Sterlite Power

Integration of Technologies - Power Flow Controllers & Dynamic Line ratings for RE Penetration


Leadership with purpose
EMPOWERING
HUMANITY
by addressing the toughest challenges of energy delivery

OUTLINE

- Introduction
- Overview of Dynamic Line rating Technologies
- Overview of Power Flow Controllers
- Simulation Studies
- Conclusion

Introduction

Challenges

- **Increasing demand and generation** - need for transmission capacity to achieve reliability and security of supply.
- **Challenges in building new lines** – RoW issues, delay in projects e.t.c.,
- **Increasing Renewable energy mix** – the power flows varies with respect to time, seasonal as well as daily variations.
- **Conservative approach** on transmission line loadings thus resulting in network additions – may not be **economical always.**
- **Curtailment in RE generation** due to periodical bottlenecks.

Objective

- Increase **flexibility and capacity** utilization of existing power grid.
- **Optimization of CAPEX** – Harnessing the hidden capacities of the existing system
- **Manage congestion** within the existing grid

Advanced Technologies

- Transmission thermal loading limits are estimated conservatively and are limited by static ratings, need to unlock the hidden capacities considering the dynamic rating.
- Advanced **Dynamic Line Rating (DLR) Technologies** are providing viable solutions to monitor transmission capacity in real time.
- Advanced modular **Power Flow Controller (PFC) technologies** are being adopted and are providing several advantages over traditional technologies in terms of installation, compactness, easy deployment & redeployment.
- With the **integration of technologies (DLR + PFC)** hidden capacities can be harnessed along with optimal utilization of transmission system.

Dynamic Line Rating (DLR) Technologies

Conductor Thermal Rating – Dependency

Material Properties, **Diameter**	Specific to Physical & Chemical properties
Surface Conditions	Vary with respective to Time
Ambient Weather	Vary with respect to weather. Influence of cooling power

Thermal Loading of line:

- The thermal rating/loading of the line is limited by **maximum allowable conductor temperature** without clearance violations or loss of tensile strength.

Heat Balance - Thermal model

$$\frac{dT_c}{dt} = \frac{1}{mC_p}[R(T_c)I^2 + q_s - q_c - q_r$$

Where,

q_s = Solar heat gain

q_c = Convection heat loss

q_r = Radiated heat loss

- When heating is greater than cooling, the temperature will rise proportionally and vice versa
- Heat generated in line (resistance and current)
- Heat being added (solar radiation)
- Heat being removed (cooling effect)

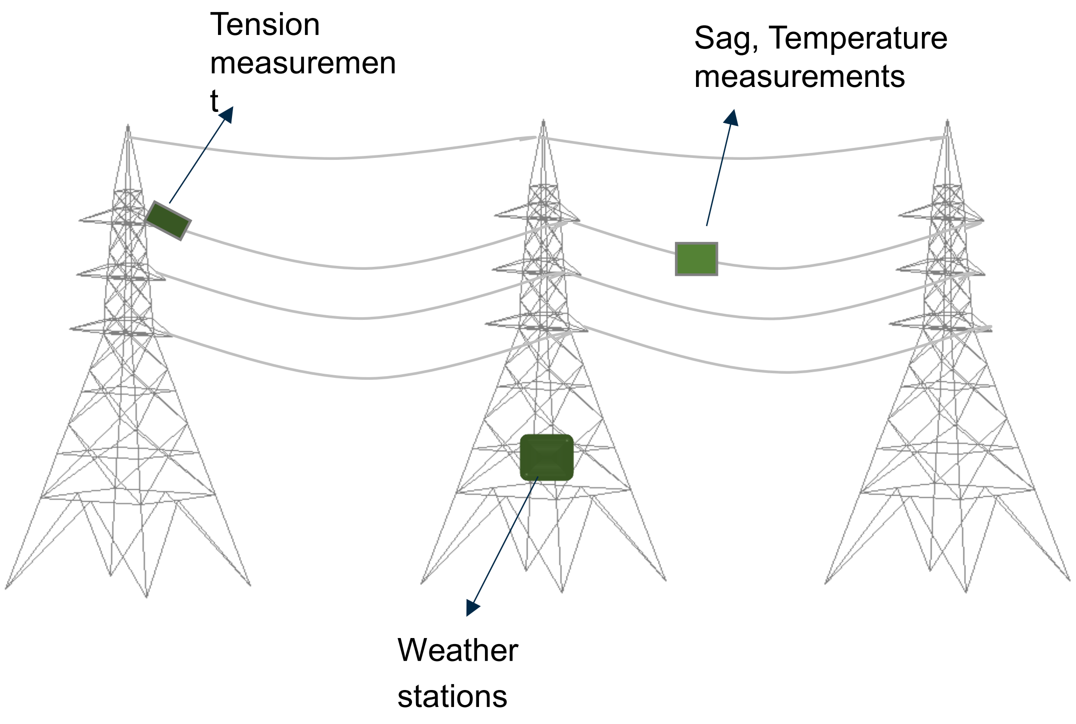
Dynamic Line Rating (DLR) Technologies…

Basic DLR System

- **Sensors –** Locate on or near T/L. Monitors various parameters and communicates to the DLR system.
- **Substation Data collectors –** The end substations collects the data communicated by the sensors and send the central location.
- **Communication and data storage –** Secured wireless communication and data storage.
- **Data Analytics** to determine the Dynamic Ratings

