Enhancing the Voltage Profile in Distribution System with 40GW of Solar PV rooftop in Indian grid by 2022: A review

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Agenda

- Introduction
- Objective
- Distribution system
- Methods for Enhance the voltage profile
- Conclusion

Introduction

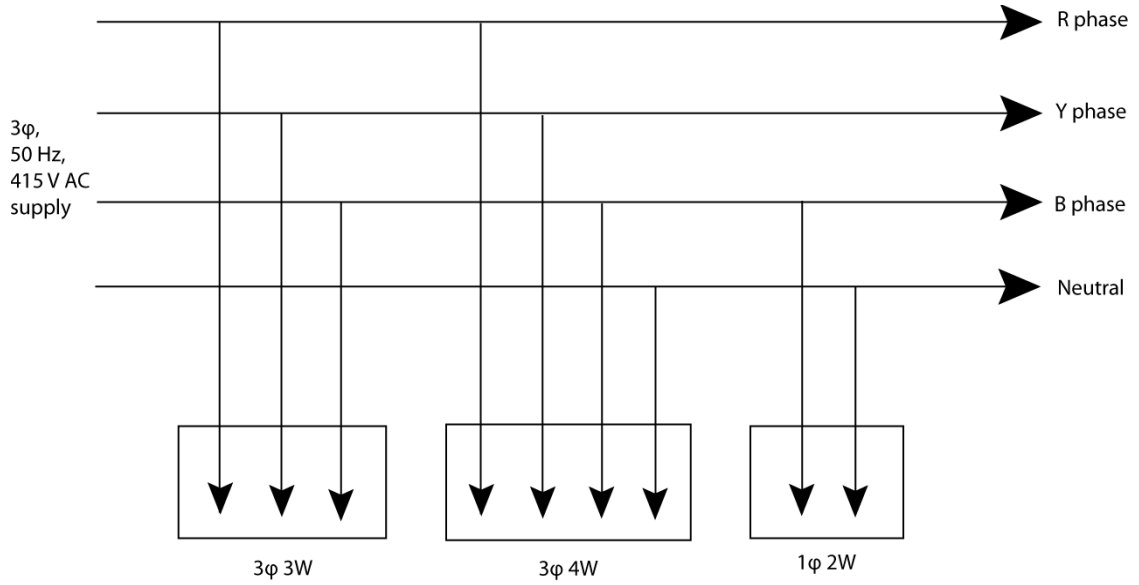
- Injection/drawl of reactive power from distribution grid resulting in poor voltage profile
- Intermittent characteristics of solar affects the distribution
- Distributed generation improves the voltage profile and power loss
- Govt. of India planning to increase solar rooftop power to 40 GW by 2022
- It is essential to maintain the voltage profile with higher solar integration in distribution grid

Objective

Improve the voltage profile in distribution system with higher penetration of solar rooftop power.

Distribution system

- Comprises residential, commercial and industrial system



3ϕ 4W distribution system

Distribution system cont…

- Distribution system for low voltage are
  - 3ϕ 4W
  - 3ϕ3W
  - 1ϕ 2W
- Residential systems are connected in 3ϕ 4W or 1ϕ 2W system
- Low voltage commercial and industrial systems are connected in 3ϕ 3W or 3ϕ 4W system

Distribution system cont…

- In many locations small scale commercial and industrial system located vicinity to residential system.
- These locations were sharing the same distribution feeders with residential systems.
- Most of the small scale commercial and industrial system loads are 3ϕ and connected in 3ϕ 4W system while in residential system most of the loads are 1ϕ connected in 1ϕ 2W.

Distribution system cont…

- Maintaining the Power Factor (PF) is mandatory for commercial and industrial system while it is not mandatory for residential system.
- The drawl of reactive power by the loads in residential system is not significant in non peak hours but it is significant during peak hours.

India's 175 GW Renewable Energy by 2022

- Solar – 100 GW (40 GW from solar rooftop)
- Wind – 60 GW
- Small hydro – 5 GW
- Bio energy – 10 GW

