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Evaluating the Effect Placement Capacitor and Distributed Photovoltaic Generation for Power System Losses Minimization in Radial Distribution System

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Abstract. Power loss minimization have many advantagess to the distribution system radial among others reduction of power flow in feeder lines, freeing stress on feeder loading, deterrence of power procurement from the grid and also the cost of loss compensating instruments. This paper, presents capacitor and photovoltaic (PV) placement as alternative means to decrease power system losses. The paper aims to evaluate the best alternative for decreasing power system losses and improving voltage profile in the radial distribution system. To achieve the objectives of paper , they are used three cases tested by Electric Transient and Analysis *Program (*ETAP) simulation. Firstly, it performs simulation of placement capacitor. Secondly, simulated placement of PV. Lastly, it runs simulation of placement capacitor and PV simultaneously . The simulations were validated using the IEEE 34-bus test system. As a result, they proved that the installation of capacitor and PV integration simultaneously leading to voltage profile correction and power losses minimization significantly.

INTRODUCTION

Reduction of power loss mostly relates to electric power distribution. Approximately 5%–13% of total power generated is expelled like the shape of power losses at the distribution level[1]. The power losses and voltage drops on the distribution network are larger than the transmission lines, this is because the X / R ratio of impedance on the distribution network is lower[2].

The radial distribution system is the most typical type of distribution systems which assemblied by distribution company, because of their economize[3]. Types of consumers and distribution network components which generally consist of motor and transformer as inductive loads caused the system has lagging power factor. This leads to a decrease in system capacity, an increase in losses and voltage drops. Based on the current components flowing in the distribution network, the power losses in the distribution network are divided into active and reactive power losses.

Various studies have examined the minimization of power losses in distribution networks that are divided into capacitor placement, network reconfiguration and placement of Distributed Generators (DG) or dispersed generators[4]. The power losses generated by the reactive current components can be minimized by the installation of capacitors[5-7]. Capacitor size must also be efficient to correct the voltage profile of the system close to the threshold of voltage stability or standar voltage regulation[8]. The use of DG to overcome the problem of power loss and improvement of current voltage profile is also increasing. DG is defined as a small-scale generating unit with a maximum capacity of 100 MW which is generally connected to the distribution network although it does not close

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the possibility of being connected to transmission lines[9]. The rapid development of DG requires a proper planning for electric service providers to integrate DG on the distribution network in terms of size, location and type DG[10]. One of the most widely integrated DG types in the distribution network is the type of photovoltaic (PV). PV utilizes the intensity of sunlight that is very potential because it is a source of renewable energy[11]. This DG type has a characteristic generate active power so that this type of DG is used as compensation of active power on distribution system which can decrease active power losses. Many researches have tested the effectiveness of PV use for decrease power losses at single or multiple locations[12,13]. However, the properties of PV that only compensate for the active power, it requires additional other devise to compensate for a considerable reactive power. In this paper, presents the results of research on the significance of the effect of the use of capacitors and PV on the distribution network singly and simultaneously to the loss of power loss in the distribution network.

PROBLEM FORMULATION

The problem of selecting the location and size of the appropriate capacitor and DG unit is expressed based on the power loss index and the voltage profile index on the system using a load flow study.

1. Power loss index

The general formula used in previous research to find the optimal value of capacitor or DG size and placement is to minimize system power loss[14]. The power loss reduction factor index is stated as:

$$PLI = \frac{PL\ (base) - PL\ (PV/cap)}{PL\ (base)} \tag{1}$$

PL ($base$) denotes power loss before or initial condition (wthout PV or capacitor) and PL (PV/cap) denotes power loss after installation PV or capacitor in the distribution system.

$$PL = \sum_{k=1}^{N_{br}} |I_k|^2 + R_k \tag{2}$$

where I_k denotes line current and R_k denotes resistance of line-k.