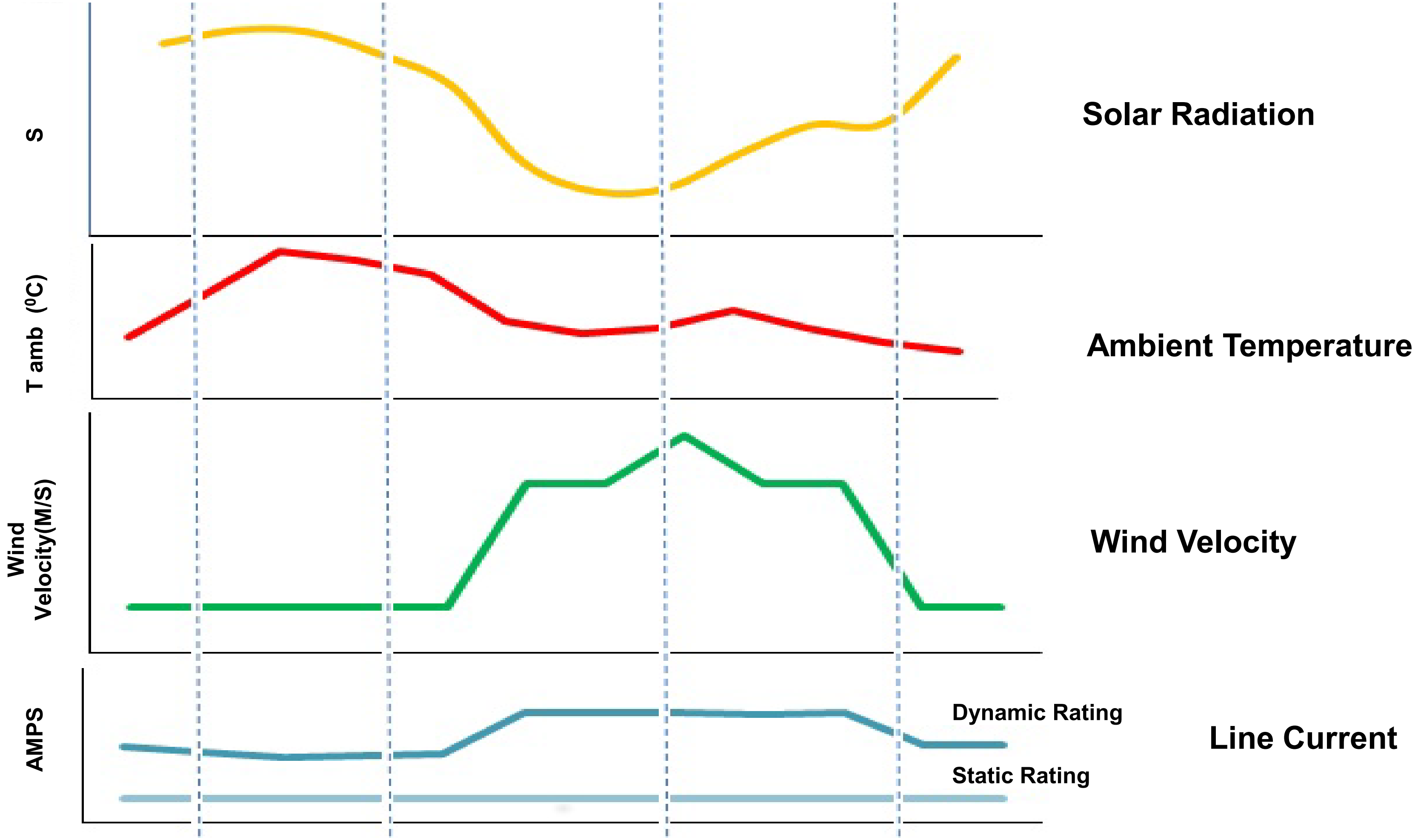
Monitoring Methods

- **Weather Monitoring –** Monitors ambient weather conditions through weather stations installed near transmission towers and conductor Temperature is estimated.
- **Line Temperature Monitoring –** Direct monitoring of conductor temperature through point sensors. Monitor conditions at the place of installation only.
- **Line Sag Monitoring –** Monitors the sag in fixed spans by through vibration sensors or through other devices measuring ground clearances. Temperature is estimated form these measurements.
- **Line Tension Monitoring –** Monitors the tension of the line though load cells. Sag and Conductor temperature is estimated from the data.



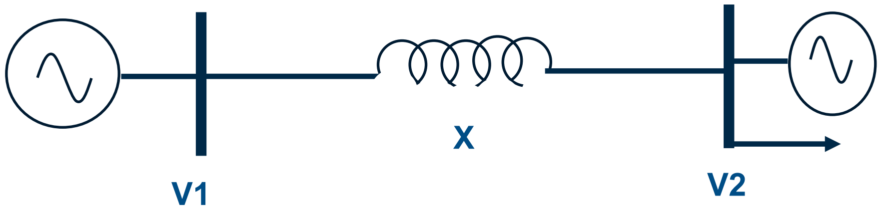
- DLR system utilizes the weather monitoring data and direct monitoring data provided by sensors to estimate the Real Time Ampacity of the Transmission lines.

