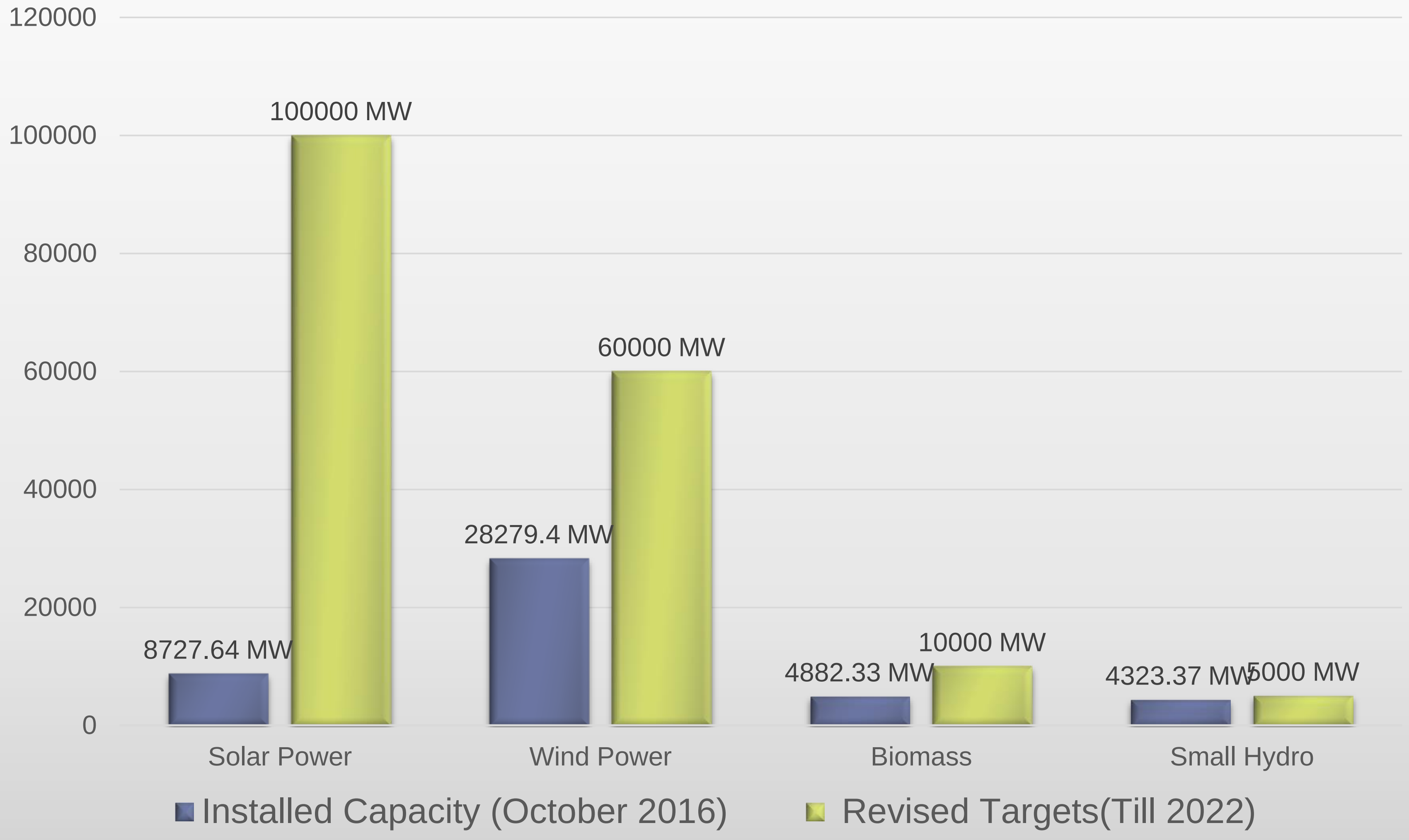
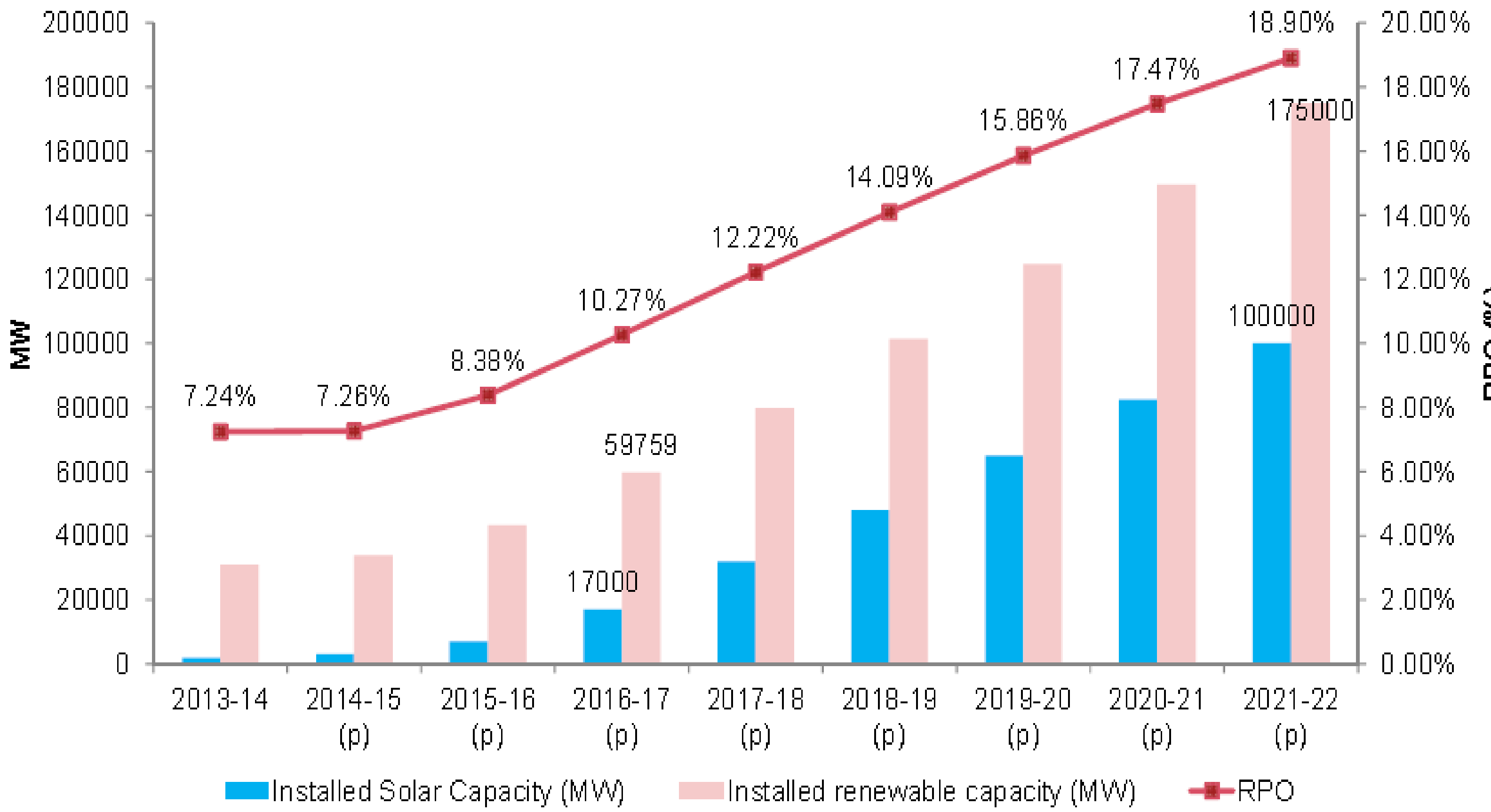
Installed RE Capacity Vs. Revised RE Targets
A Long Way To Go.....



