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MINIMIZATION OF POWER LOSS BY TAP CHANGING TRANSFORMER USING PSO ALGORITHM

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ABSTRACT:

Load uncertainty increases with increase of power consumption in the recent years and it causes the power losses and low voltage profile in the radial distribution system. By the increase of distribution transformer tap settings the voltage profile of buses will be improved and reduces the power losses in the distribution system. But execs of voltage levels are causes to higher power losses in the distribution system. This paper aims to reduce the real and reactive power losses in the distribution system by changing the transformer tap settings using PSO algorithm. Proposed methodology examined on standard 15 bus distribution system with EV charging station and DG system. Constant power and constant Voltage dependent load modeling are considered.

KEYWORDS:

15 BUS TEST SYSTEM, DISTRIBUTION SYSTEM, PSO ALGORITHM, LOAD MODELING, REAL AND REACTIVE POWER LOSSES.

I. INTRODUCTION

Many losses, such as distribution, transmission, and demand losses, can have an impact on the system. Load flows, sampling techniques and regression analysis are used to minimize these losses. A power system is associated with various constraints, such as generation equipment, transmission control, utilization-based control, and classic service provided to users. During this process, some type of loss is affected, as previously stated [1], [2]. In the broad sense, in India's electrical systems, 20-25 % of distribution losses occur; to reduce these losses, two technologies are available: network reconfiguration and optimal location of Distribution Generation (DG). The distribution system creates a better path for power usage from the generation station to the end customer. Feeder topology is used for network reconfiguration, and tie switches in the feeder topology operate at emergency/normal conditions of open/close switch configuration.

Similarly, how various techniques are used for network reconfiguration, which is very effective and used to balance the load. When the normal functioning of the network reconfiguration follows the criteria below, the first rule is that the distribution power the system maintains stability and reliability, which usually improves exploit equipment in the system and, as a result, enhances system overabundance However, because the above rule has the disadvantage of increasing system costs, analysis methods are employed to counter the issue. To do so, take the reliability index and evaluate the radial network's reliability estimation.

Second, load balance has been maintained during the system reconfiguration. Practically, the network is dynamic, with loads fluctuating up and down. However, distribution network reconfiguration is used to transfer power from a massive load to a fewer load, reducing the overload effect and maintaining a proper voltage profile. Power losses are also reduced throughout this process [3]. [4].

The distribution system can provide power to consumers, but it suffers from power losses. Engineers must and should make every effort to reduce losses; in the system, all equipment is employed to maintain high efficiency; but, while the power system is operational, it increases costs. As a result, several criteria are used to reduce losses, such as network reconfiguration, DG placement, and capacitor installation. The next technology is optimal distribution generation (DG), which is one of the reasons for increasing renewable energy units as fossil fuels become scarcer. Why are DGs so popular? Because of their benefits, such as improved voltage and reduced real and reactive power losses. Because of this, the DG's reliability and efficiency have improved. When selecting the DG, two criteria such as the location and size of the DG are affected. [4], [5].

Installation of DGs and capacitors in the power system provides significant benefits to the distribution system since high-quality power can be transmitted to customers easily, and the system's performance is enhanced. In addition to reducing losses, and cost, and preserving the environment during the integration of power plants, distribution generation also increases voltage and system stability. That is why DG placement and size are more significant; in essence, it is entirely dependent on analytical approaches, such as the loss formula, which is used to compute the ideal DG allocation. To determine the optimum size and position of DGs, various analytical methods are used such as Genetic Algorithm (GA), Differential Evolution Algorithm (DEA), Particle Swarm Optimization (PSO), and Exchange Market Algorithm (EMA) [6], [7].

Consumers essentially demand high-quality power from the distribution system, but this is virtually impossible due to power loss and low voltage gain. Capacitor placement to compensate for reactive power is an enormous way for minimizing the above problem. Shunt capacitors are extensively used in distribution systems to reduce real and reactive power losses while also improving voltage profiles. Shunt capacitors can be installed using a variety of strategies, including the cuckoo search algorithm, the firefly algorithm, and meta-heuristics techniques [8].

