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Active Distribution Systems and
Distributed Energy Resources

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Analytic and Heuristic Optimal Reactive Power Management with Shunt Capacitors in Distribution System of Southern Regional Grid of India

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Motivation

- Due to increased demand, the remote location of generators far from load centres, and the presence of many long radial lines, distribution networks face low voltage issues.
- With the rise in distributed renewable energy resources, the short circuit strength of buses is reduced, and this further causes higher variation in voltage profile over a day.
- In order to improve the voltage profile and voltage stability in the distribution network, reactive power support plays a key role.

Method/Approach

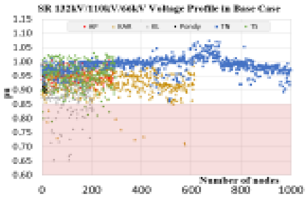
- In this paper, two methods are presented for optimal selection of size and effective location for placement of Shunt Capacitors in the distribution system of Southern Regional Grid of India to minimize the deviation of bus voltage in the distribution system during stressed system conditions.
- An analytic method based on pockets consisting of a group of connected nodes
- A heuristic method based on Particle Swarm Optimization (PSO) technique

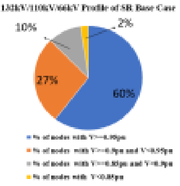
Background

- The Indian Electricity Grid Code (IEGC) mandates providing adequate reactive power compensation by respective State Transmission Utilities in the distribution system.
- Conventionally, low voltage buses are identified and capacitor banks will be added in lumped quantum in the distribution system.
- Problems with Selective deployment of capacitor banks:
  - o not economical
  - o causes local voltage issues at load centres
  - o generators which are not in the vicinity of load centres will go to absorption mode due to rise in voltage in adjacent nodes.
  - o low voltage nodes at load centres may still persist and it will further result in a greater number of capacitor banks requirement in distribution system.

System Considered for Study

- Base case was modelled for peak load where demand was high and voltage profile in downstream network (132kV/110kV/66kV) was considerably low.





Proposed Analytic Method

- PSSE, MATLAB, and Python Programming.
- Objective of this study is to improve voltage profile of pocket by adding capacitor banks.
- In each of the pockets, simultaneous optimal selection of capacity and location of capacitor banks are done.
- As we keep adding capacitor banks, size of the pocket reduces and eventually vanishes.
- Control area-wise quantum and location of capacitor bank requirement

Algorithm for Analytic Method

- Input bus and branch data of 132kV/110kV/66kV subsystem under study to MATLAB.
- In MATLAB, estimate pockets by identifying nodes with voltage less than 0.85pu/ 0.9pu .
- In PSSE, add 1 Mvar to the node with least voltage in each pockets and run power flow
- Load flow cases are carried out in PSSE
- Check whether voltage of all the nodes in each pockets are within 0.85pu/ 0.9pu?

A pocket is a set of connected node where in every node voltage is less than 0.85pu/ 0.9pu as the case may be.

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Proposed PSO Technique

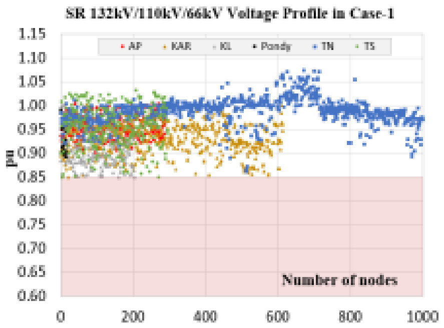
- Particle Swarm Optimization (PSO) is a population-based meta-heuristic optimization technique inspired by the social behavior of bird flocking
- PSSE and Python Programming.
- The objective function for PSO is to perform the least number of capacitor bank addition in the distribution system such that voltage in all the nodes is within the limits.
- Nodes with voltages lesser than 0.85/0.9pu (as the case may be) are identified as candidate buses.
- In PSO, low voltage buses were taken as variables, and capacitors were optimally added at each candidate bus.
- During each run, 5 candidate buses were selected and optimally capacitor banks were added with a maximum of 1Mvar up to a predefined number of iterations (depending on the tolerance limit provided).
- Once the value of capacitor bank to be added is found in PSO, then again new candidate buses are identified.
- This process will be continued until there are no more candidate buses in the distribution system considered under study

Simulation Study

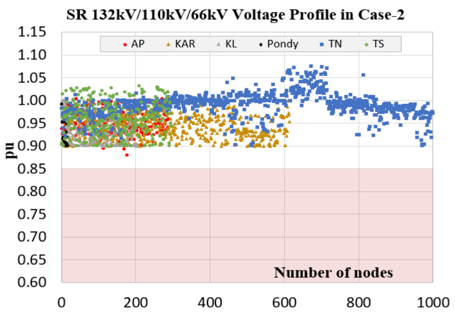
- Both the proposed techniques were studied for two cases.
- In case-1, the number of capacitor banks required to ensure voltage more than or equal to 0.85pu in 132kV/110kV/66kV system was considered.
- In case-2, the addition of capacitor banks to ensure 0.9pu and above in 132kV/110kV/66kV system was considered.
- Control area wise capacitor banks requirement in Mvar using Pocket method and PSO technique are arrived.