Share of RE in Future Energy Mix
Source: MNRE

175 GW RE will contribute to **18.9%** of the entire power consumption in India in 2022



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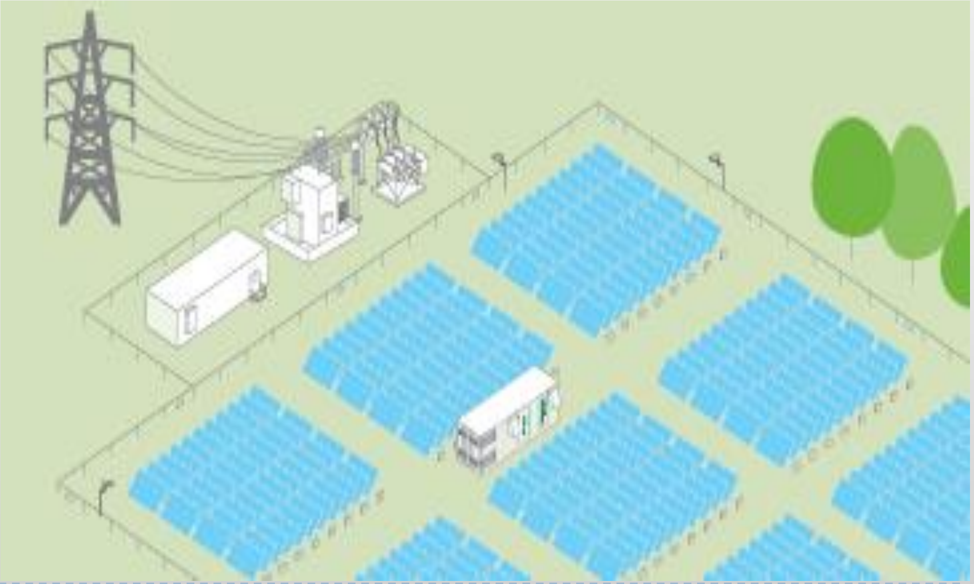
Renewable Generation - Challenges

- Intermittent and variable
- Season and Weather dependent
- Location and time of day dependent
- Does not match the load demand curve
- Wind generation is unpredictable
- Solar generation is predictable but non controllable

Integration of Renewable Energy in Grid

- Balancing by conventional energy sources (large part of which is thermal) is required
- Greater the penetration of RE in Grid greater is the requirement of balancing



Expected All India Duck curve with 20GW Solar Power in Grid

Expectation from Thermal plants

- Backing down and cyclic loading
- Frequent start/stops may be required
- Higher ramping rates during loading and unloading

But base load conventional plants are not designed for such cyclic loading.

Start-up of Steam turbines (BHEL make)

Start type	Outage hours	Mean HP Rotor temperature (deg C)	Start-up time (Rolling to full load in min. approx)
Cold Start	190 hr	150 deg C	255
Warm Start	48 hr	380 deg C	155
Hot Start	8 hr	500 deg C	55

