

# Conference :- Heat Rate Efficiency Summit 2023

Topic :  
Heat rate improvement of thermal power  
plants through real time, closed loop,  
advance process control based solutions

**MR SUBHRAMANYAM EDAMANA**  
Tata Consulting Engineers Limited



**Council of Enviro Excellence**

**3<sup>RD</sup> HEAT RATE  
EFFICIENCY  
SUMMIT 2023**



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# 3rd Annual Heat Rate Efficiency Conference, 2023

Heat rate improvement of thermal power plants through real time, closed loop, advance process control based solutions

30<sup>th</sup> Nov- 1<sup>st</sup> Dec, 2023

Mr. Subhramanyan Edamana  
Digital Anchor, PED Cluster



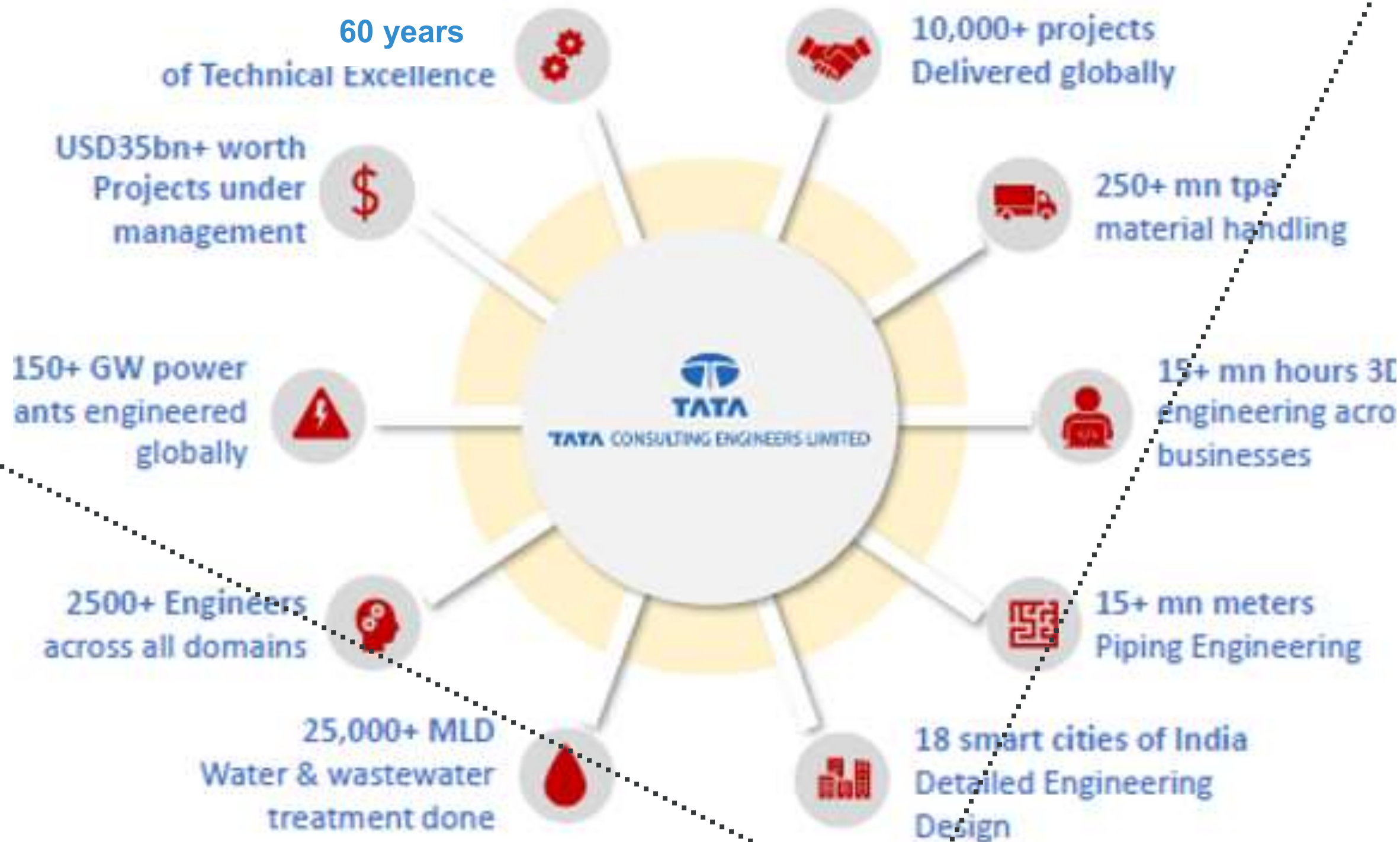
# AGENDA

- About Tata Consulting Engineers Limited
- Key Trends in Power
- Heat Rate of TPPs – Present Status
- Heat Rate Variations and Reasons
- Advanced Process Control – Essential Solution for HR Improvement and Flex Operation
- TCE Differentiators

# TCE – Company Overview



## TCE snapshot



## SERVICES

### WE OFFER

#### Design & Engineering

Project Concept Development, Pre-feasibility & Feasibility Reports, Detailed Project Reports, Environmental Study Reports, System Studies, Frontend Engineering Design (FEED), OE Services, Detailed Engineering

#### Project Management & Safety

Project Management, Engineering Review, Construction Management / Supervision, Program Management, Interface Management, Specialised Services, Quality & Safety Audits, Outage Management

#### Digital & Advanced Technology

Unified 3D Engineering, 4D, 5D Simulation, Building Information Management, Asset Digitisation & Asset Information Management, Industry 4.0 & Asset Performance Management, Product Engineering Design and Analysis, Turnkey Machine Development

#### Procurement Management

Procurement Assistance, Quality, Inspection & Equipment management, Vendor Quality Assessment, Vendor Management, Inquiry/Tender Preparation and Award

# Power Business Unit



**Six Decades** of experience in providing Concept to commissioning Value added engineering services.

- **Thermal** – Coal, Gas, Captive & Cogen – 120GW
- **Nuclear** – PHWR, FBR – 7GW
- **Hydro** – Small, Medium, Large – 15+GW
- **Renewables** - Solar, Wind, Biomass, WtE – 15+GW
- **T&D** – Transmission Lines, Substation, Distribution and System Studies
- **Opex** Services across Sectors



