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Improving the Voltage Stability of Distribution Network Using Capacitor Banks and PV Arrays Based on OpenDSS

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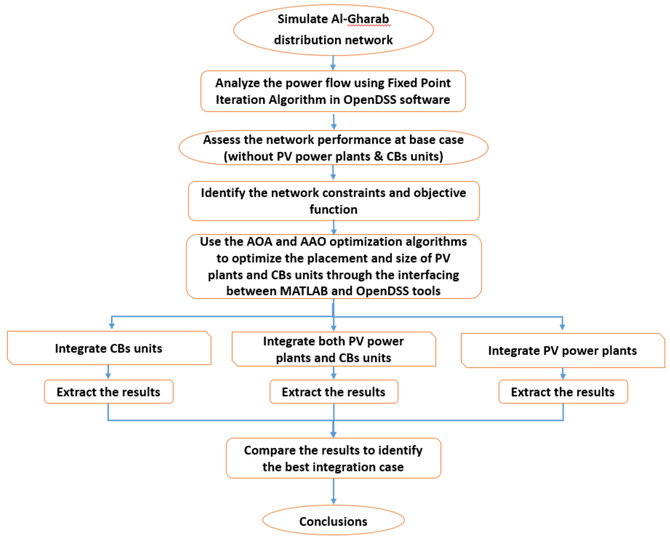
Abstract

This study endeavors to enhance the voltage profile, mitigate energy losses, and narrow the gap between electricity generation and consumption in the Al-Gharab distribution network in Al-Qadisiyah, Iraq. The Al-Gharab radial distribution network is afflicted by voltage drops and fluctuations, frequent power interruptions, and power losses. The researchers are studying the potential of supporting the network with the Capacitor Banks (CBs) and incorporating Photovoltaic arrays (PV arrays) as a means of improving its performance. The optimal placement and size of the CBs are determined using the AutoAdd Optimization (AAO) technique, while the optimal size and location of PV arrays are determined through the implementation of Archimedes Optimization Algorithm (AOA). The results are analyzed and extracted under various scenarios as follows: a. Base case system analysis, b. Integration of PV arrays, c. Integration of CBs without PV arrays, and d. Integration of CBs with PV arrays. The results showed that the best improvement of the network performance was obtained in case of integration of the CBs with PV arrays, especially the scenario of integration three units of CBs with PV arrays. Where the minimum voltage improved from (0.91848 pu) to (0.975 pu), and the total active and reactive power losses were decreased by (85 %) and (51 %) respectively.

Objective

The objective of this study is to integrate PV arrays and CBs individually and then combine them together to determine their impacts on the Al-Gharab distribution network. Also, to determine the optimal number, size, and location of the PV arrays and CBs to suit the proposed network conditions.

Work Steps



Results

❖ ***Case 1: Integration of PV arrays:***

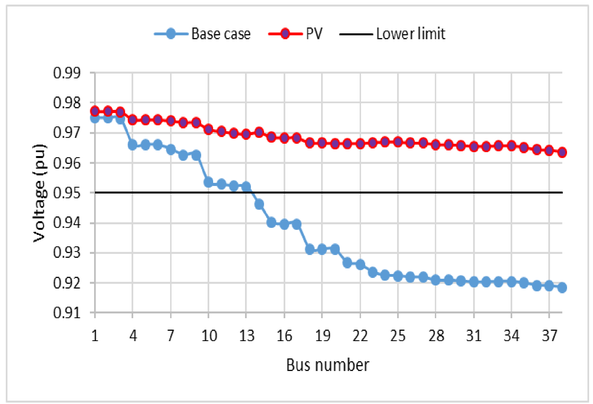


Fig. 1. Voltage profile of the network at case of (Integrating PV plants only).

❖ ***Case 2: Integration of CBs units only:***

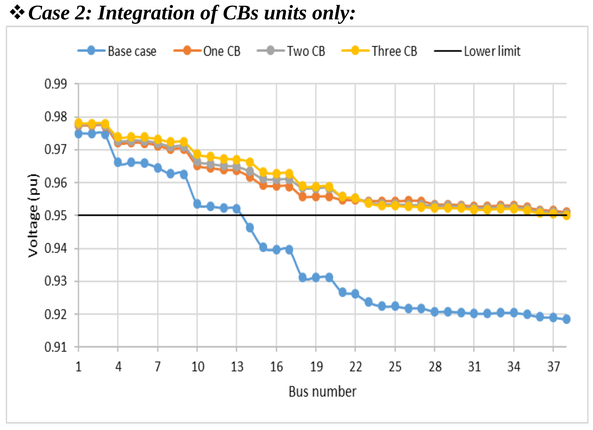


Fig. 2. Voltage profile of the network at case of (Integrating CBs units at multi scenarios).