Normal Mode : 2000-2200 starts

Slow Mode : 8000 starts

Fast Mode : 800 starts

Effect of Load Cycling on Power Plant Components

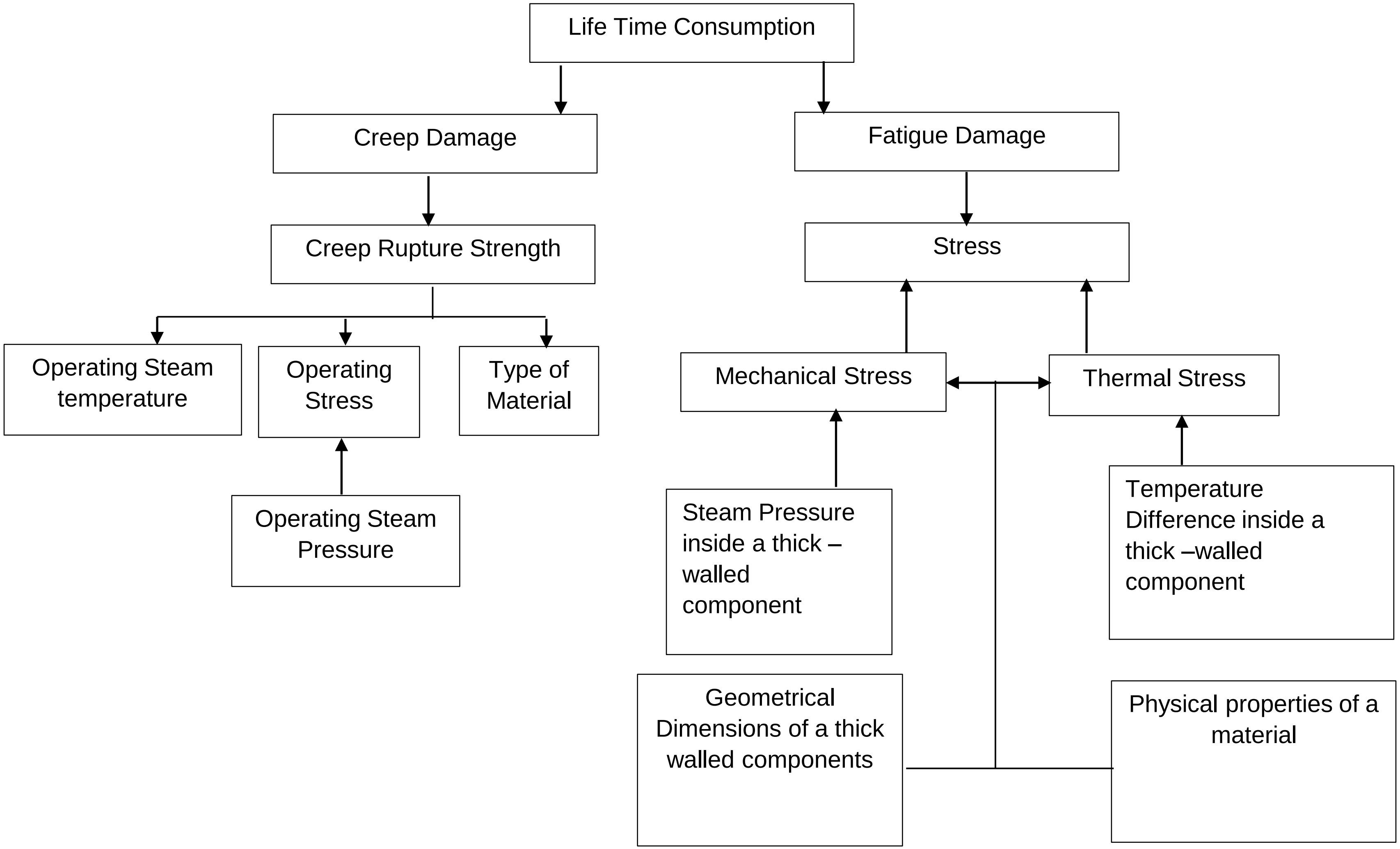
Depending on the operational conditions, turbine and boiler components are exposed to various damage mechanisms

Creep – Slow and continuous deformation of materials due to high temperature exposure even at constant load

Thermal Fatigue – Failure of metal when subjected to repeated or fluctuating stresses due to thermal cycling of components

Components affected – HP/IP rotors, Blades, Casings, Valves, Header, Y-Piece, T-piece, MS/HRH Pipelines

Life Expenditure of Components



Life Expenditure Computation

The consumed life of a component is the sum of the life consumed by Creep & Low Cycle Fatigue

MINER SUM M_C IS INDICATOR OF THE LIFE EXPENDED DUE TO CREEP

&

MINER SUM M_F IS INDICATOR OF THE LIFE EXPENDED DUE TO LOW CYCLE FATIGUE

Life Expenditure Computation

FOR STATIONARY COMPONENTS :

M = MC + MF = 1 *WARNING POINT*

FOR ROTATING COMPONENTS :