Dynamic Line Rating (DLR) Technologies…



Power Flow Controllers

Power Equation -Simplified



$$P = \frac{V1V2\ Sin\delta}{X}$$

Where,

P	**=**	**Active power transmitted**
V1	**=**	**sending end voltage**
V2	**=**	**Receiving end voltage**
X	**=**	**Reactance of the interconnection**
δ	**=**	**Angle between V1 and V2**

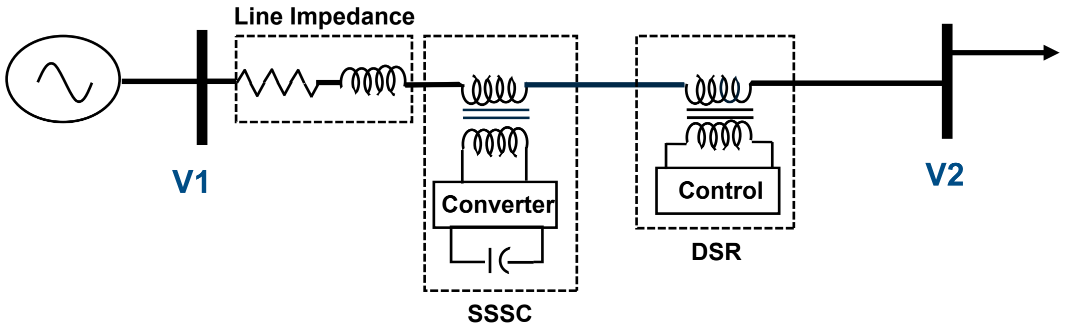
- Active power transmitted in a line can be controlled by the parameters mentioned in the equation.
- **Series capacitors -** improve power carrying capacity of lines. (series capacitor reduces the overall reactance of the line)
- Traditional devices like **phase shifting transformers** improves the power carrying capacity by controlling the **Angle** $\boldsymbol{\delta}$ between the sending end voltage and receiving end voltage.
- **Imposes challenges** in terms of scalability, sizing, deployment and operational issues. Design to specific locations and space requirement are other challenges.
- FACT devices (TCSC, UPFC etc..,) can significantly improve the transfer capacity and the utilization of power system. However, the practical implementation is limited due to high cost, customised design etc..,

- Advanced **Distributed FACT device** technologies can overcome the challenges/limitations imposed by the traditional devices in terms of scalability, compactness, ease of installation & operation.

Power Flow Controllers….

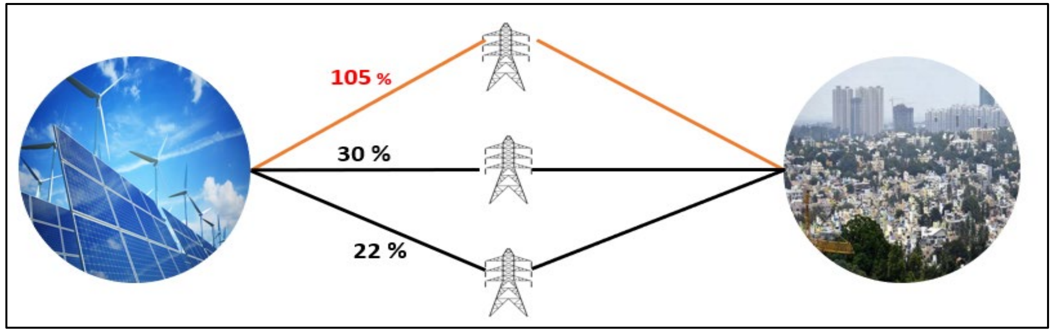
Distributed FACT devices (D-FACTS)

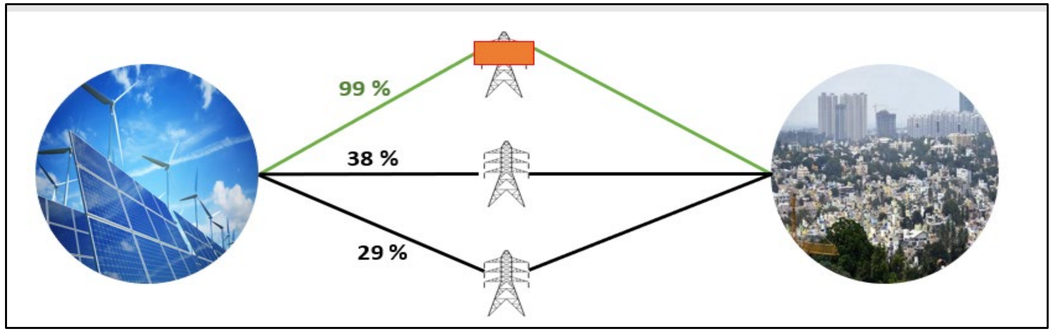
- D-FACT Devices – Working principle of
  - Static Synchronous Series compensator (SSSC) – Control the power flow by varying line impedance.
  - Distributed Series Reactor (DSR) – Injects reactance in a line, thus pushes power away from overloaded line



Distributed Series Reactor (DSR) devices

- Devices are modular and installed by clipping the devices on each phase of the conductors.
- Injects series reactance in a line and pushes power away from the overloaded line to other parallel paths.
- Adjust the line reactance in real time to change the power flows in network.
- Number of devices per phase is determined by the amount of compensation required as each device injects fixed amount of reactance.