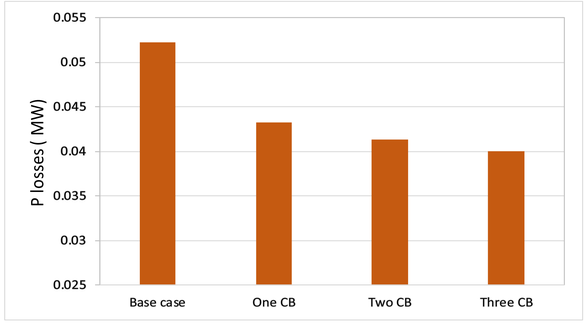


Fig. 3. Power losses of the network at case (Integrating CBs units only)

❖ ***Case 3: Integration both PV arrays and CBs units:***

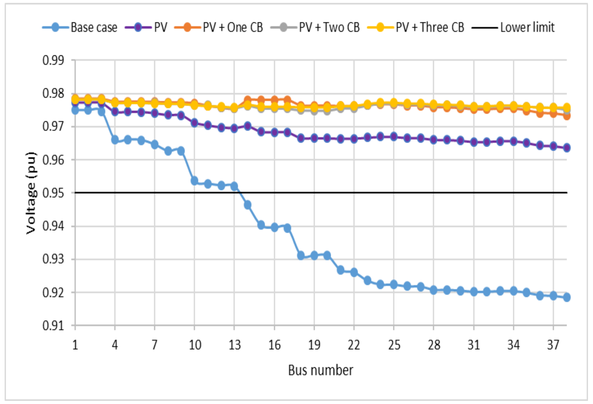


Fig. 4. Voltage profile of the network at case of (Integrating both PV plants and CBs units).

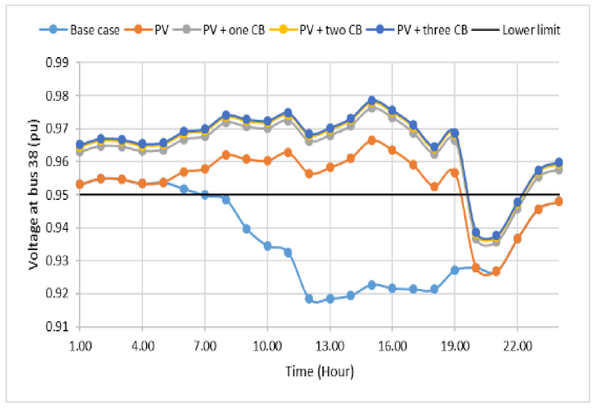


Fig. 5. The daily voltage profile of the weakest bus in the network (bus 38) at multi cases.

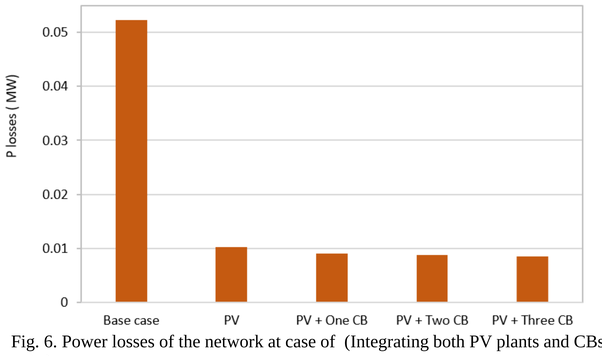


Fig. 6. Power losses of the network at case of (Integrating both PV plants and CBs units)

Al-Gharab distribution network

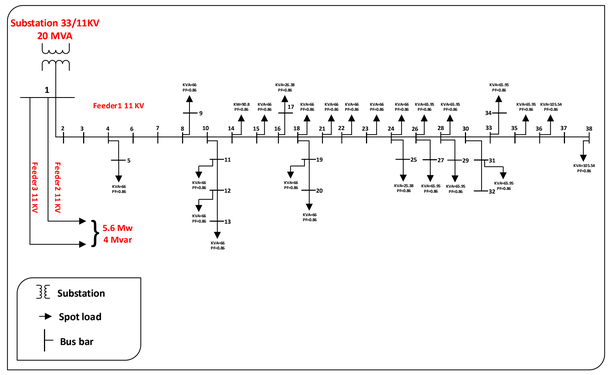


TABLE I: The optimization results of integrating both PV plants and CBs

Integration scenario	CBs size (KVAR)	CBs location	Min voltage	Total power losses(P - Q)
Base case	-------	-------	0.91848 @ bus 38	0.0522 MW - 0.348916 MVAR
PV arrays	-------	-------	0.96363 @ bus 38	0.0102 MW - 0.209706 MVAR
PV+ one unit of CBs	430	bus 16	0.97341 @ bus 38	0.0090 MW - 0.194333 MVAR
PV+ two units of CBs	200, 195	bus 36, bus 11	0.97484 @ bus 38	0.0088 MW - 0.181751 MVAR
PV + three units of CBs	140, 130, 120	bus 38, bus 12, bus 19	0.97568 @ bus 38	0.0085 MW - 0.170662 MVAR

Conclusion

The simulation results showed the beneficial impact of incorporating the CBs and PV on the network's performance, the best case is (Integration both of CBs with PV arrays), where minimum voltage improved from (0.91848 pu) to (0.975 pu) compared with the base case. Also, the total active and reactive power losses were decreased by (85 %) and (51 %) respectively. Additionally, the results showed that there are no discernible disparities between the three scenarios in integration of CBs units. But, from a technical perspective, there exists a minuscule inclination towards the third scenario (PV + three units of CBs), however, from an economic standpoint, it is more advantageous to adopt the first scenario (PV + one unit of CBs) given its appropriateness in exploiting smaller spaces for the integration of the CBs units, as well as the costs associated with the construction and maintenance of the CBs units are lower in comparison with the third scenario. This study proved the potential positive impact of integrating PV arrays. So, it opens horizons for the future work to research and study another types of available power resources in Al-Gharab region for economic and technical comparison with the PV arrays.