Power System Operation and Control C2

System Control Room Preparedness: Today and in the Future PS1

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Reactive Power Management and Other Challenges with High Renewable Penetration: Case study of Indian grid

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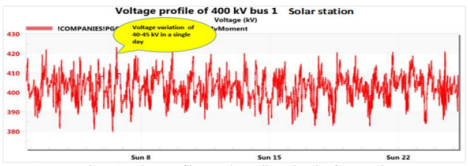
Motivation

- Voltage excursions are observed at RE pooling stations and near by stations throughout the day.
- To expedite ways to address reactive power management using available capabilities in inverter.
- To bring out the policy change for the better management of the high RE Integrated Grids.
- To emphasize the protection and other operational aspects experienced while integrating the RE in Indian Grid

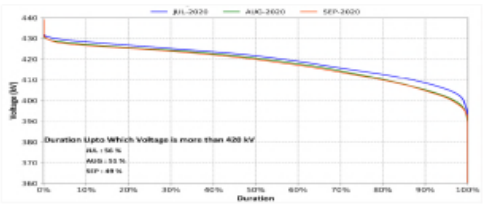
Method /Approach

- Analysis of reactive capability curves, Power Plant Controller capabilities .
- Discussion with OEM and developers to understand the feasibility on voltage control and night mode operation.
- Trial experiments were carried out for typical days. Subsequently two months trial operation was conducted to arrive at the findings

Background



- Voltage profile at a 400kV solar pooling substation for a month showing a variation of 40-45kV in a day.
- Conventional mitigation techniques adopted: switching bus reactors, switching line reactors, utilizing dynamic reactive capability in conventional plants, operating hydro plants in synchronous condenser mode, switching capacitor banks, and STATCOMs



- Voltage Duration curve of 2050 MW ultra-mega solar power park pooling station in SR

Objects of Investigation

- Exploring voltage control mode and Night Mode/SVG mode of inverters at a typical 150 MW Solar plant in Northern Region (NR) and 2050 MW Ultra Mega Solar Park in Southern Region (SR).
- Suggest the policy change required to utilise the existing reactive capabilities in RE plant.
- To Highlights protection and other operational aspects while integrating high RE Penetration

Discussion

- Typical inverter reactive power capability ranges from 33% to 95% of active power capacity
- Experiments in Northern Region and Southern Region on Night mode /SVG Mode showed that Night mode operation of PV inverters can be used to contain the over voltage conditions in grid.
- Penalties for reactive power drawl envisaged in the PPA(Power Purchase Agreement) of certain states is discouraging the RE generators to absorb reactive power even in case of high voltages.
- Reason for High voltages: lightly loaded lines during the lean generation period, underlying network (220kV and lower) without any loads, and capacitive injection from underground cables
- 'SYNCHRONIZE LOSS' was reported in one of the tripping that was caused by grid instability due to Voltage Phase Jump detection by Passive Anti-islanding Detection Relay (PDR). Changing the PDR setting from 5° to 20° with a 200ms detection time (i.e. reduction of sensitivity of inverter detecting abnormal condition) prevented the inverters from going into the standby mode.
- Operational experiences of two major solar eclipses December 26, 2019 and the another on June 21,2020 enhanced the confidence of system operators in the coordination of ramping up and down of generation and managing the load generation balance.

Modes of Inverter Operation

- Voltage control mode- taking local voltage or Point of Interconnection (POI) voltage as a reference voltage.
- Reactive Power or Q control mode- Inverter/PPC supplies/absorbs a fixed amount of reactive power.
- Power Factor (PF) control mode- inverter/PPC operates at a defined power factor.

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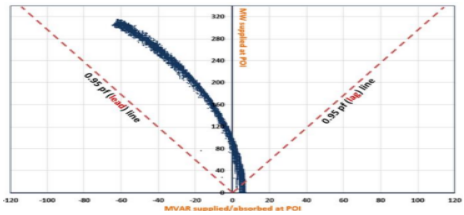
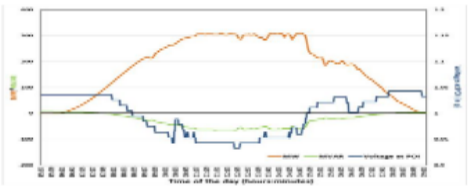
Operation in PF Control Mode

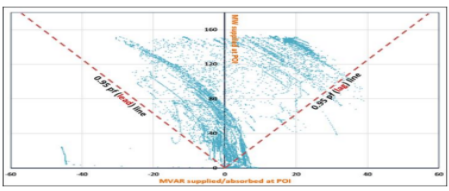


- PQ curve of a PV plant (operating in power factor mode) and its typical day's behavior

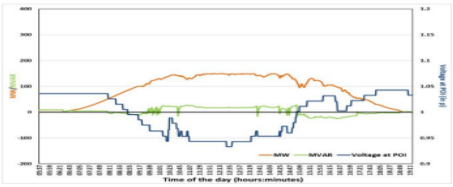


- Power factor control mode with fixed leading power factor causes more var absorption and low voltages at the time of high solar generation

Operation in Voltage Control Mode



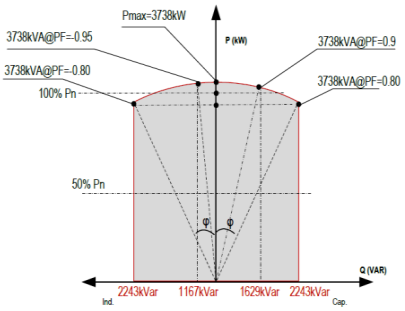
- PQ curve of a PV plant (operating in voltage control mode) and typical day's behavior .