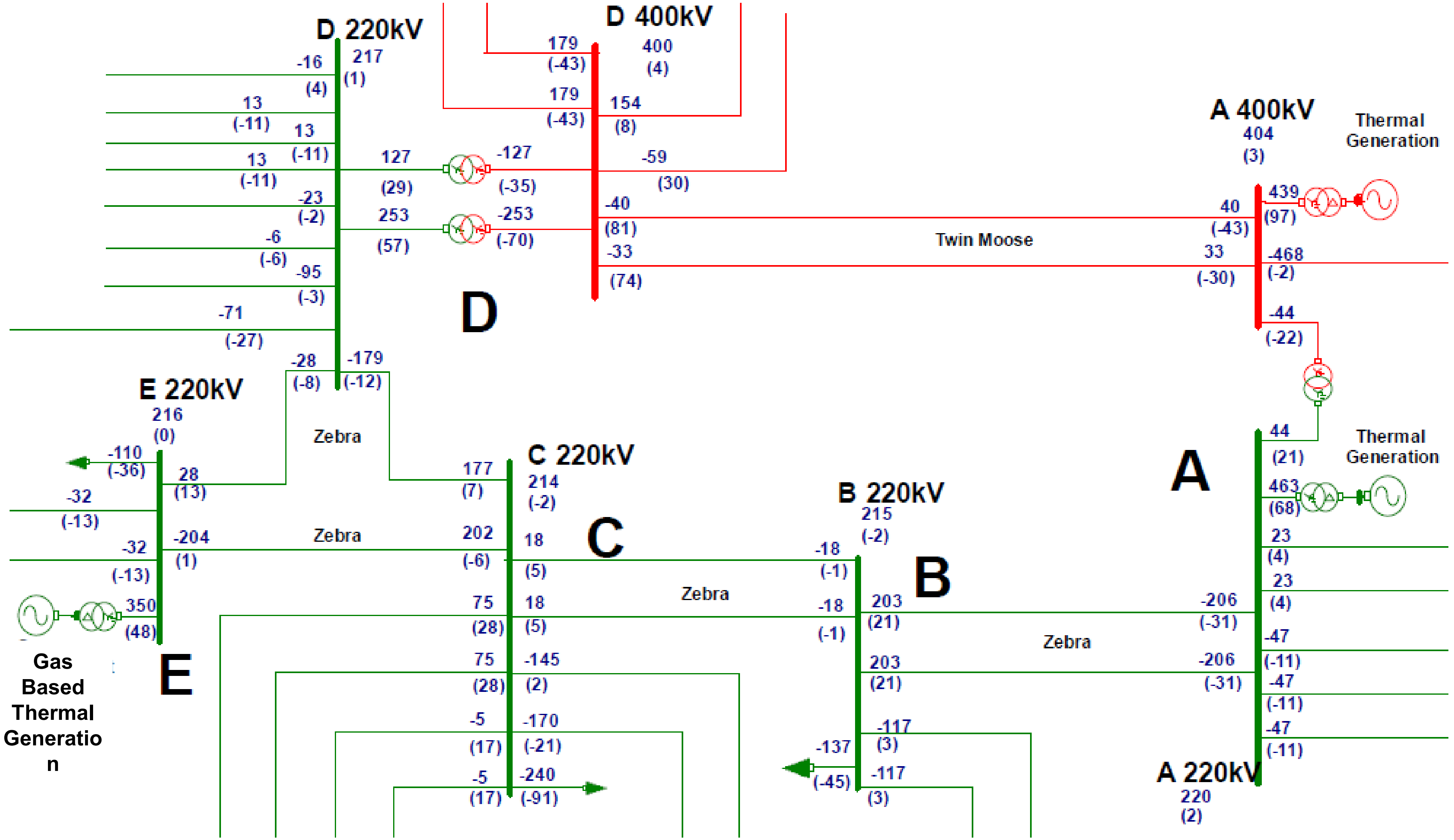
Integration of Technologies

Integration of Technologies (DLR + PFC)

- The approach of **Integrating the available advanced technologies** would enable larger utilization of exiting assets and available capacities.
- Advanced DLR technologies, through data analytics are capable to forecast the transmission line capacity apart from providing the dynamic line rating.
- The power flows can be controlled & routed to the parallel networks with spare capacity, where the real time/forecasted spare capacity data is provided by the DLR technologies.
- These technologies are **not substitute of grid development, but a complementary method** to better exploit existing transmission capacity.
- These technologies can be implemented to **harness the hidden capacities**, however critically overloaded lines should be dealt with **uprating methods i.e., either by increasing thermal capacity of line or voltage upgradation**.
- The technologies **can be integrated as a solution for any grid upgradation** or **strengthening projects** to minimize the shutdowns.