Steam Power Plants



Gas Turbine Power Plants



Hydro Power Plants



Transmission & Distribution



Renewable Energy



Opex



Nuclear Power Plants



Research Reactors



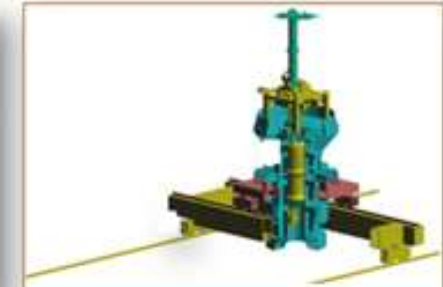
Nuclear Waste Management



Spent Fuel Processing



Nuclear Fuel Fabrication



Fuelling Machine

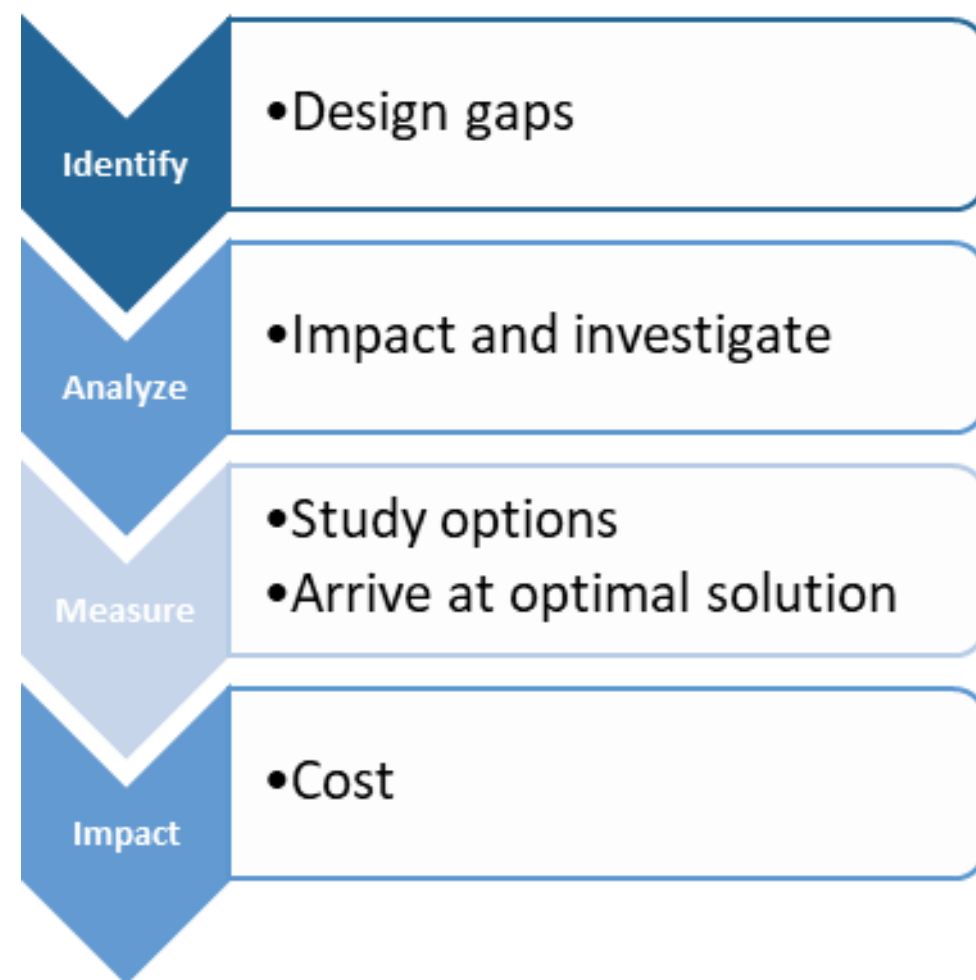
# Opex Services



# Opex Services



## Design Gap Analysis – SPOF



Customer – NOMAC  
 Plant – 3x686.5 CCP at Rabigh, Saudi  
 Scope – Identify SPOF for loss of gen

## Fuel Conversion / Modifications study



Customer – EPC Customers  
 Plant – Jazan, Asir & Shar Sharourah  
 Scope – LDO to Crude Oil DES

## Environmental Upgrades

**Clients** 40+ Plants, 120+ Units in India  
 Total 55+ GW Footprint  
 20+ Customer / Groups

De-SOx /De-NOx/Multi-Pollutant Control System Retrofits



## RE Integration



Client – Jhajjar Power Limited  
Plant – 2x660MW, Jhajjar  
Scope – RE Integration studies

## Heat Rate Improvement



Client – Under NDA.  
Plant – 300MW, Sub critical unit  
Scope – Implementation of APC based heat rate improvement solution

## Plant Digitalization



- Implementation support for Digital Transformation
- Deployment of customized Digital Points Solution
- Deployment of Platform based solution (APM)

## Renovation & Modernization



Client – MSPGCL (Mahagenco)  
Plant – Unit#6 210MW, Nagpur  
Scope – R&M project of 210 MW  
STG uprated to 228MW

## Performance Gap Analysis & Efficiency Improvement



Client – Indorama Ventures Ltd.  
Plant – Thailand, Indonesia, India, USA,  
Russia and other different locations of  
IVL Plants  
Scope – Identification of performance  
Gaps & implementation