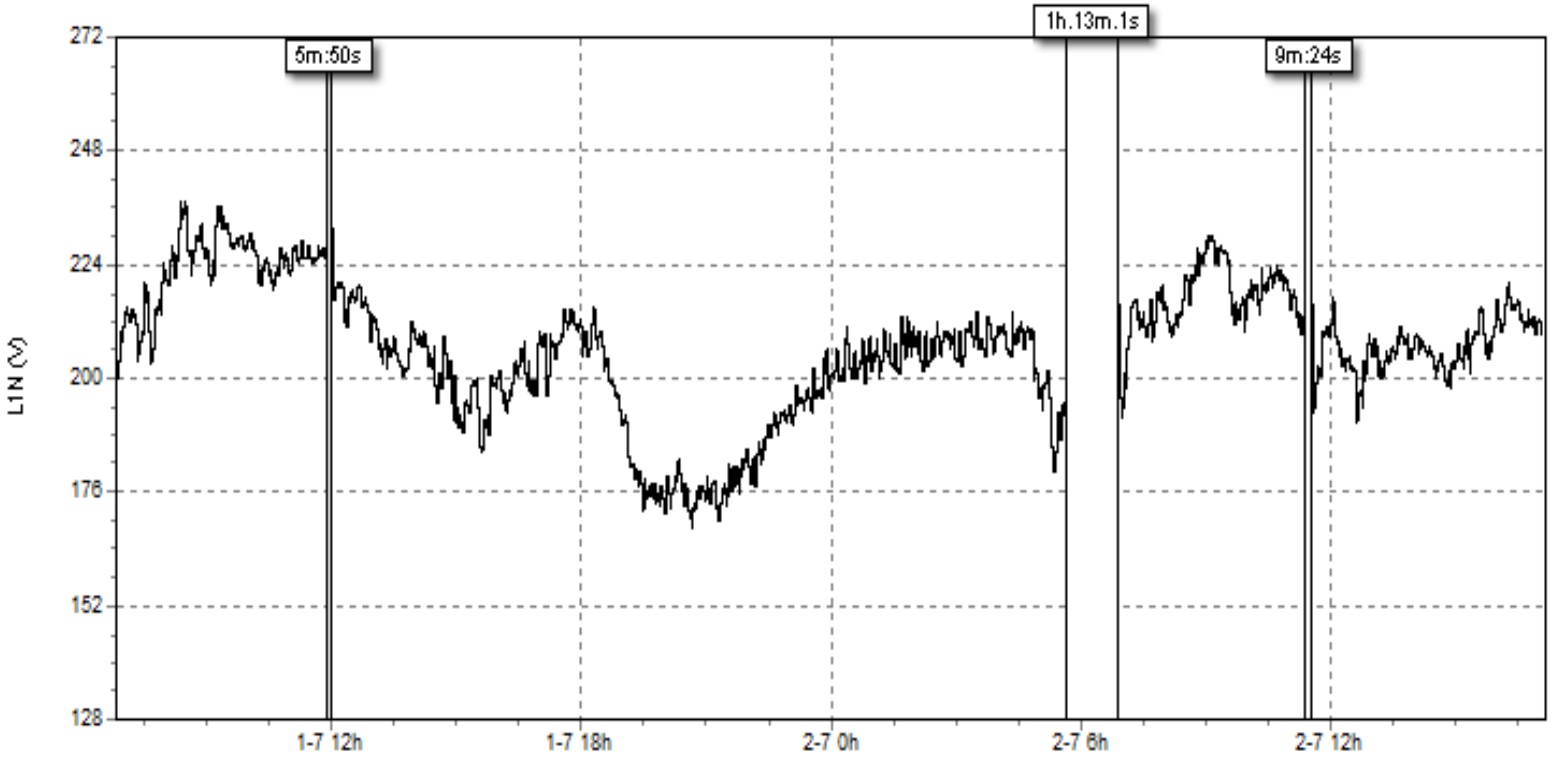
Poor voltage profile in distribution system

Poor voltage profile in distribution system due to various reason like

- Drawl of more reactive power
- Unbalanced loading amongst the phases
- Overloading
- Under sized cables/conductors
- Improper power factor compensation