2. Voltage profle index

The voltage profile index helps identify the pairs of location and size that give higher values of voltage deviations from the base voltage. The voltage profile index[15] is stated as:

$$\text{VPI} = \sum_{i=1}^{NB} |V_i - 1| \tag{3}$$

Where NB is total number of buses and V_i is the magnitude voltage on the i_{th} bus.

Furthermore, the substation voltage is reviewed as 1.0 p.u and the lower and upper limit of voltage magnitude of buses 0.90 and 1.10 p.u are assumed, consecutively.

This value is one of the success criteria for the placement of capacitors and PV in addition to the minimization of power losses.

To identify the effect of capacitor and PV placement on the radial system distribution network, the following steps are performed:

1. Determine the base conditions of power flow as consideration of the value of active power and reactive power to be injected into the system and location of capacitor and PV placement.
2. Arrange the buses in descending order of their power loss. The bus having the highest real power loss is the candidate bus for PV sitting and the bus with the highest reactive power loss is considered as the candidate bus for capacitor placement.
3. Determine the value of capacitor and PV based on the value of active power value and reactive power to be injected according to the result of power flow. The maximum PV capacity is fixed as 75% of the total feeder loading and the capacitor capacity is fixed as 100% of total MVAr loading of the network.
4. Simulation of capacitor and PV placement is tested with 3 scenarios .
   a) Scenario 1: capacitor placement
   b) Scenario 2: PV placement

c) Scenario 3: Placement of PV and capacitor simultaneously. Each scenario results refer to the Eqs. (1) and Eqs. (2) to obtain the best placement scenario. Fig. 1 shows the flow chart of simulation placement PV and capacitor.

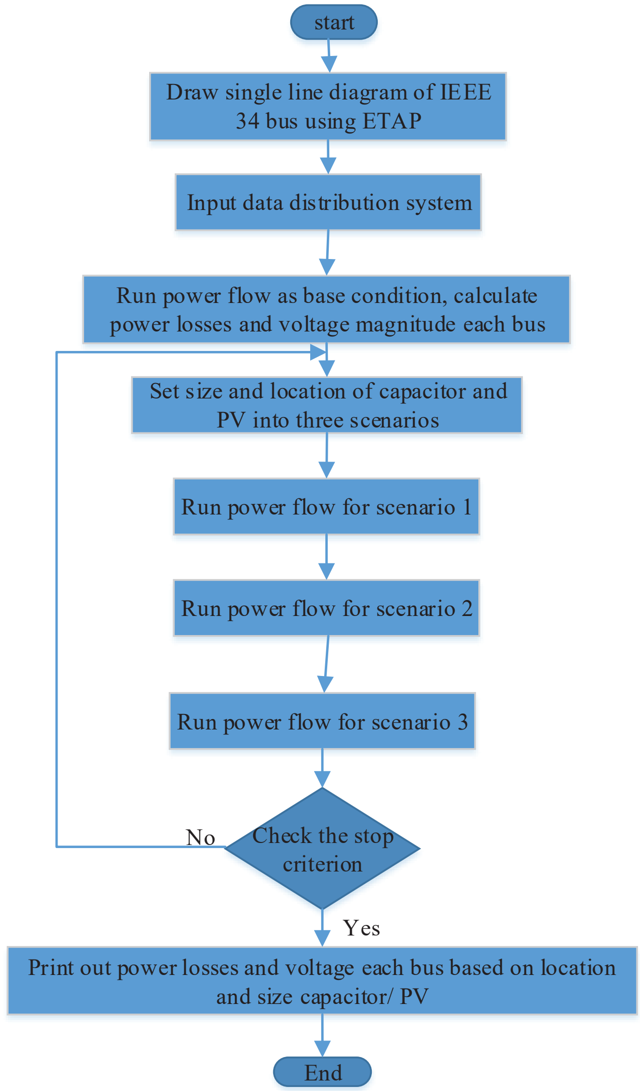

FIGURE 1. Flowchart

RESULTS AND DISCUSSION

In order to get simulation purposes, the distribution network used is the IEEE 34 radial type test system that shown in Fig. 2. Data from the system is obtained from[16] with total system loads considered as 334 W + 224 kVAr. Initial condition of system calculated by ETAP load flow . The total power loss active and reactive for the initial condition are 20,4 kW + 17,5 kVAr. In the first case, the simulation of the placement of the capacitor is done at two point at the bus 9 and bus 19, consecutively.