## Digital Point Solutions

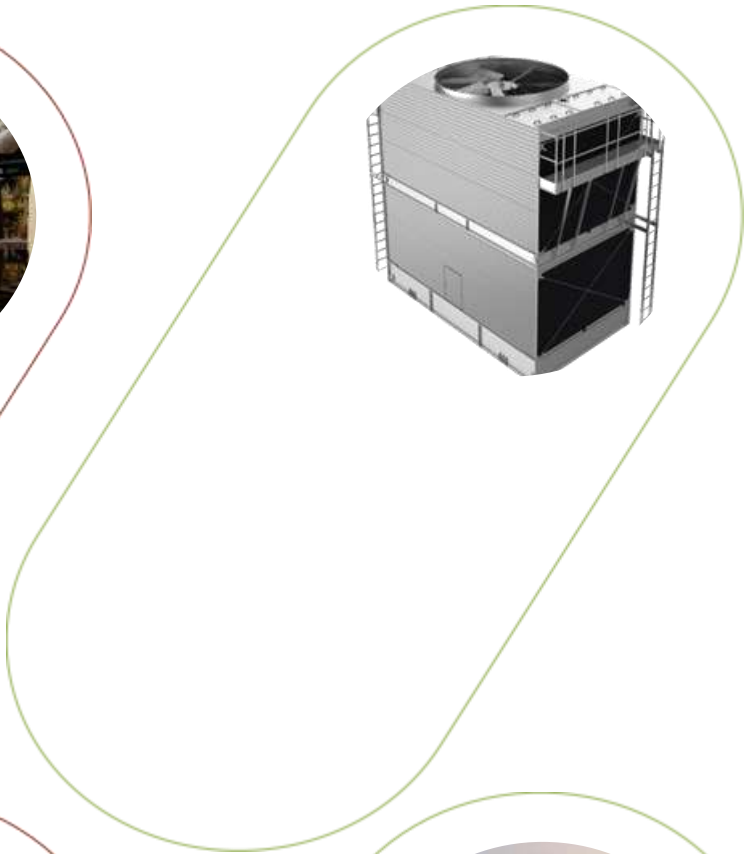
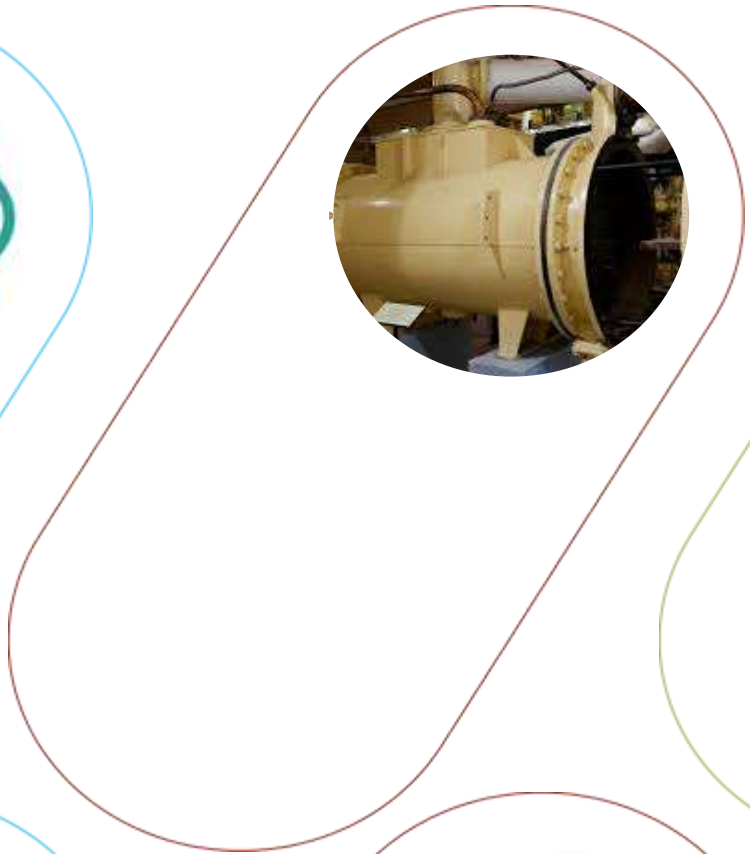
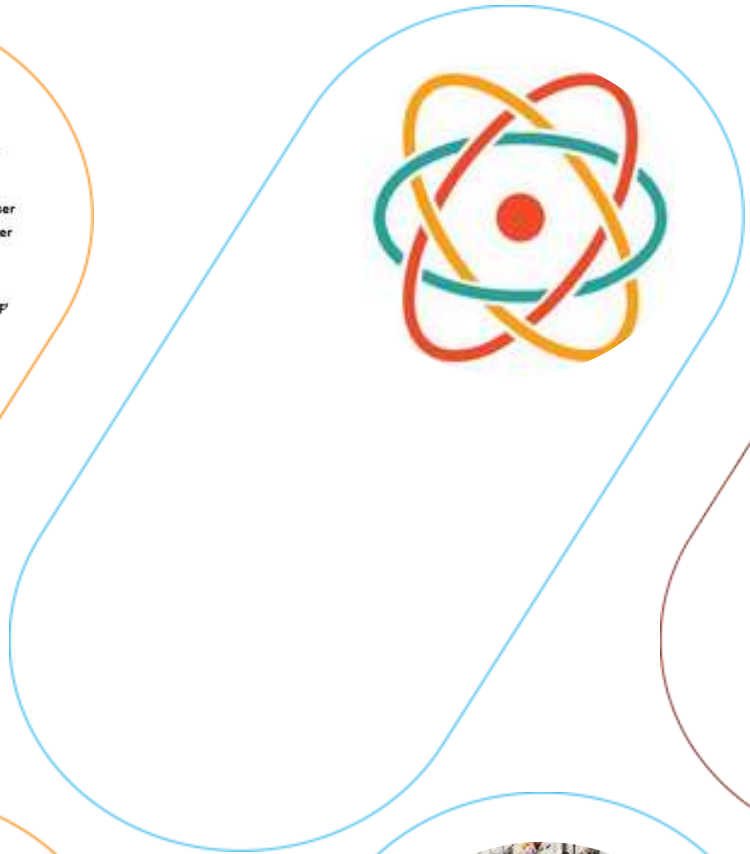
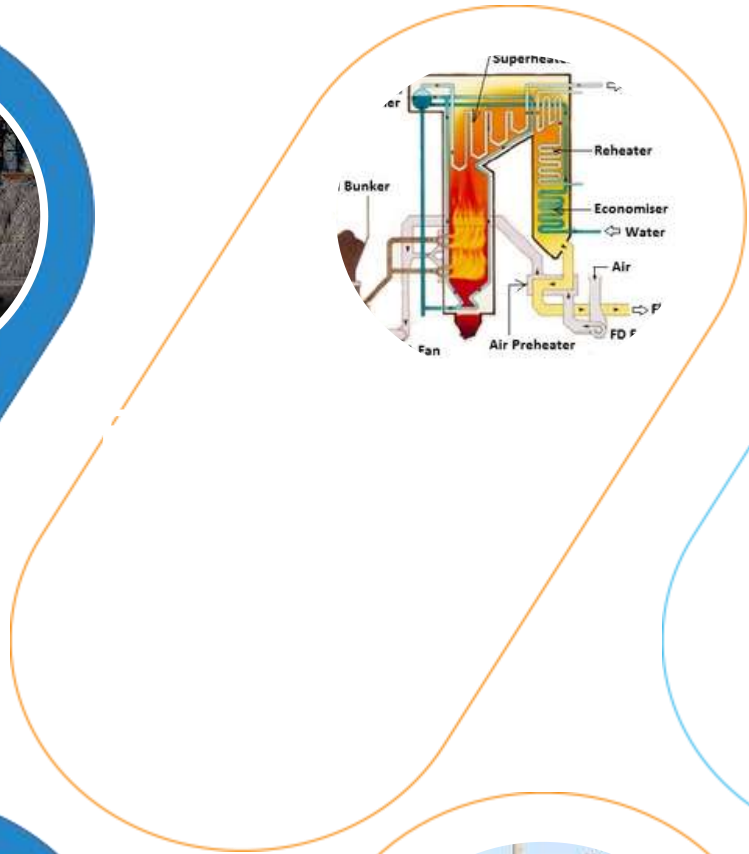


- Boiler Modelling & Simulation @ HZL, 80MW Captive TPP
- Cooling Tower Performance monitoring & diagnosis @ Tata Steel, Jamshedpur

# TCE- Digital Point Solutions



**Coal Inventory Management & Optimisation**



**Pump Performance Monitoring & Diagnosis**





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# Key Trends in Thermal Power Plants

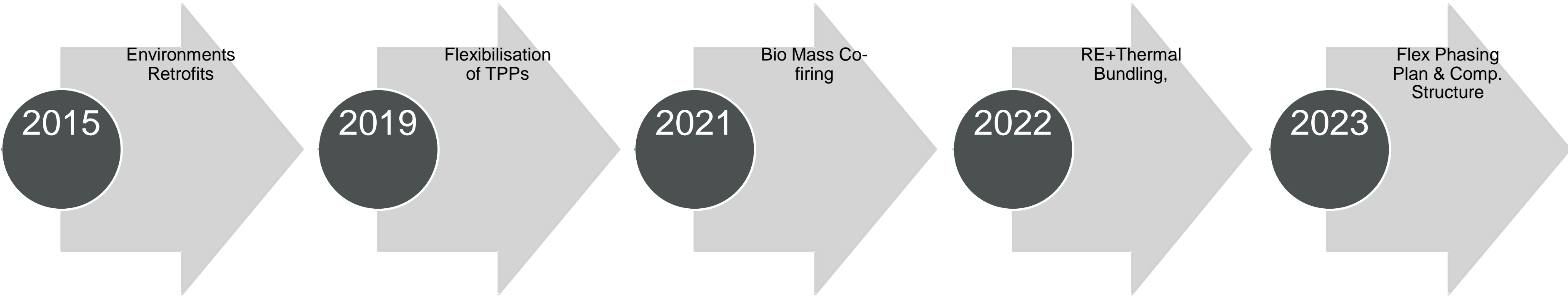
## Energy Transition

- Renewable Energy Addition
- RE+ Thermal Bundling
- Flexibilization of TPPs
- Environmental Retrofits
- Biomass Firing
- NH<sub>3</sub> Co-firing