M = M C + MF = 0.5 *WARNING POINT*

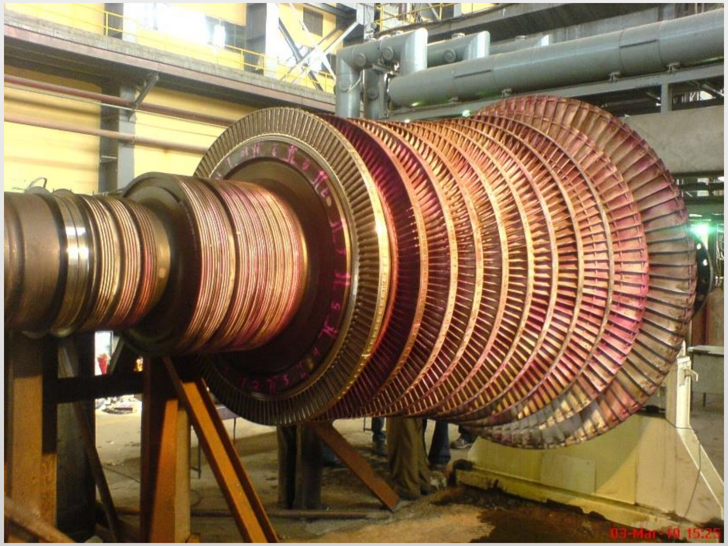
Approaching the Warning Point of Effective Miner Sum indicates that the life of the component has reached its limit.

Impact of Cycling on Equipment and Operation

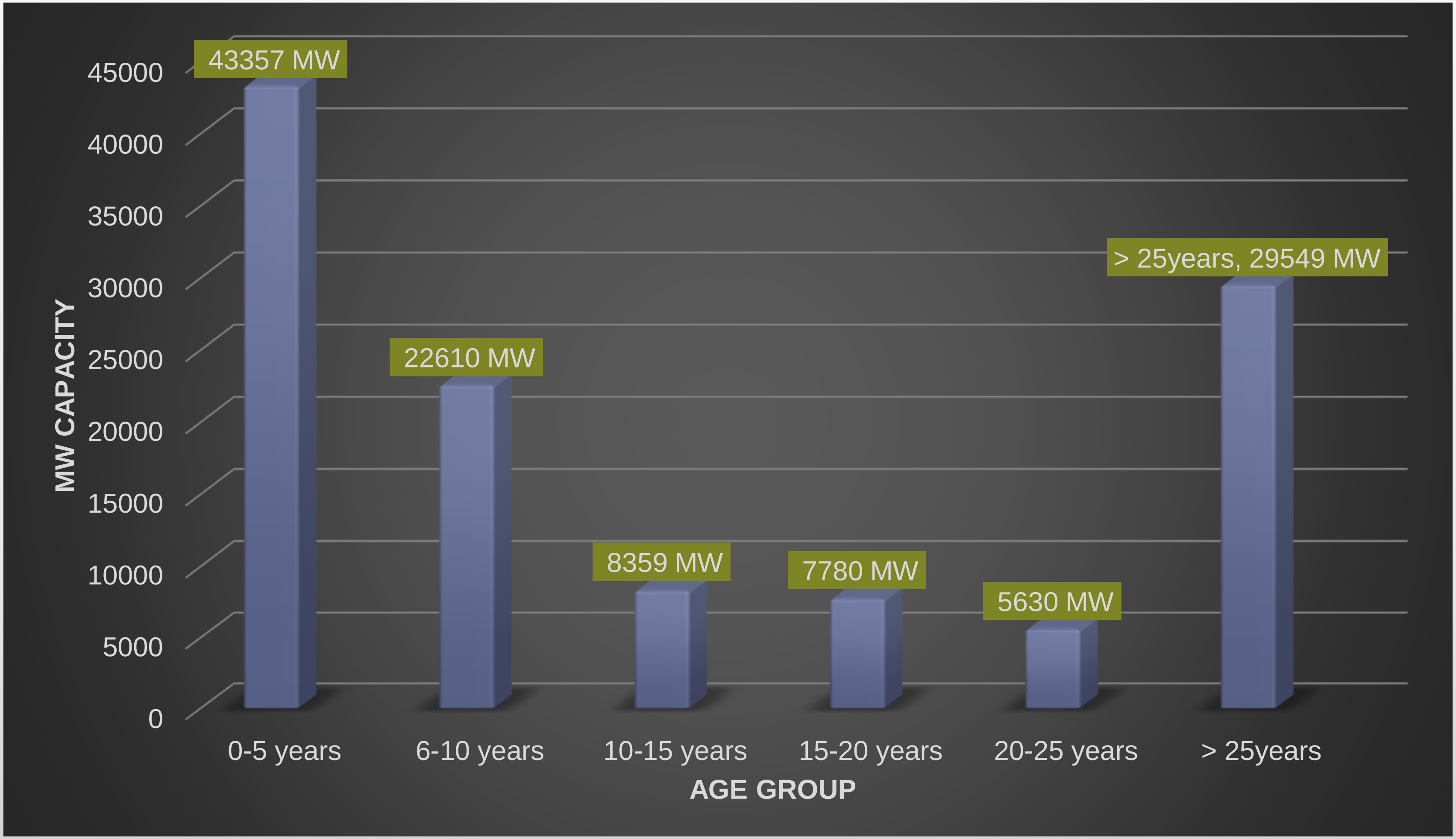
- Critical components are subjected to thermal stresses which are cyclic in nature
- Higher fatigue rates leading to shorter life of components
- Advanced ageing of Generator insulation system due to increased thermal stresses
- Efficiency degradation at part loads
- More wear and tear of components
- Damage to equipment if not replaced/attended in time
- Shorter inspection periods
- Increased fuel cost due to frequent start-ups
- Increased O&M cost