Simulation Studies

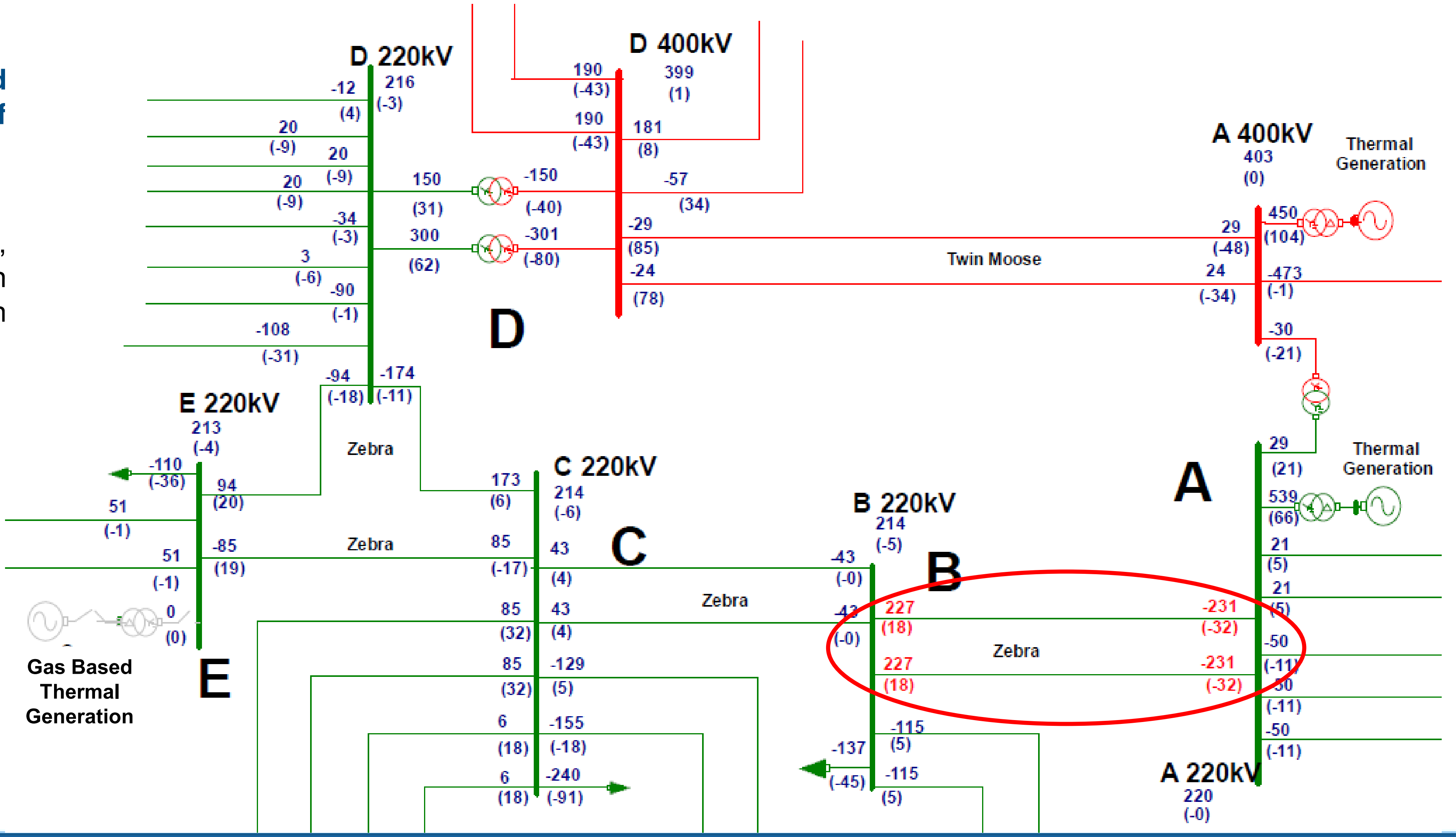
- A particular part of transmission system is considered for the study with the available data.
- Few scenarios are presented by testing power flow controller.
- Coal base thermal generation near **A**
- Gas base generation near **E**
- The generation is scheduled to meet the load, as per available data.
- Fuel Shortage – Backdown of Gas based thermal generation and rescheduling of available generation.
- **Base Case:**
  - Normal loading and generation scheduled as per the demand.



Simulation Studies

Case 1: Shut Down of Gas Based Generation and rescheduling of available generation in the network