## Digitalisation

- Advance Process Control Solutions
- @Digital Point Solutions
- Asset Performance Management

# Thermal Power - Changing Scenarios



Paris Summit  
175GW RE  
by 2022

Glasgow Summit  
450GW RE  
by 2030



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# Heat Rate of TPPs— Present Status

# Heat Rate - Benchmarks

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# HR Variations For Different Units – Ref: CEA



**Table 2 – Gross Heat Rate Deviations**

<b>Capacity range of units</b>	<b>No. of units</b>	<b>Average Design Gross Heat Rate (kcal/kWh)</b>	<b>Average Operating Gross Heat Rate (kcal/kWh)</b>	<b>Average deviation (%)</b>	<b>Range of operating GHR (kcal/kWh)</b>
100–110 MW	8	2413.3	2994.4	24.1	2696 – 3601
120–125 MW	9	2415.4	2894.5	19.8	2690 – 3730
140 MW	4	2381.7	2822.9	18.5	2750 – 2905
195–200 MW	5	2385.7	2873.6	20.5	2393 – 3962
210 MW	49	2408.3	2765.8	14.8	2384 – 3064
250 MW	5	2300.6	2685.6	16.7	2546 – 2773
500 MW	5	2254.6	2561.3	13.6	2508 – 2647

\*Heat Rate calculated using the design & operating model

# Boiler Efficiency Variations For Different Units



**Table 4 – Boiler Efficiency Variations**

<b>Capacity range of units</b>	<b>No. of units</b>	<b>Average Design Boiler Efficiency (%)</b>	<b>Average Operating Boiler Efficiency (%)</b>	<b>Average Deviation (%)</b>	<b>Range of Operating Boiler Eff.</b>
00–110 MW	8	86.9	80.5	7.4	78.8 – 82.3
20–125 MW	9	86.1	80.1	7.0	75.0 – 82.5
40 MW	4	85.9	80.7	6	80.0 – 81.5
95–200 MW	5	86	80.8	6.1	73.0 – 85.0
110 MW	49	85.8	81.7	4.8	71.0 – 86.0
150 MW	5	87.2	83.4	4.4	82.7 – 85.6
200 MW	5	87.7	82.3	6.1	79.0 – 84.1

\*Boiler Efficiency calculated using the design & operating model



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# Heat Rate Variations and Reasons

## Accountable Losses

- Deviations in critical parameters from design
- Deterioration in equipment performance
- Fuel characteristics / Quality
- Auxiliary power consumption
- Operation practice in the Plant

## Unaccountable Losses

- Passing of valves, traps
- Passing of high energy drains
- Equpt. where performance assessment difficult
- Radiation loss, natural & forced convective loss
- Uncertainties of Instruments

$$\text{Actual} - \text{Design} = \text{Accountable \& Unaccountable Losses}$$

# Reasons for High Operating Heat Rate



- Inefficient boiler combustion
- Higher Super-heater and Re-heater spray
- Poor performance of milling system - Coal/Air ratio, mill outlet temperature, mill fineness,
- High dry flue gas loss due to unwanted excess air
- Poor sealing & heat transfer in APH
- Inefficient soot blowing – **Optimise based on steam temperature**
- Higher Boiler Tube leakages
- Poor condenser vacuum and high cooling water inlet temperature- CT fan operation can be optimised
- High heat loss (air ingress) due to poor insulation
- Variation in fuel quality – Multiple set points for combustion based on 5-6 type of coal- Specially for milling system & air quantity
- Higher APC
- Minor leakages in the system and valves passing
- Improper maintenance & spare planning