Simulation Results

- Voltage profile of 132kV/110kV/66kV systems of 6 control areas under case-1 after the deployment of shunt capacitors.



- Voltage profile of 132kV/110kV/66kV systems of 6 control areas under case-2 after the deployment of shunt capacitors



- SR 132kV/110kV/66kV Voltage Profile Comparisons

	Base Case	Case-1	Case-2
% of nodes with V>=0.95pu	60%	62%	65%
% of nodes with V>=0.9pu and V<0.95pu	27%	28%	35%
% of nodes with V>=0.85pu and V<0.9pu	10%	10%	0%
% of nodes with V<0.85pu	2%	0%	0%

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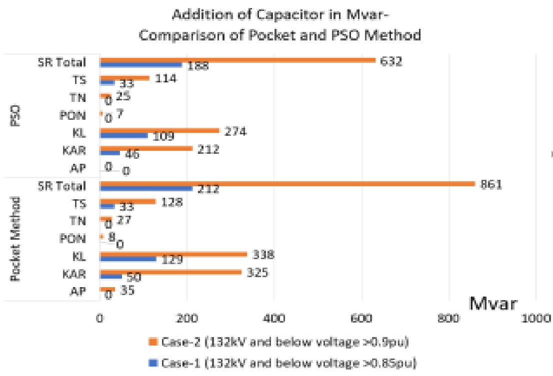
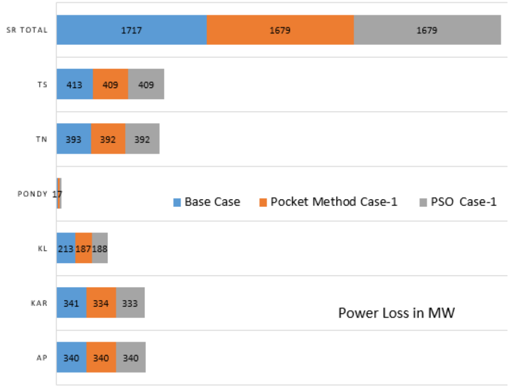
Simulation Results (Continued)

- Capacitor Requirement in Mvar comparison between Pocket method and PSO



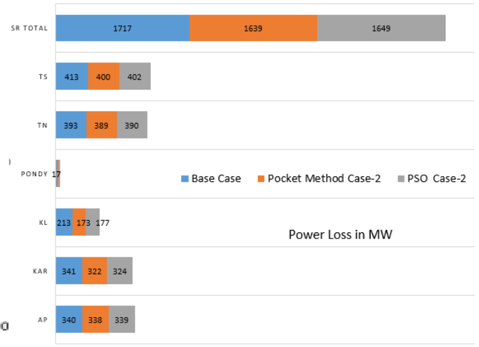
- In addition to the improvement in the voltage profile of the distribution system, another benefit from the capacitor bank deployment is the reduction of system losses.
- Control area-wise net Power Loss in MW in base case and case-1 using Pocket method and PSO.



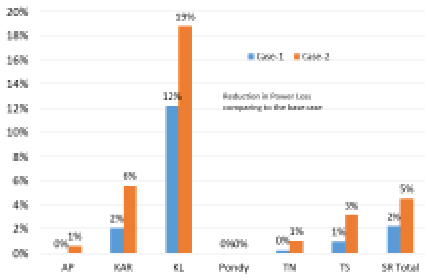
- Comparing to the base case, reduction in control area wise net power loss was observed during both the cases in both pocket method and PSO.

Simulation Results (Continued)

- Control area-wise net Power Loss in MW in base case and case-2 using Pocket method and PSO.



- Control area-wise percentage reduction in net power loss for case-1 and case-2.



Conclusion

- In this paper, two approaches were presented to optimize the location and capacity of capacitor banks to be deployed to mitigate low voltage issues.
- With both the proposed techniques, there was an improvement in the voltage profile and the values were found to be within the operating range.
- Both the techniques were economical comparing to the conventional lumped addition of capacitor banks in the system.
- PSO based approach provides better results than the pocket method.
- Reduction in capacitor bank requirement (Mvar) using PSO method compared to pocket method in case-1 is 11% and in case-2 is 27%