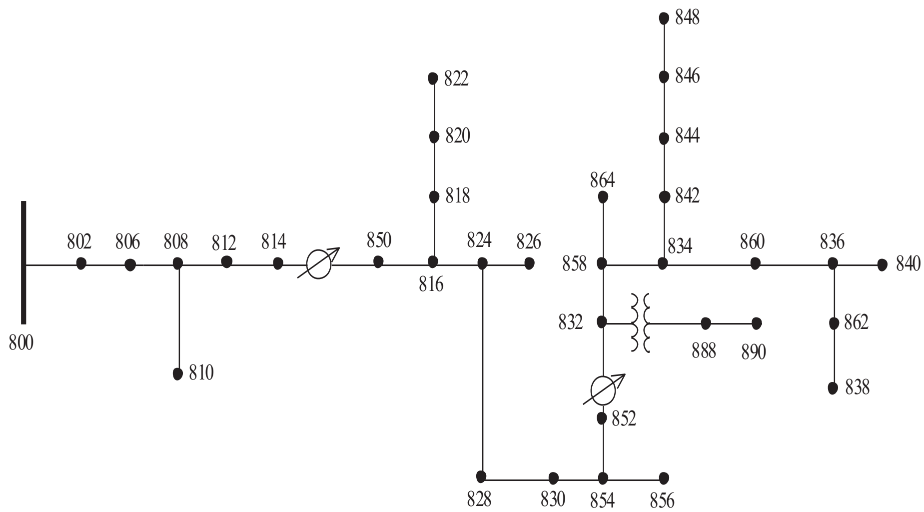

FIGURE 2. Single line diagram of a 34-bus radial system

Determination of the placement of capacitors in buses 9 and 19 it refers to the initial load distribution and drop voltage. Where the value distribution of the capacitor in bus 9 serves one load and the bus 19 serves the others load. In the third test, the capacitor size is divided into 5 kVAr and 219 kVAr on each of the buses 9 and 19.

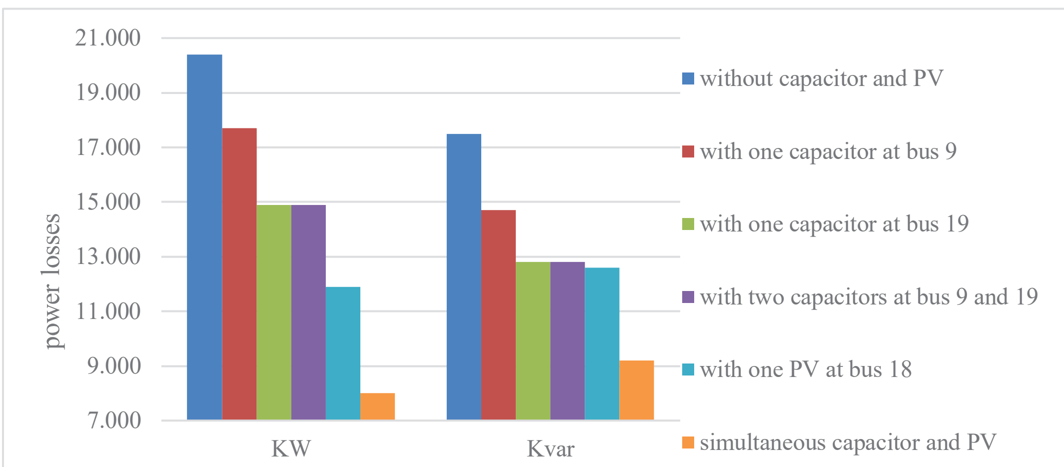

FIGURE 3. Power loss after and before placement capacitor and PV in 34 bus system