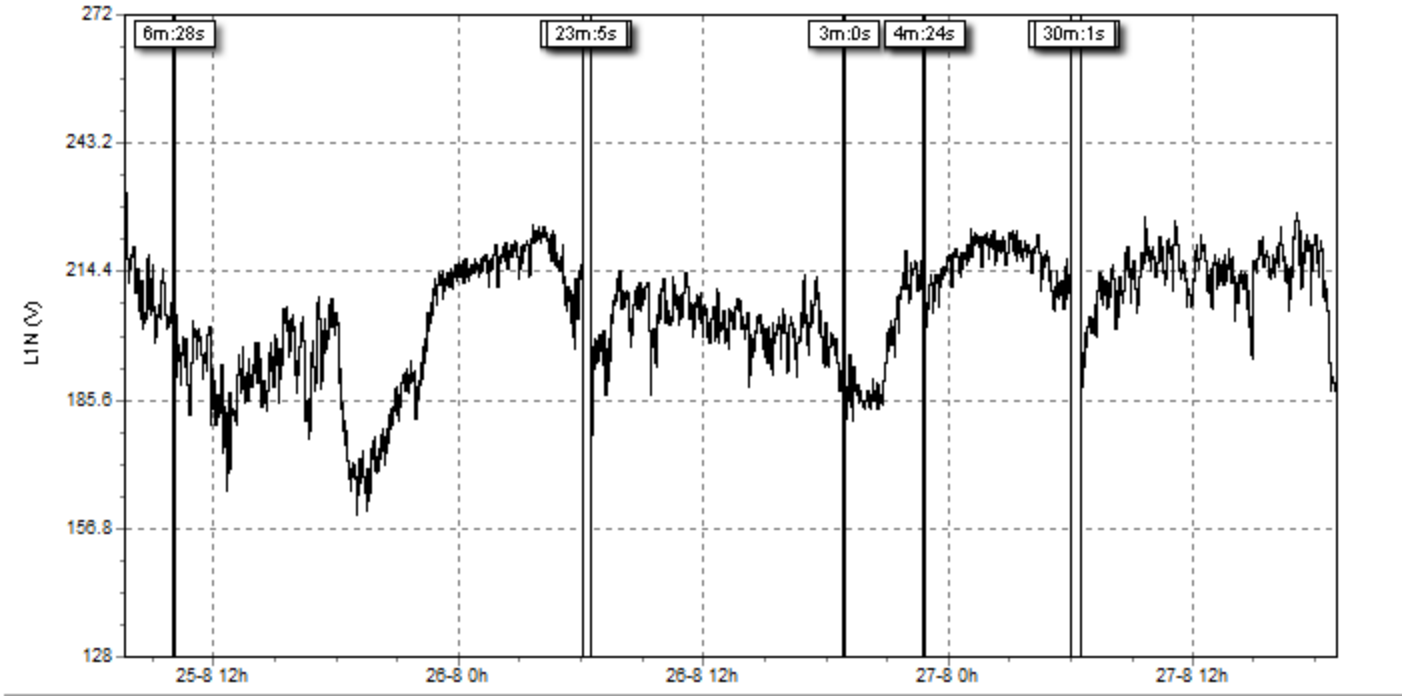
Voltage profile in Distribution system

Voltage profile between 01/07/2017 06:55 to 02/07/2017 17:06 hours



Voltage profile in Distribution system cont..

Voltage profile between 25/08/2017 07:47 to 27/08/2017 18:56 hours



Methods for Enhancing the voltage profile

Various methods to improve the voltage profile in distribution system

- Application of capacitor bank
- Load balancing amongst the phases
- Re-conditioning of distribution lines
- Bifurcation of distribution lines
- Distribution energy storage
- Re-configuration
- FACTs devices

Application of capacitor banks

- Reactive power is directly proportional to voltage and drawl of more reactive power by RL loads impacts the voltage profile
- By supplying the reactive power locally into the system can enhance the voltage profile
- This can be achieved by installing the capacitor banks locally into the system by counteract the reactive power demand by the load.

Application of capacitor banks cont..

- The reactive power compensation by capacitor banks are fixed compensation and variable compensation by Automatic Power Factor Correction (APFC)
- Application of capacitor bank is the economic solution for voltage profile enhancement in distribution system
- The overall cost depends on type of compensation fixed or variable

Application of capacitor banks cont..

- Economics involved in fixed compensation is less compare to the same rating of the variable compensation
- Cost of variable compensation is 15 – 25% higher than fixed compensation for the same rating
- Solar inverters can able to operate 0.8 lag PF to 0.8 lead PF

Application of capacitor banks cont..

- The various operation of distribution system with integration of SPV and APFC are

Condition	Operation	Reactive power support	Voltage profile
1	Only Transformer	Only grid through transformer	Poor
2	Transformer and SPV	Transformer and SPV	Improved voltage profile
3	Transformer, SPV and APFC	Transformer, SPV and APFC	Better voltage profile

- Condition 1: transformer alone

supplying both real and reactive power, losses increased and voltage profile is decreased

Application of capacitor banks cont..

- Condition 2: Transformer & SPV

➢ Adding SPV in the distribution system reduce the power loss and improve the voltage profile by locally supplying real and reactive power

➢ During night time, SPV cannot supply both real & reactive power and this is becomes like only transformer (condition 1) powering the load (both real and reactive power)

Application of capacitor banks cont..