# Effect of Deviation in Parameters on Heat Rate (Typical 200 MW)

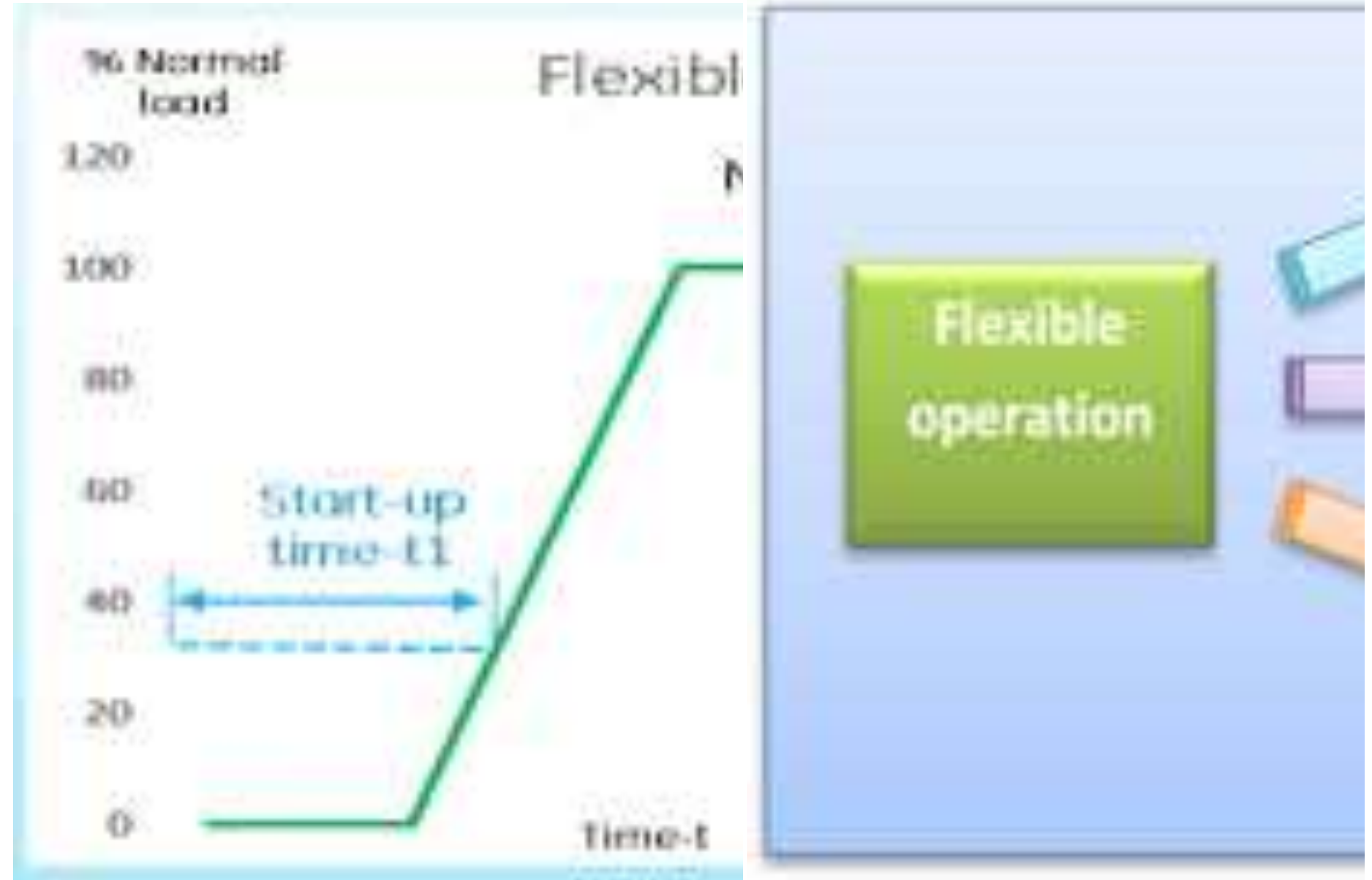


Parameters	Variation	UOM	Impact
HP Turbine efficiency	1%	KJ/kW hr	20.0
IP Turbine efficiency	1%	KJ/kW hr	15.5
MS (Throttle) Pressure	1 bar	KJ/kW hr	3.4
MS (Throttle) Temperature	1 deg C	KJ/kW hr	2.6
RH Temperature	1 deg C	KJ/kW hr	2.4
SH Attemperation	10 TPH	KJ/kW hr	1.2
RH Attemperation	10 TPH	KJ/kW hr	10.5
Excess Air (O2)	1%	KJ/kW hr	31.0
Exit Gas Temperature	1 deg C	KJ/kW hr	4.8
Condenser Pressure	1 mmHg	KJ/kW hr	8.5
Unburnt Carbon	1%	KJ/kW hr	12.4
Coal Moisture	1%	KJ/kW hr	8.3
Auxiliary Power	1%	KJ/kW hr	90.7
Make Up	1%	KJ/kW hr	25.4
FW Temperature	1 deg C	KJ/kW hr	2 - 3.5

Source – Public Domain Data

# Flexible Operation

- Reduced life of power plant components due to thermal, creep fatigue
- Increase in corrosion fatigue due to impact on cycle chemistry
- Increase in the heat rate and auxiliary power consumption
- Increase in tangible operation & maintenance cost and future expenditure
- Increase in oil consumption due to frequent starts and stops



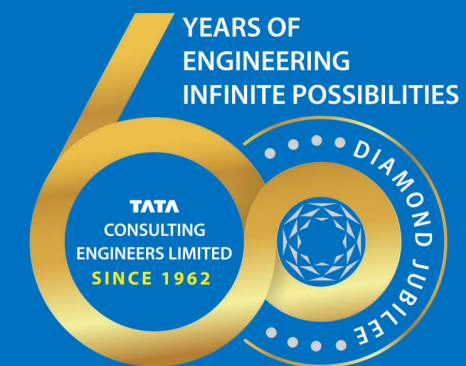
Source: CEA

**Note:** Reduction in MTL shall be confirmed from plant specific studies.



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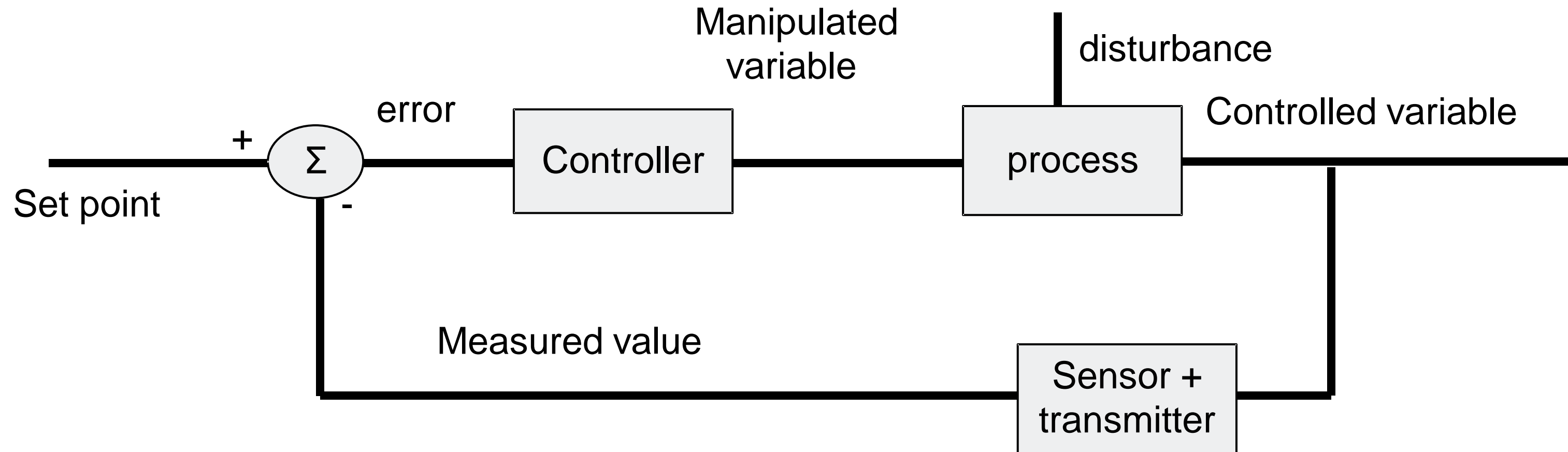
# Advanced Process Control – An Essential Solution for Heat Rate Improvement and Flex Operation

# Unique Drivers for APC



- Large fluctuations in power demand
- Wide variation in coal quality
- Unoptimized operational parameters due to such operating conditions
- Response of DCS control loops (fine tuned for design coal)
- Heat rate performance degradation