II. LITERATURE SURVEY

When compared to transmission losses, the power loss effect in distribution networks is more catastrophic, i.e., losses in distribution networks will raise operational costs. As a result, losses in the distribution network must and should be controlled. While there are several options for reducing these losses, distribution system reconfiguration is the most effective. A collection of linear and non-linear constraints is selected from the objective function to implement the mixed-integer optimization approach for loss reduction in the system. Because this mixed-integer conic programming model contains non-linearity requirements, finding a solution using efficient heuristic tools is difficult. Different distribution networks were used in this paper to compare the results of the Decimal Codification Genetic Algorithm (DCGA), which not only reduced losses but also improved the voltage profile [9].

The operating cost may be affected whenever the voltage profile is increased by reducing system losses. The researchers are attempting to reconfigure the network for optimal system performance while keeping costs low, such as the placement of a compensator capacitor. Many algorithm-based controls are now available; the basic PSO approach is simple to use for testing various distribution systems, but its performance is inadequate for big networks due to the massive calculations required. The nature of power is dynamic, and when a large number of distribution network equipment units work together, the power ambiguity causes voltage drops and network losses. To regulate these PSO methods, the system should be combined with a Genetic Algorithm (GA), since this will improve the system's efficiency under load shading conditions. The GA algorithm is used in this process to collect data from renewable energy sources (RES) and PSO combined to compute the minimum system losses when all nonlinear restrictions are taken into account. Using the IEEE-33 and IEEE-66 buses, the authors are sorely tested [10].

Because of the importance of the service point, the engineers did extensive calculations for Distribution Network Reconfiguration (DNR). Many strategies are employed to achieve a solution for minimizing losses in network systems, including correction of power factor, voltage balance maintenance, and harmonic reduction, all of which are used to provide affordable support for the system. The DNR has both convex and non-convex difficulties; hence a new graphically based DNR is used to solve them. It has a graphical representation, fast convergence compared to optimality, and great efficiency [11].

The radial system integral of decentralized generation absorbs all difficulties from the grid; the location and size of Decentralized Generation (DG) boost power losses correspondingly diminishes voltage. The Moth Flame Optimization (MFO) Algorithm is used to compute the size and location of DG in the distribution network, which will optimize the voltage profile. Chaotic Moth Flame Optimization (CMFO) is responsible for this functionality; CMFO controls the exploration and exploitation rates, which are critical for simulation iterations [12].

It is hard for a power-producing plant to achieve its required demand using a traditional structure. As a result, more support from Wind Turbine Generation (WTG) and Renewable Energy Sources (RES) was required for power generation. These are linked to distributed generation systems, but there is a difficulty with the distribution generation's suitable placement and size. Because the voltage will shift during this operation, a novel Voltage Stability Factor has been developed to preserve voltage stability [13].

III. LOAD FLOW IN DISTRIBUTION SYSTEM

Load flow analysis gives the line losses for existing power plants capacity extension and for new power plants establishments. This data helps to place the capacitors/DG in the radial distribution system. Forward/Backward Sweep algorithm applied to the distribution system to calculate the real and reactive power losses.

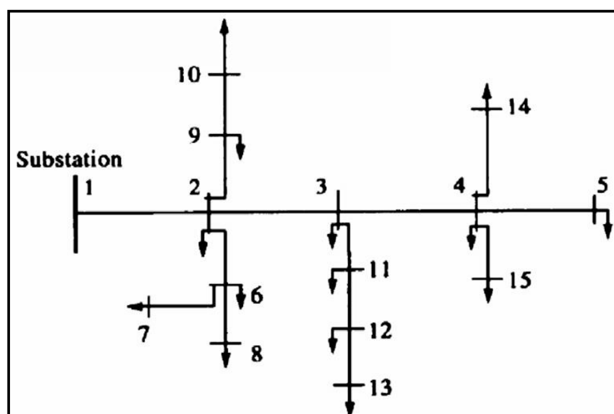

FIGURE 1: LINE DIAGRAM OF STANDARD 15 BUS DISTRIBUTION SYSTEM.