- Condition 3: Transformer, SPV & APFC

➢ Adding APFC along with SPV and grid supply improves the voltage profile

➢ During night time, APFC responsible for supplying the localized reactive power and transformer supplying the real power

➢ Size and location of the APFC & SPV can be obtained from load flow studies

Load balancing amongst three phases

- This problem majorly exists where the combination of residential, commercial and industrial system sharing same distribution feeders
- Unbalance is mainly due to residential system because of single phase
- However these loads are not balanced amongst each other phases

Load balancing amongst three phases cont..

- Higher voltage drop in highly loaded phase, lower voltage drop in lightly loaded phase
- 3ϕ loads connected in same feeders receives the unbalanced voltage magnitude
- At many locations utility company having the restrictions to providing the 3ϕ supply to agricultural
- When utility is providing 2ϕ supply, 3ϕ 4W distribution becomes to 2ϕ 3W system
- A common feeder is used for residential, commercial and agriculture

Load balancing amongst three phases cont..

- 1ϕ loads are connected in any of two phase R & Y or R & B or Y & B
- This cause the higher voltage drop in loaded phase
- A 3ϕ SPV connected parallel with the distribution grid cannot deliver the power in the absent phase
- It reduces the installed capacity of the SPV to two by third (2/3) of its rating

Load balancing amongst three phases cont..

- So for this condition, 3ϕ SPV converted into three 1ϕ SPV
- The 1ϕ SPV can connect that particular two (available) phase only and absent phase in this distribution grid becomes unused

Load balancing amongst three phases cont..

- Unbalance can be reduced by distribution company by
  - continuously providing the 3ϕ power supply
  - balancing the single phase loads amongst each other
  - when a significant single phase loads going to add into the distribution system a load flow assessment needs to be carry out to find the feeder loadings
- This method is economically feasible and able to accomplish in short duration

Re-conditioning of distribution lines

- In this method higher impedance conductors are replaced with lower impedance conductor
- This method effectively increases the voltage profile of the system by reducing voltage drop while reduction of line impedance will have an impact in short circuit current
- Replacement of entire distribution lines to new lines need higher capital investment and time consuming

Re-conditioning of distribution lines cont..

- Cost of this method can be reduced by changing only the specific higher conductor instead of entire distribution lines
- A separate study (load flow assessment and short circuit study) should be carried out in order to find these lines in the distribution system

Bifurcation of distribution lines

- In this method existing single feeder or line is split into two or more feeders
- Load assessment should be carried out to re-allocate the loads into new lines
- This method requires construction of new lines/infrastructure
- Economics and time frame for this method is high due construction of new feeders
- This method is recommended for permanent solution to voltage profile problem

Distribution energy storage

- Energy Storage System (ESS) utilize the excess amount of RE power (solar) when it is highly available time to non-available or less available time by storing the energy
- Various energy storage systems are exits like flywheel energy storage, Battery Energy Storage System (BESS), super capacitors, Super Magnetic Energy Storage (SMES) etc

Distribution energy storage cont..

- For selection of which storage device is based on specific application, rating and size, speed and economics involved
- The cost of these storage system are quite different from each other
- Flywheel energy storage and BESS are economically lower compare to super capacitors and SMES
- BESS will give the ability to meet the challenges of Time Shift (TS) to meet the loads, Grid regulation (voltage & frequency) and Peak demand saving

Re-configuration of distribution lines

- Network Reconfiguration is operating switches to alternate the circuit topological structure by changing the status of sectionalizing switch position to open or close
- This method is modifying radial feeders from time to time by changing the switch position to open or close
- From this method, load is transferring from heavily loaded circuit to lightly loaded circuit

Re-configuration of distribution lines cont..

- This method improves the voltage profile by reducing the overload and reduces the losses
- This method has complex Infrastructure and higher capital

Deployment of FACTs devices

- FACTs devices are capable for supplying or absorbing the reactive power in dynamically varying condition
- Voltage profile in the system is maintained by supplying or absorbing the reactive power by FACTs devices
- Load flow study needs to be carryout in order to know the requirements of FACTs device like type, location and rating
- Economics involved in this method is high

Conclusion

- Maintaining the voltage profile in the distribution system is a major concern for distribution company
- It is essential to maintain the voltage profile in the distribution system with integration of SPV
- The technical and economics involved in various methods are discussed to/for improve the voltage profile with integration of SPV
- Adopting these kind of approaches will help us to achieve the 40 GW of solar rooftop power in Indian power system within the year of 2022.

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Any Queries?

Thank You All

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