# Feedback Control-Conventional PID Controller



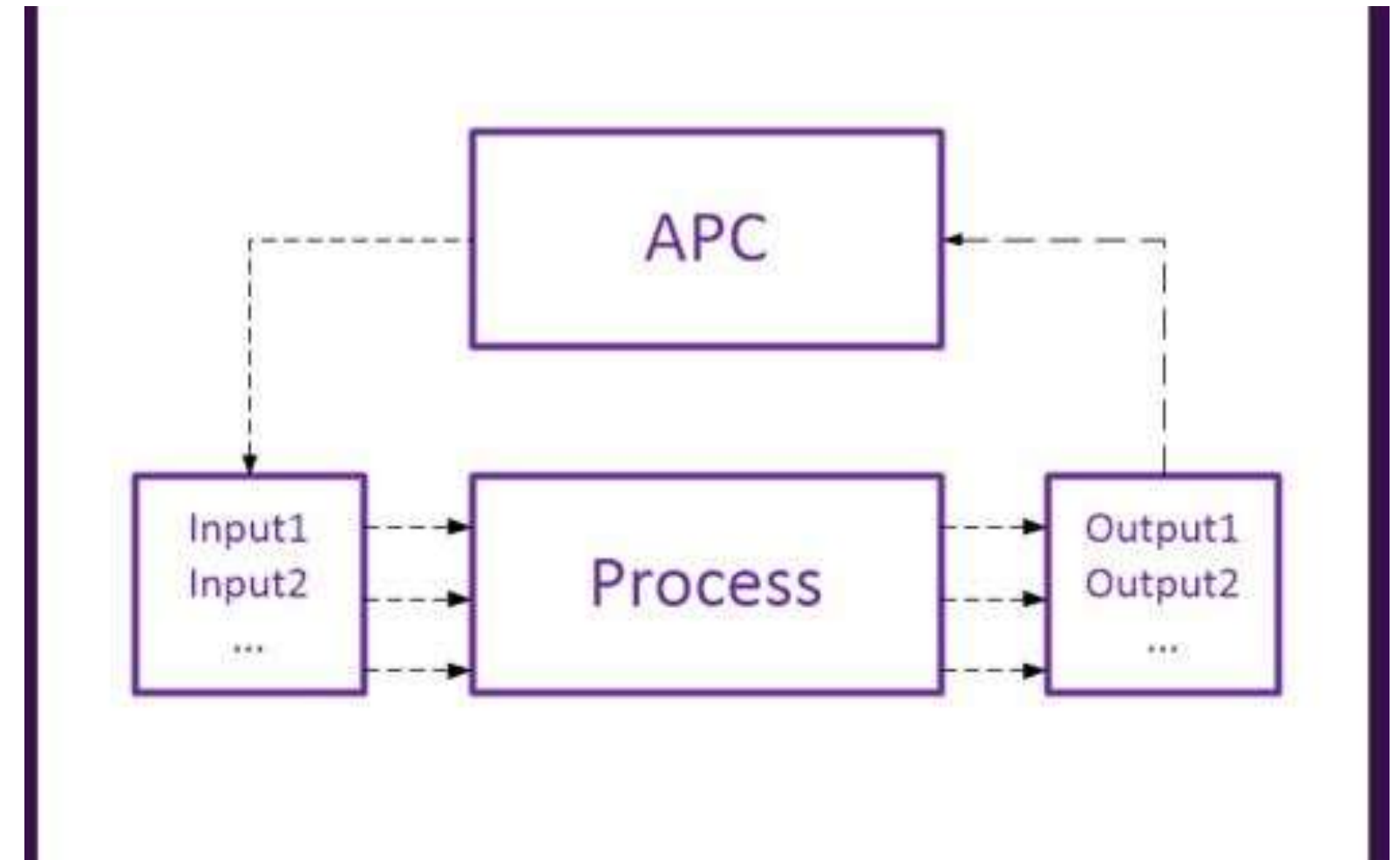
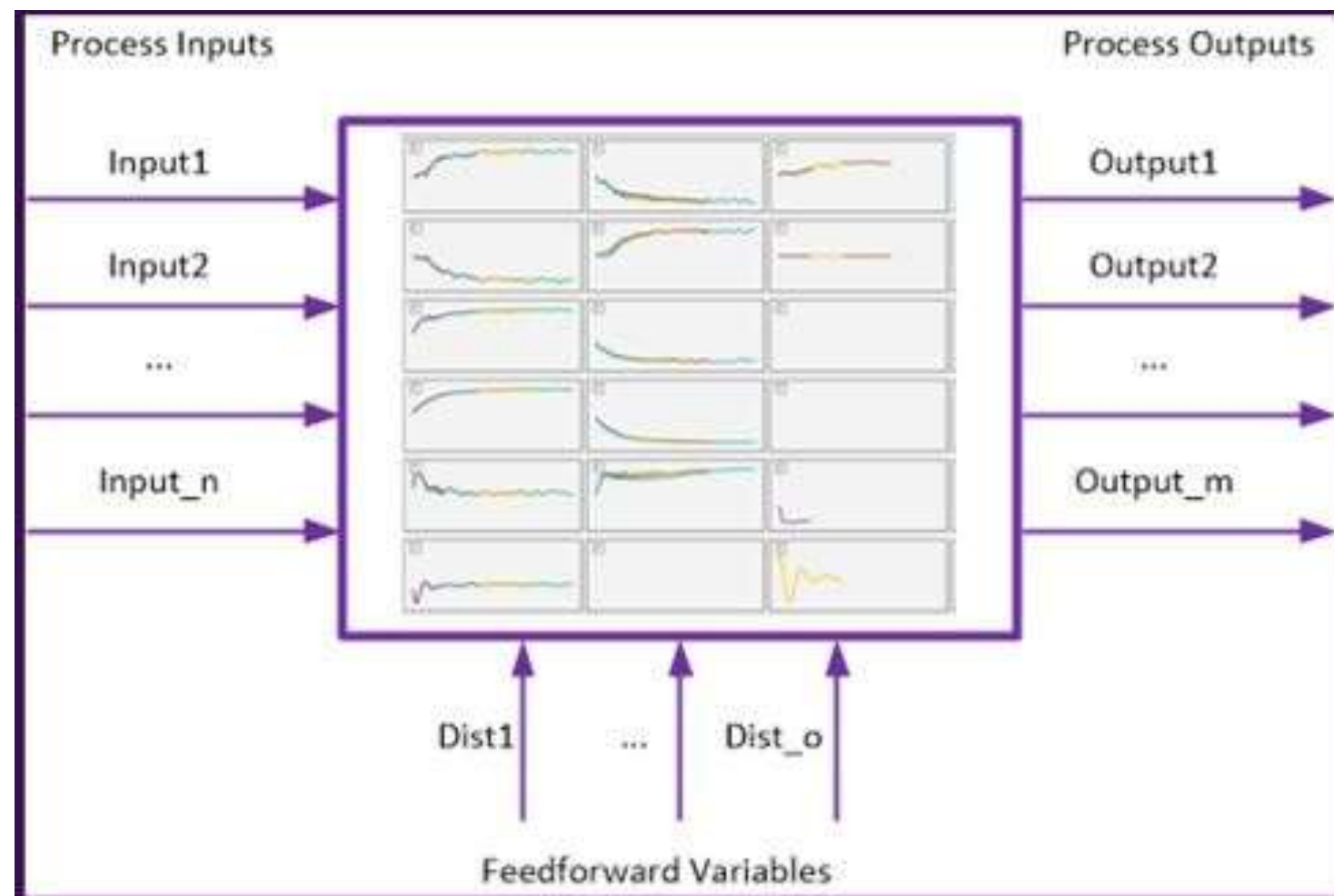
## Terminology:

- Set point
- Manipulated variable (MV)
- Controlled variable (CV)

## Terminology:

- Disturbance or load (DV)
- Process
- controller

# Advance Process Control (APC) for HR Optimization



- Closed loop solution- Works in coordination with existing DCS
- Simultaneously control multiple loops
- Support full operable range
- Part load efficiency optimisation

- Dynamic Mathematical Model Based
- Model Prediction & Controller
- Multi variable controller, optimizer
- Influences the PID controllers

