ROTATING ELECTRICAL MACHINES A1

GENERATION MIX OF THE FUTURE PS1

10430_2022

Opportunities in India for Peak Load Stations with Nation's commitment of massive penetration of Renewables in the Generation Mix

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Motivation

- In Indian perspective, wherein off-peak to peak demand ratio varies from 0.6 to 0.8 on seasonal basis from winters to summers, peak load generating stations play significant role in grid management to fulfill peaking and ramping requirement. In the shifting paradigm of energy mixing with increasing Renewable Energy (RE) penetration these peaking stations particularly hydro are playing an important role in handling ramping and intermittency of RE. These peaking stations operate at a low PLF.
- Hydro generation in India is maximum during summer (with snowmelt) /Monsoon season and minimum during winter season. Accordingly, operational hours of Hydro generating stations vary from 24 hours in the Summer/Monsoon (June to August) to only 3 hours in the winters in consonance with the inflow. Annual PLF of Hydro stations varies from 30% to 35%. Seasonal force majeure events like high silt contents in the water also reduce operational hours of hydro stations.
- Gas-based generating stations in India bear with less operational hours due to inadequacy of domestic gas (gas availability is just 25% of the requirement for 80% PLF) and high prices of imported gas (RLNG) and Liquid fuel. The PLF of these stations has shrunk from 67% in 2009-10 to around 25% in 2020-21 with almost 50% of stranded gas based installed capacity.
- Indian grid management faces challenges of wide variance in voltage profile at major 765kV and 400 kV nodes with around 5 to 10% variation on diurnal basis. Parallel AC transmission lines switching to the tune of 100 to 150 is being carried out even after exhausting all available static and dynamic reactive compensation to maintain grid voltage profile particularly during the winter season. After high level of RE-penetration, voltage variation at RE-connected nodes is expected throughout the year resulting in requirement of frequent switching operation of transmission elements that reduces the grid reliability apart from being detrimental to switching equipment's life.
- In order to achieve Government of India's ambitious target of 500 GW RE penetration by 2030, dynamic MVAr support and rotational inertia are of utmost importance (apart from ramping and peaking support) for reliable and resilient grid operation. Inertia and dynamic MVAr requirements of grid may be fulfilled by running peak load generating stations (with less no. of operational hours) in synchronous condenser mode of operation during non-generating hours.

Peak Load Generators Operation

- The peak load generators like hydro and gas are heavily dependent upon water and gas availability. In winter season the snow fed hydro stations are having very less water so the plants are being operated only during morning and evening to meet the peak demand and ramping requirements. All India hydro generation of sample days in lean hydro season is shown below.

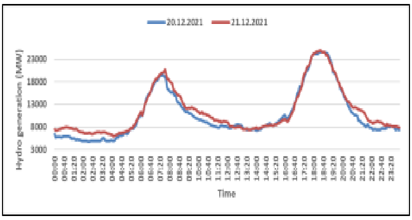

Figure I: All India Hydro generation of sample days

- It can be seen from Fig I that in lean hydro season maximum all India hydro generation goes up to 25000 MW but the minimum generation is around 5000-6000 MW. So most of the time many a hydro units are in idle mode due to constraint of water availability.

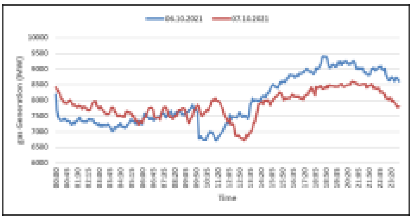

Figure II: All India gas generation of sample days

- In the above trend (Fig II) the all India gas generation of peak demand period is shown and it can be seen that out of 25 GW Gas installed capacity only 9 GW was in operation mainly due to non- availability of APM gas.
- Issues arising during generation hours of renewable energy and corresponding generation reduction in conventional generating stations: -

(1) Low Voltage issues in RE complex: In figure III it can be seen that when solar generation increases the 220kV voltage reduces.

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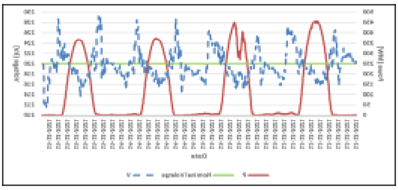

Figure III: Voltage vs Transformer loading at fatehgarh-2 pooling point

2) Reduction in grid inertia: In below figure it can be seen that when solar generation increases the grid inertia reduces.