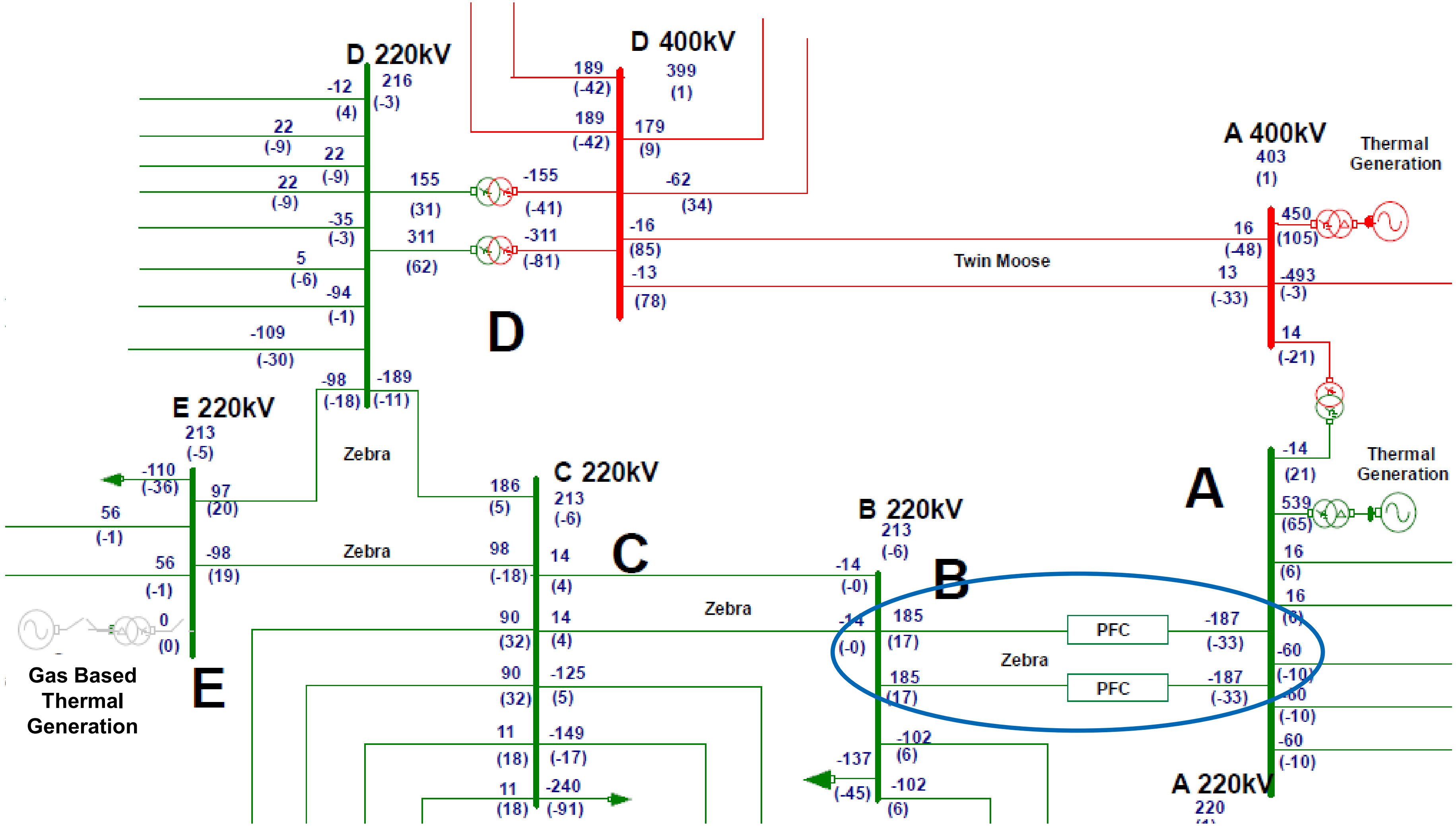
- Due to reschedule of generation, increase in thermal generation in area A, the 220kV D/C line between S/S A & B is overloaded.



Simulation Studies

Case 2: Shut Down of Gas Based Generation and rescheduling of available generation in the network – Application of Power Flow Controller