- plant is injecting var to the POI to boost the voltage during the peak solar generation period in voltage control mode.
- The reactive support is seen to be limited to the value corresponding to 0.95 lag to 0.95 lead power factor

Reactive Power Capability Curve

- The reactive support at rated active power output is least and at other operating points, the reactive power capability exceeds the value at rated active power output.
- It is recommended to mandate the RE generator to operate in voltage control mode as per the capability curve which would help in maintaining the voltage profile.



- Some of the existing RE generators are yet to implement voltage control mode due to non availability of PPC.

Night Mode of operation in Inverters

- High voltages are being experienced during night hours at solar and nearby substations when there is no generation in solar plants.
- Most of the inverters are equipped with the capability to absorb reactive power using a feature known as Night mode.
- A typical inverter has a capability to provide reactive power of around 33% of active power capacity for absorption during night hours.
- recently commissioned inverters are having a reactive capacity as high as 95% of active power capacity.

Study Conducted in Northern Region

- ISTS Solar plant of 150 MW (comprised of 60 inverters).
- PPC was configured to make net reactive power import at line zero
- Reactive power generation was around 33% of installed capacity during the 'no generation' period and the active power consumed for the same came out to be around 3-4% of the installed capacity.
- Reactive power support cost appx ₹ 0.02/kvarh

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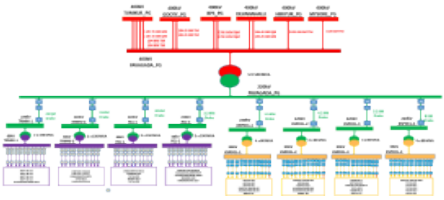
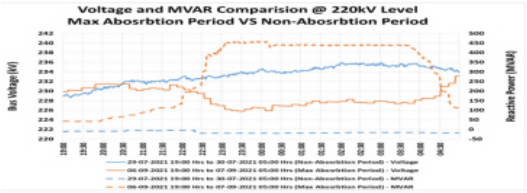
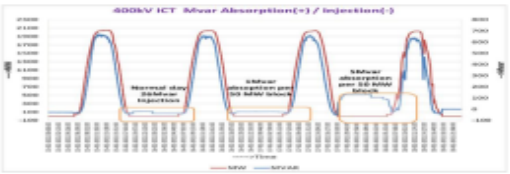




Typical Day Tests at 2050 MW Ultra-Mega Solar park in SR

- A capacity of 1575MW participated in the testing.
- 36 Mvar (1 Mvar absorption per 50MW block) on first day and 180 Mvar absorption (5 Mvar absorption per 50MW block) on next day

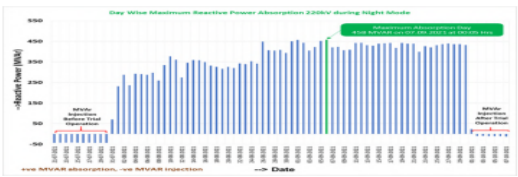


- Voltage dip of 3kV was observed for 128 Mvar support at grid side. No technical limitations were observed.
- The real power consumption during night hours increased by 0.26 MU for 12 hours

2 Months Night Mode Trial at 2050 MW Ultra-Mega Solar Park in SR

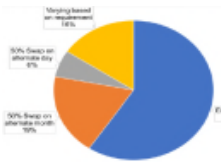
- Trial period- August 2021 to September 2021.

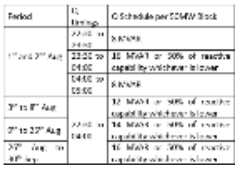
- Summary of night mode feature along with its controllability for the 2050 MW ultra-mega solar park in the southern region
- 9 developers participated in trial operation. Incremental auxiliary consumption was treated as a regional loss



- Maximum reactive power absorption of 458Mvar was observed on 07.09.2021 00:05 hrs.

- Appx 2.5% of active power consumption is required for supporting 100Mvar of reactive` power absorption.
- No technical constraints were observed except false alarms, planned/ forced feeder shut down, communication issues in string inverters, delay in getting OEM consent.





- Pattern adapted by developers in loading inverter to meet the desired reactive power schedule

Regulatory Changes Required

- Voltage control ancillary services or any other commercial incentive mechanism to be introduced. Devised commercial mechanism may cover the incremental auxiliary consumption as well as increased O&M expenses.
- SVG (Static VAR Generator)/Night mode capability to be mandated by regulatory mechanism
- Voltage mode to be explicitly mentioned in grid code to fully utilize the reactive capability which is currently limited to 0.95 PF.
- Penalty clause imposed by certain states to inject VAR to the grid may be reconsidered by the respective states.

Conclusion:

- Voltage control mode as per the capability curve is the preferred mode
- The case studies have also indicated that sufficient reactive capability is available at PV Inverters to support during non-generation hours using the night mode facility.
- Suitable regulatory intervention such as the introduction of voltage control ancillary services or any other commercial incentive mechanism would facilitate the utilization of the reactive capabilities inherently available in the inverter.
- Paper also touched upon the protection-related issues with RE station and solar eclipse