# Action Plan for Flexibility –Specific to Plant

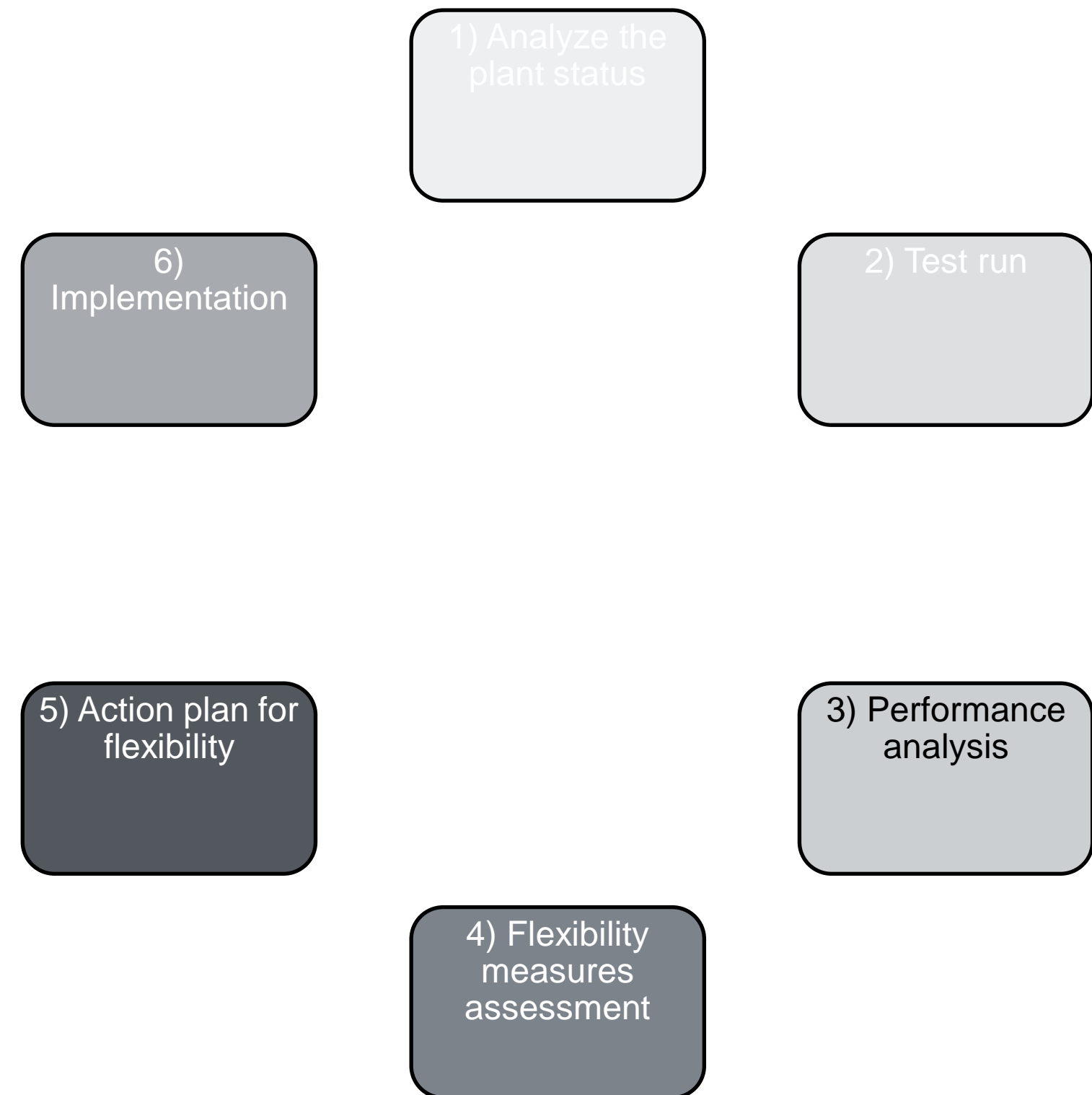
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- **Change in Operation Procedure to enhance operational flexibility**
  - Plant start-up/ shut-down, sliding pressure operation, Bypass operation etc.,
- **Changes into plant monitoring system to enhance operational flexibility**
  - Flame stability monitoring, mill stability and optimization, combustion optimization, flue gas flow stability, additional metal temperature measurement, furnace temperature, soot blowing optimization etc.,
- **Control system optimization to enhance operational flexibility**
  - Control loops fine tuning for wider range
  - Automatic start-up/ shut-down of equipment/system
  - Additional control loops if required etc.,
- **Digital Advance Process Optimizer to enhance plant performance viz a vis economics**

Following steps would be followed in order to prepare an individual plant for flexible operation

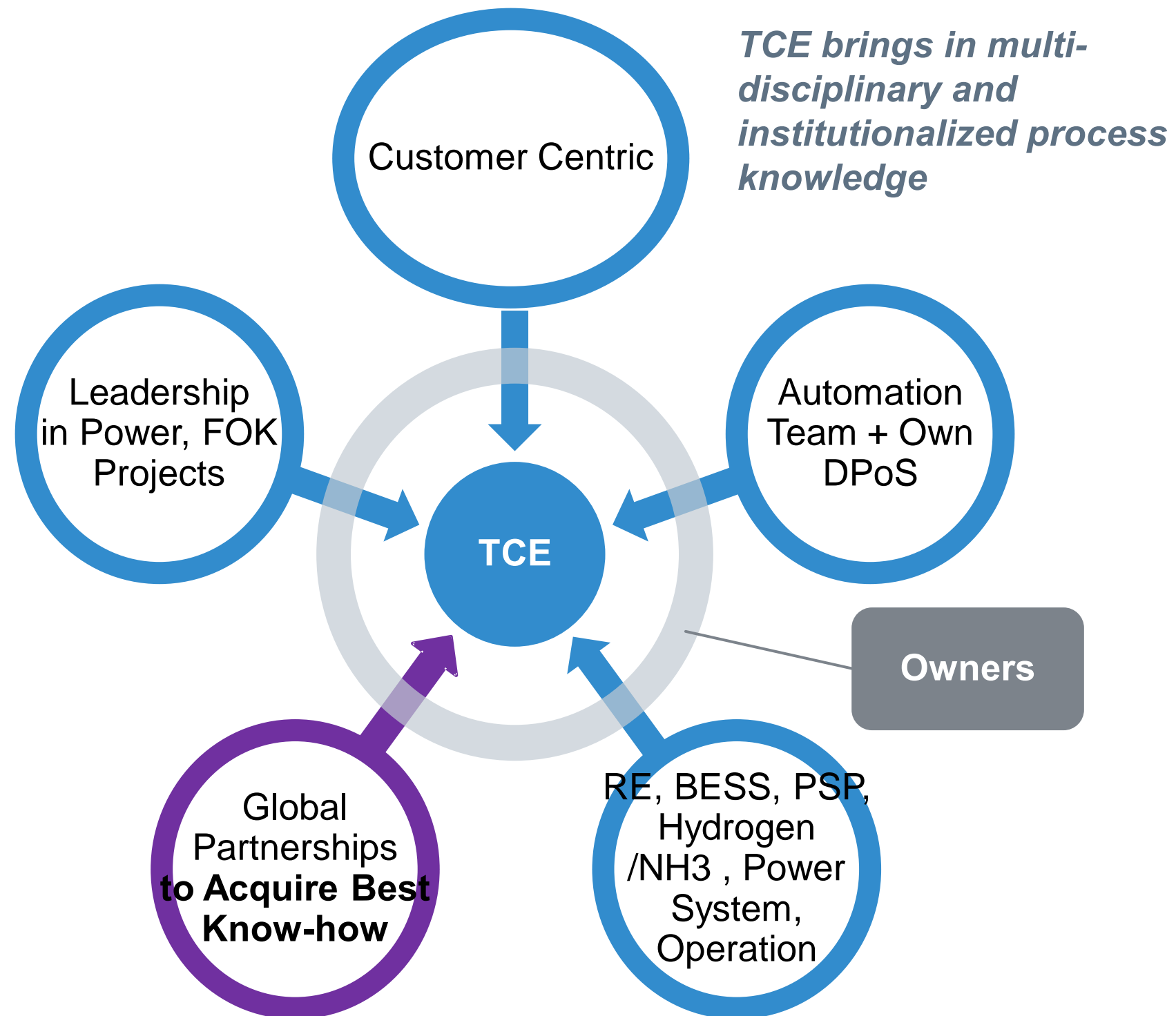
- **Analyze-** the plant condition using historic data
- **Test run-** Shall be performed to access the condition and limitation related to flexibility.
- **Performance analysis-** Analyze the plant performance on the basis of information and data collected during test run and historic data
- **Flexibility assessment-** Based on historical data analysis and performance analysis flexibility enhancement measures to be selected according to cost benefit analysis.
- **Action Plan-** it shall be developed based on flexibility assessment.
- **Implementation-** Selected measures for flexibility enhancement will be implemented at plant .