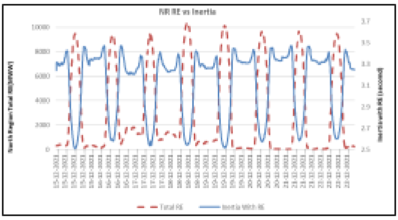

Figure IV: NR RE vs Inertia

- Above issues may be mitigated to some extent in case if peak load generating stations are used as Synchronous Condenser during non-generating hours.
- Synchronous Condenser: A synchronous condenser is a synchronous machine connected with the grid, being driven by it as a synchronous motor. Synchronous condenser injects reactive power in the grid when over excited and absorbs reactive power from the grid when under excited. Utilization of synchronous condenser in the grid operation is a proven technology with following advantages.
- Synchronous generators have inherent capability to operate in synchronous condenser mode of operation with some renovation and modernization (R&M). The Key requirements are means of accelerating the generator to synchronous speed and means of detaching the prime mover from the generator after synchronization. This feature will enable the synchronous generator to be driven by the electrical system (as motor) at synchronous speed.

(1) Improved System inertia and limiting RoCoF

(2) Dynamic MVAr response

(3) Increases Short Circuit Ratio (SCR) and hence provides short circuit strength to the grid.

(4) Fast response and LVRT capability.

(5) Increased short-term overload capability and hence improved transient and steady - state voltage support.

Synchronous condenser mode of Hydro Generating stations

- In India only around 10% of hydro stations have capability to run in synchronous condenser mode. Hydro generators can be operated in synchronous condenser mode by blocking the water in to the turbine and running the turbine-generator on air friction load. Suitable cooling arrangement is required to be done to limit turbine runner blades metal temperature rise. In case of water submersed turbines, compressed air system may be used to restrict the water level in the draft tube below the runner's bottom. Additionally, suitable modifications in the control system are required to regulate the response of the machine.
- In Northern region of India one of the hydro HEP was run in synchronous condenser(SC) mode during off peak hour, sample trend of performance in SC mode is shown below (Fig V),

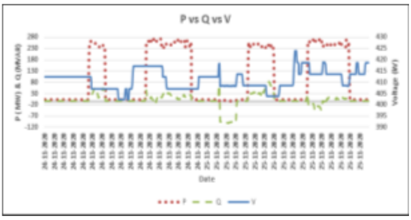

Figure V: P vs Q vs V of a hydro station running in operating in synchronous condenser mode

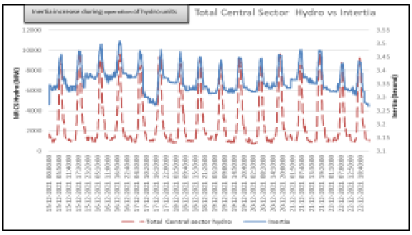

Figure VI: Central Sector Hydro vs Inertia

- From above trend (Fig VI), it may be seen that during diurnal peaking of hydro stations there is significant increase in inertia of grid, during non-operation of hydro units the inertia drops sharply. There is huge scope for inertia support if hydro generators would be operated in SC mode during non- generating hours.

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Synchronous condenser mode of Gas based Generating stations

- The gas based generating stations may be operated in synchronous condenser mode by shutting down the gas turbine and allowing the generator to be motored by the electrical system. Suitable clutch belt arrangement (disconnecting device) is required between the gas turbine and synchronous generator to isolate both, as and when required.
- Out of 25GW of gas installed capacity, peak gas generation has remained to the tune of only 9 to 10 GW during last 3 last years. Trend of all India gas generation for last three years is shown below:

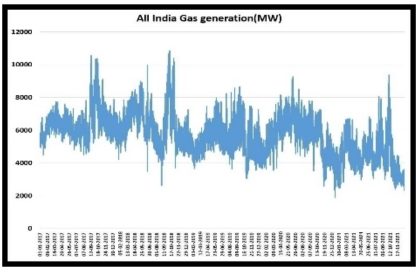

Figure VII: All India Gas Generation for Last 3 Year

- Thereby operation in SC mode would increase the utilization of gas based capacity for dynamic MVAR and Inertia support apart from being a source of additional revenues for gas based generating stations.

Conclusion

- Although synchronous condenser mode of operation has high operating cost due to high auxiliary loss, high O&M cost (due to mechanical wear), yet in a scenario of increasing renewable penetration, these may prove to be a robust solution for stable, reliable, and resilient grid operation.
- Policy and regulatory level intervention is required for necessary renovation and modernization, augmentation of control systems. Market based incentive mechanism in the form reactive ancillary services is also required to motivate the stakeholders for capital investment.