Backward sweep technique is used for determining the line current and is represented as $I_1, I_2, \ldots I_n$.

Load Current: $$I_L = {P_i - jQ_i}/{V_i^*} \quad (1)$$

Load Current: $$I_{n-1} = I_n + \sum K = nI_K \quad (2)$$

In the forward sweep technique, voltage at each bus calculated by applying KVL.

$$V_{n+1} = V_n - Z_n * I_n \quad (3)$$

VOLTAGE DEPENDENT LOAD MODELLING:

Voltage variations are considered w.r.t. time, the following equations represents the real and reactive power demands with the voltage dependent load modelling [14]

$$P_{d,i}(t) = P_{d,i(0)} * V_{i(t)}^{\propto} \quad (4)$$

$$Q_{d,i(t)} = Q_{d,i(0)} * V_{i(t)}^{\beta} \quad (5)$$

DG Placement:

Placing the DG's in the distribution system at bus numbers 5,7,9,10,12,14, and 15 to compensate the load at that buses 75%, 75%, 25%, 25%, 25%, 25% respectively [15]. Here only the PV system considered as the DG and it generates the real power only. DG supports the distribution system and helps to improve the voltage profile and reduces the both real and reactive power.

Modelling of distribution generation

$$P_{di,new} = P_{di,base} - P_{DG,i} \quad (6)$$

MODELLING OF PHOTOVOLTAIC SYSTEM

$$P_{spv}^{rated} * \frac{G_t}{1000} = P_{spv} \quad (7)$$

WhereG_t: Global irradiance incident on the titled plane (W/m^2)

N: Number of modules

P_{spv}^{rated}: Module rated power at $G_t = 1000W/m$^2.

EV Charging Station:

EV charging stations are located randomly on the distribution system. The rating and type of the EV charging stations are mentioned in table 1. The EV charging stations consumes the energy and it increases the power losses in the distribution system.

IV. PSO BASED TRANSFORMER TAP CHANGING SETTINGS

Changing the transformer tap settings is affecting the voltage profiles of the buses in the distribution system and similarly real & reactive power losses are minimized. Lower & Higher amount of tap settings are also leads the power losses due to wastage of power supply. Particle swarm optimization applied to transformer tap settings, it founds the optimal value for distribution system with minimum power losses.

Optimal tap change value of the transformer with minimum power losses can be represented as: $Min\, F(\{\alpha P_{loss} + \beta N_{Tap}^{OLTC}\})$

Where P_{loss}represents the real and reactive power losses. N_{Tap}^{OLTC}represents tap settings of the on load distribution transformer.

TABLE 1: VARIOUS LEVELS AND TYPES OF SUPPLY IN EV CHARGING STATIONS [15]

Type	Level	Notation	Type of Supply	Max. Output	Time required to charge
AC	Level 1	ACS1	Single Phase, 120V, 16A	1.9KW	10-13 Hr
	Level 2	ACS2	Single/Three Phase, 208-240V, 80A	19.2KW	1-4 Hr
	Level 3	ACS3	Three Phase, 240V, 180A	43.5KW	1 Hr
AC	Level 1	DCS1	Three Phase, 200-450V, 80A	36KW	0.5-1.44 Hr
	Level 2	DCS2	Three Phase, 200-450V, 210A	96KW	0.2-0.58 Hr
	Level 3	DCS3	Three Phase, 200-600V, 330A	200KW	10 Mins

V. RESULTS AND DISCUSSION

Voltage dependent load modelling helps to reduces the real and reactive power losses and improves the voltage profile of the buses in the distribution system as shown in fig4.