# TCE – Differences

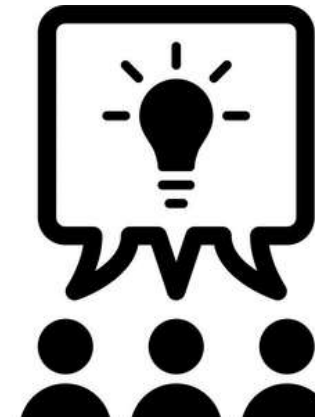


TCE is ideal 'Integrator- Partner' for Digitalisation, Flexibilization & RE Integration



## Key Engagement Models

### Advisory Services



- Understand customer's O&M need and support for Ideation to Implementation of Solutions
- Assist in identification and management of Opex, Digital, Flexibilisation and RE Integration Projects end to end

### Implementation Services



- Expertise in implementation across multiple industries
- Differentiation- Design and Operation experts involvement during implementation
- Provide end to end support including supply, installation of Domain +Digital Solutions

### Inhouse developed-DPoS



- Development of customized digital point solutions specific to process / equipment
- End to end support for development and deployment of micro –services (DPoS)

# Heat Rate Improvement through Advanced Process Control



Plant Capacity- 300MW Thermal Power Plant

## ◦ Problem Statement

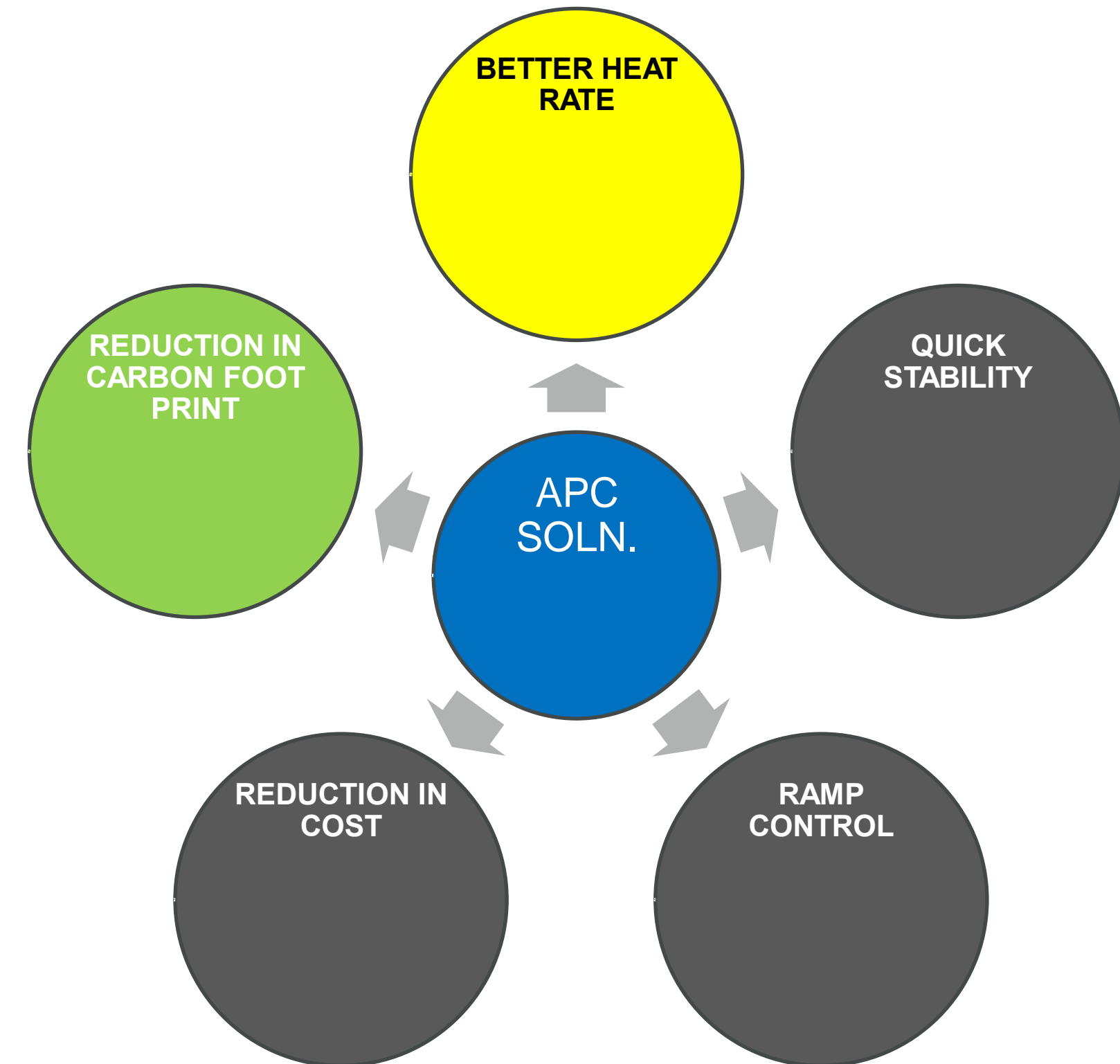
- Large fluctuations in power demand
- Wide variation in coal quality
- Unoptimized operational parameters due to such operating conditions
- Response of DCS control loops (finetuned for design coal)
- Heat rate performance degradation

## ▪ Scope of Work-

- Deployment of APC application for heat rate improvement
- Estimation of the potential improvement in heat rate from operational data analysis
- DCS vendor coordination for the modifications required for APC implementation
- Annual maintenance of the application

## ▪ Key challenges and value added solution provided by TCE-

- Identification of the control loops where the improvement opportunity exists & modification of few manual loops to auto
- Base layer control tuning
- Optimized combustion control for full & part load conditions with varied coal quality
- Quick stability achieved during load changes
- Helps the plants undergoing flexible operation





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THANK YOU

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