In the second case, the PV placement simulation is done on bus 18 with the size of 253 kW. The location of the PV placement was based on the results of the two capacitors placement test, where the result shows the voltage drop is still below the standard value. Therefore, consideration of PV placement on the nearest bus to improve the voltage profile. In a previous study[17], a 50 W PV DG test can reduce the loses of the active power losses by 74.176% and the average voltage increased by 2.066%. In the third case, capacitors and PV place on buses 19 and 18 simultaneously. Size of capacitor and PV are 219 kVar and 253 kW. The simulation results for three cases are shown in the power losses graph and the voltage profile of Figures 3 and 4. Figures 3 shows power losses of the distribution sytem for each scenarios. Placement the PV and capacitor reduce power losses significantly so that the active power losses is reduced from 20.4 kW to 8 kW and reactive power losses is reduced from 17.5 kvar to 9.2 kvar.

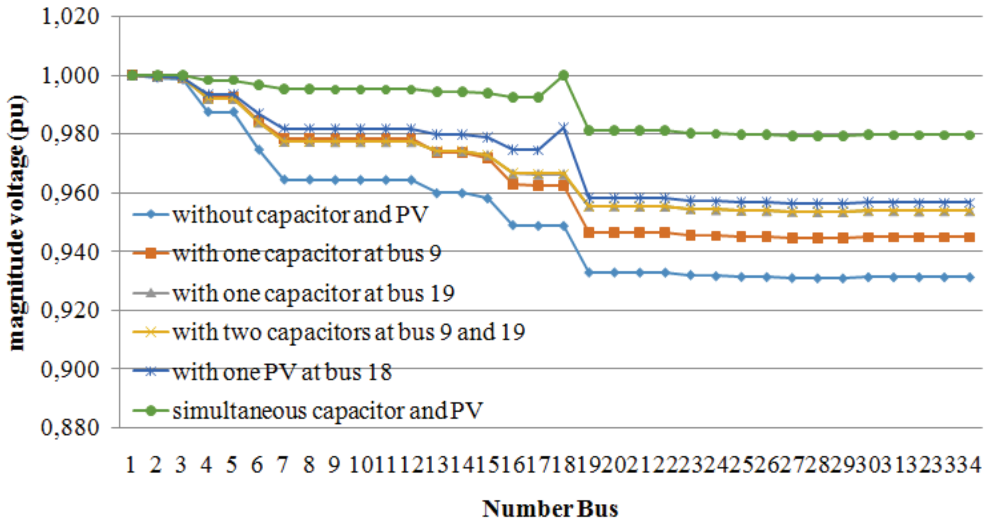

FIGURE 4. Voltage profile after and before placement capacitor and PV in 34 bus system

On other hand, figure 4 shows the voltage profiles of nodes after and before installation of PV and capacitor. It can be seen from this Figure that voltage profile of nodes improved significantly when PV and capacitor are installed simultaneously in the system. Moreover, VPI index is decreased from 0.6868 p.u to 0.2039 p.u, therefore voltage deviations of nodes from 1.0 per unit in the test system are reduced by PV and capacitor installation.

CONCLUSION

This paper has tested three cases of capacitor and PV placement simulation to see its effectiveness in decreasing the power losses. Using ETAP simulations shows that PV use is more effective at reducing power losses than capacitors. The best results are shown on the placement of capacitors on bus 19 and PV on bus 18. The PV capacity value is determined based on the load sharing value of the swing bus while the capacitor capasity values are based on the reactive power requirements of the system load. In addition to decreasing power losses, capacitor and PV placement also improves the voltage profile.

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