Other Operational Risks

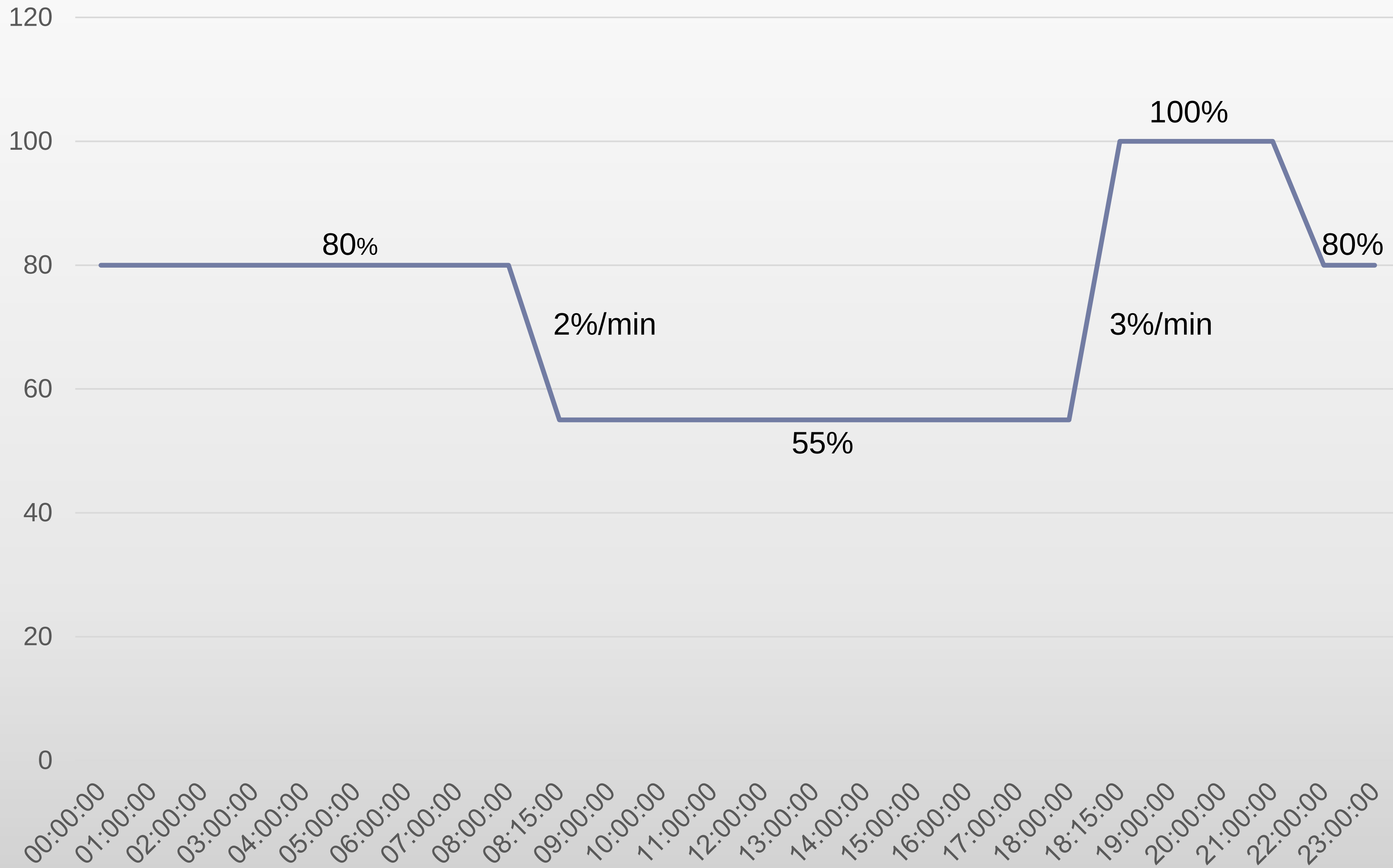
- Ventilation in HP and LP Turbine at lower loads
- Droplet erosion of LP blades
- Excitation of LP blades due to ventilation
- Frequent start/stop of major auxiliaries (PA/FD/ID fans, BFP) reduces their reliability
- Increased risk for pre-fatigued components