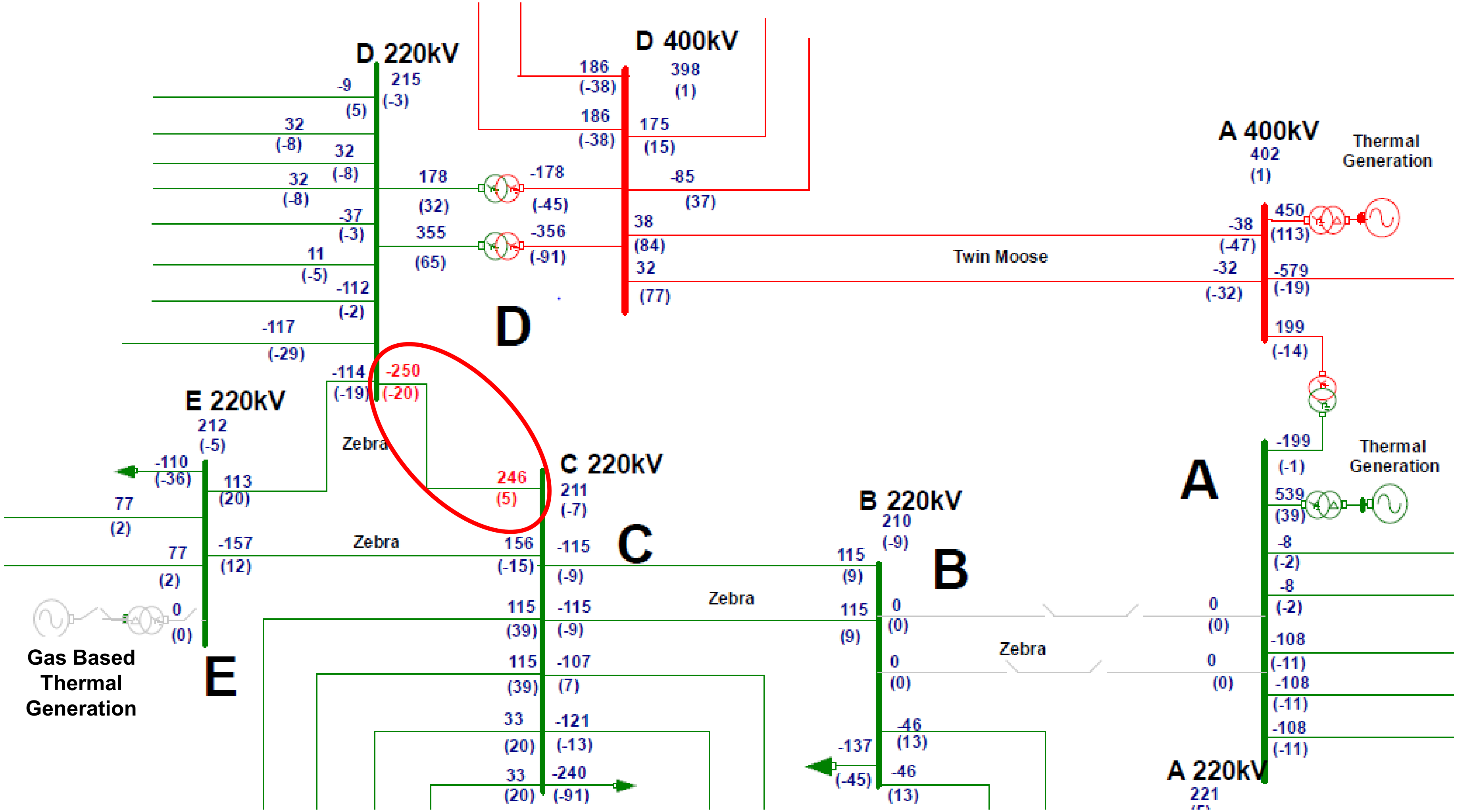
- The Power flow controller is inserted in the line so as to inject the series reactance.
- Reactance is varied to reduce the overload.
- The voltages are well within the standard limits and loading of other lines are normal.



Simulation Studies

Case 3: Shut Down of Gas Based Generation and rescheduling of available generation in the network – Requirement of System Upgrade

- Increasing Demand and Generation
- To meet the future demand the system may need to be upgraded.
- To upgrade the system the line between S/S A and B needs to be taken shutdown.
- Due to the shut down the 220kV line between S/S D and C is overloaded



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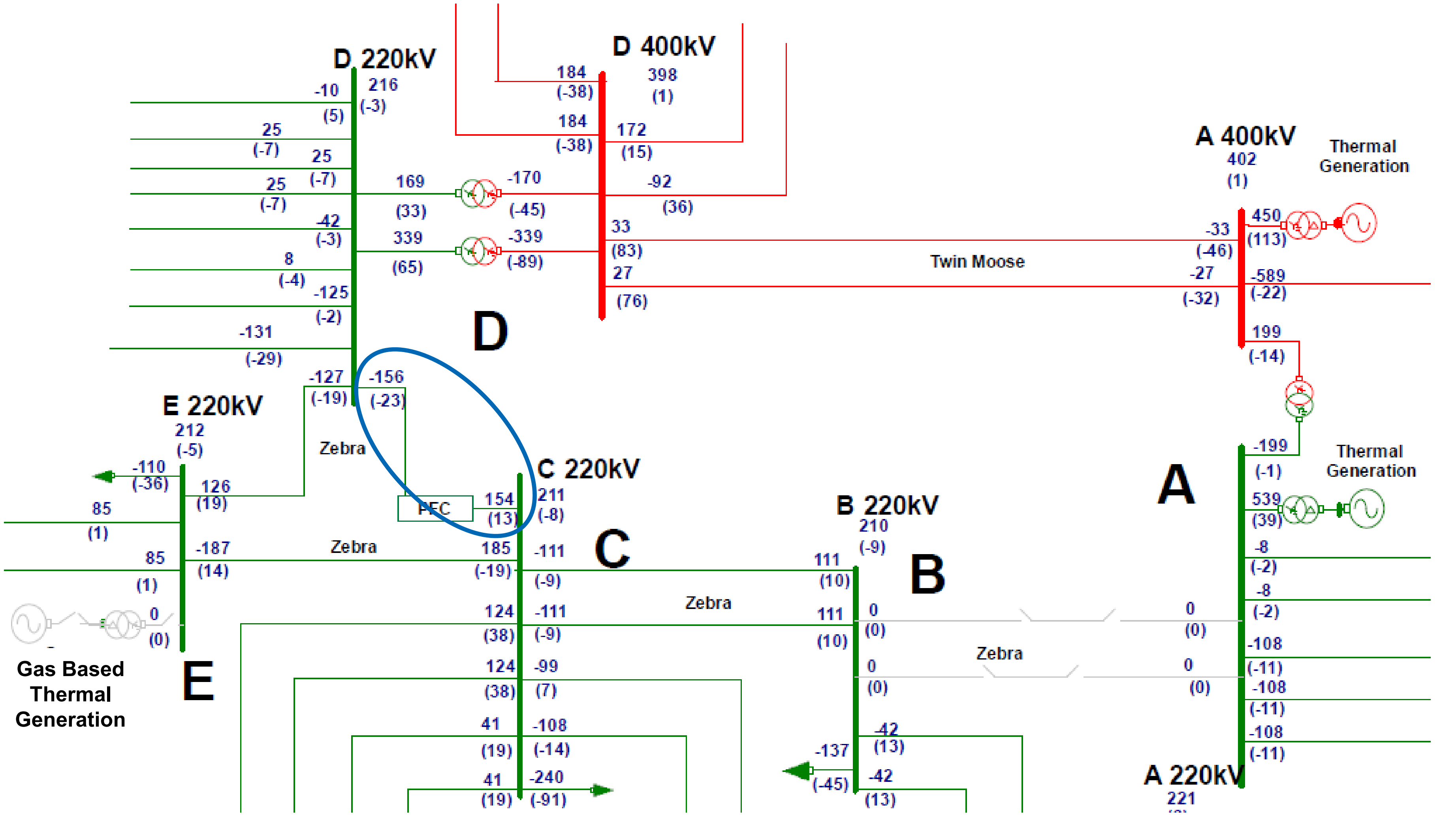
Simulation Studies