Age of Thermal Power Plants In India (in Years)



Assumed Load Demand Curve on Thermal Machines



Impact Assessment of Load Cycling

- Impact of cyclic operation on BHEL supplied equipment with assumed load curve has been investigated.
- Lower load is limited to 55% of rated and a ramp down rate of 2%/min and ramp up rate of 3%/ min. is considered.
- It is assumed that main steam and HRH temperatures are kept constant and Unit is operated in sliding pressure mode.

Cyclic Operation - Findings

- Preliminary studies indicate that load backing from 100%-55% load at a ramp rate of 2%-3% per minute will not have significant impact on life consumption of Turbine, Boiler, Generator & ESP.
- However this mode of operation will have additional cost in terms of lower efficiency at part loads.

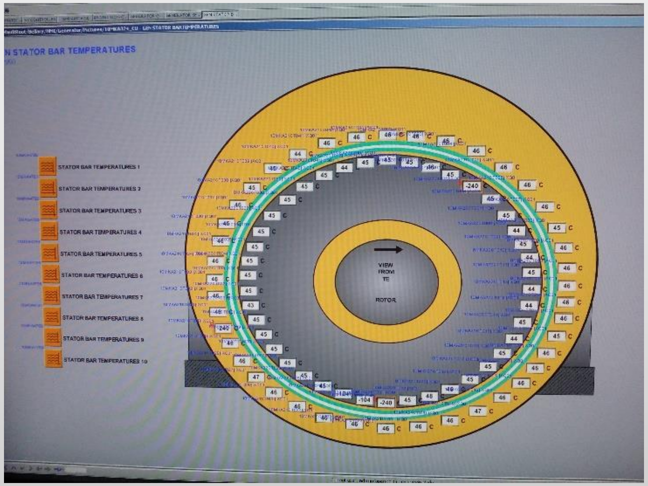
- Backing down below 55% load and/or increase in ramp rates will have effect on the fatigue life of the equipment.
- Backing down below 55% load will also have other negative impacts on the equipment as discussed earlier and need further investigation in detail.

Mitigating the Effect of Cycling

- Additional Condition monitoring systems/ Sensors
- Improved design of Boiler and Turbine to allow faster ramping and increased number of cycles
- Adaptation of Control System
- Low cycling regime for older plants (may require RLA)
- Replacement of fatigued/ worn-out components
- Shorter inspection period

Condition Monitoring for Flexible operation

- Complete operation data is available
- Continuous online consumption of life expenditure
- Detection of highly stressed parts for inspection
- Scheduling of RLA
- Exploring the margins available for optimization of operating modes
- Online monitoring of Generator components as early warning system



Condition Monitoring Systems

- Turbine Stress Controller (TSC)
- Boiler Stress Monitoring System (BOSMON)
- Blade Vibration Monitoring System (BVMS)
- Stator End Winding Vibration Monitoring
- Rotor Flux Monitoring
- Partial Discharge Monitoring
- Additional sensors for health monitoring

Renewables integration - Overall impact

Thus increased penetration of renewables will lead to

- Increased cost due to cycling resulting in higher tariff from conventional sources
- Reduced equipment life and thus earlier replacement of plants


THANK YOU