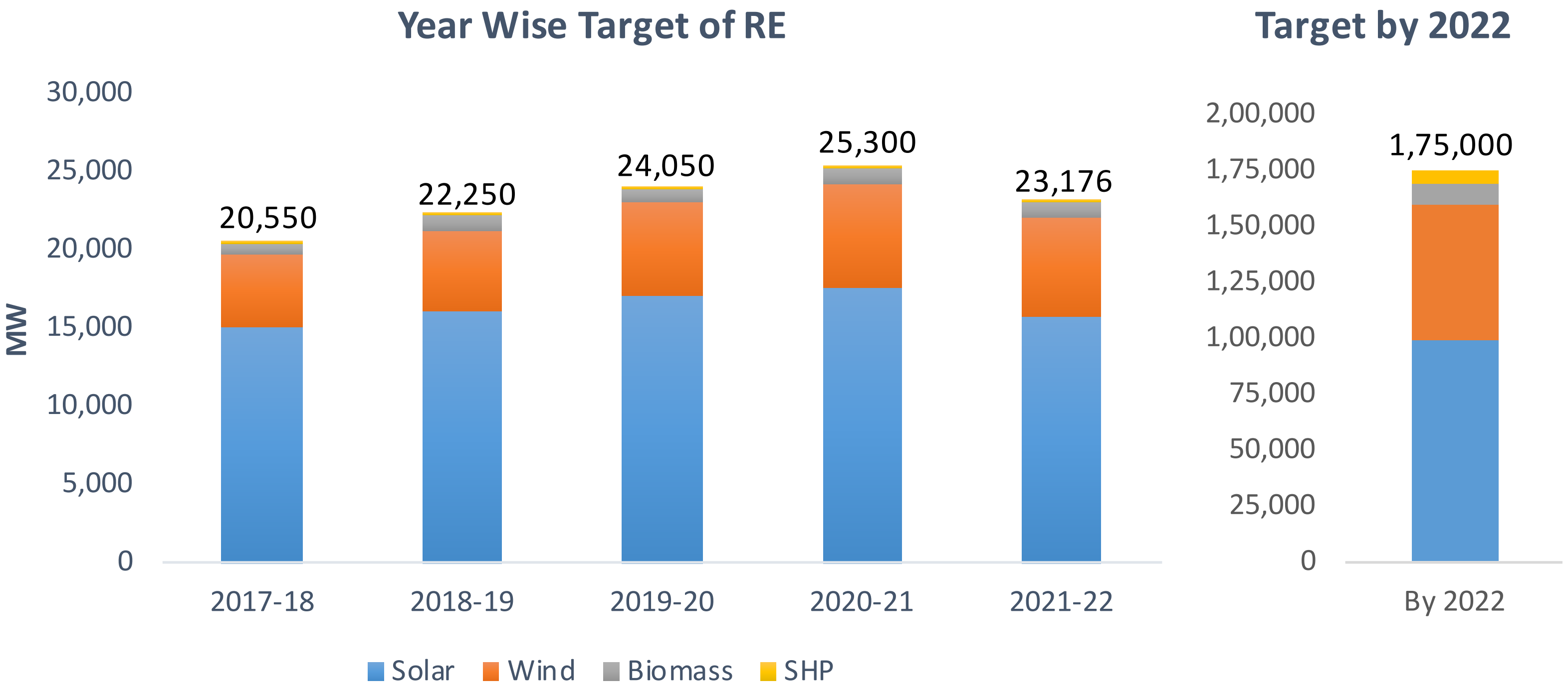
Case 4: Shut Down of Gas Based Generation and rescheduling of available generation in the network – Requirement of System Upgrade – Application of PFC

- The Power flow controller is inserted in the line so as to inject the series reactance.
- Reactance is varied to reduce the overload.
- The voltages are well within the standard limits and loading of other lines are normal.



Conclusion

- Emerging need for
  - **rethinking, in designing/planning the system economically.**
  - To **adopt advanced technologies** to enhance flexibility of grid.
  - Enhance the capacity through **uprate/upgrade with the support of technologies** along with strengthening of grid (network additions)



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