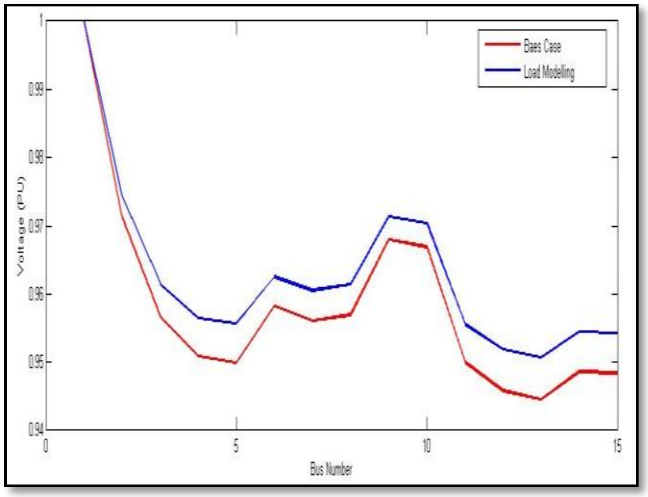

FIGURE 4: COMPARISON OF VOLTAGE PROFILE BETWEEN CONSTANT POWER LOAD MODELLING & VOLTAGE DEPENDENT LOAD MODELLING.

After placement of PV system in the distribution system with different size of compensation at various buses and the PV system (DG) placements reduces the real power losses majorly and slightly decreases the reactive power losses and relatively increases the voltage profile at buses as shown in fig.5.

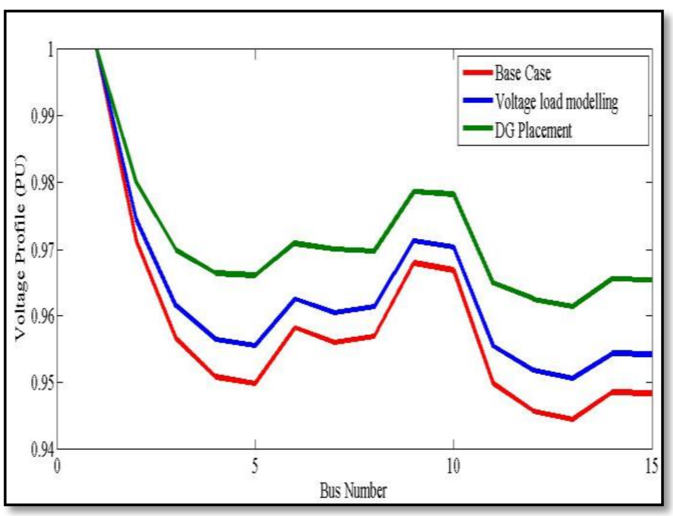

FIGURE 5: COMPARISON OF VOLTAGE PROFILE WITH BASE, VOLTAGE LOAD MODELLING, AND DG PLACEMENT CASES.

Fig. 5 shows the comparison of voltage profile improvement in the distribution system when the DG system placed. The real and reactive powers are compensated with the help of DG placement in the distribution system.

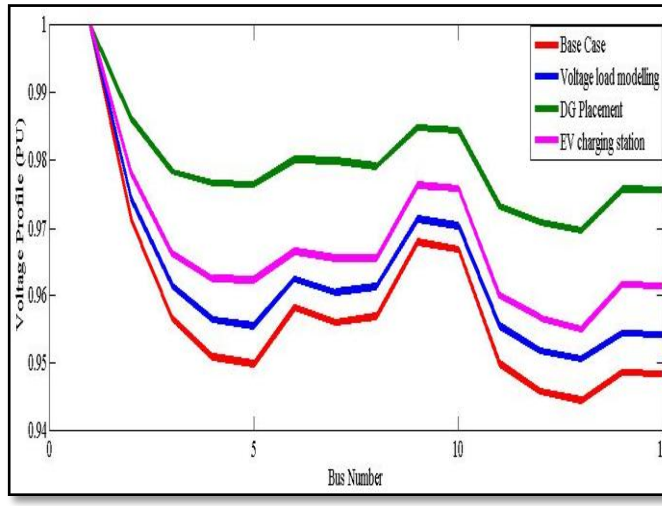

FIGURE 6: COMPARISON OF VOLTAGE PROFILES IN VARIOUS CASES WITH EV CHARGING STATIONS.

Fig.6 shows the voltage profile drop in various bus numbers due to inclusion of EV charging stations compared to DG placement. The load uncertainty is also increases the distribution system real and reactive power losses.

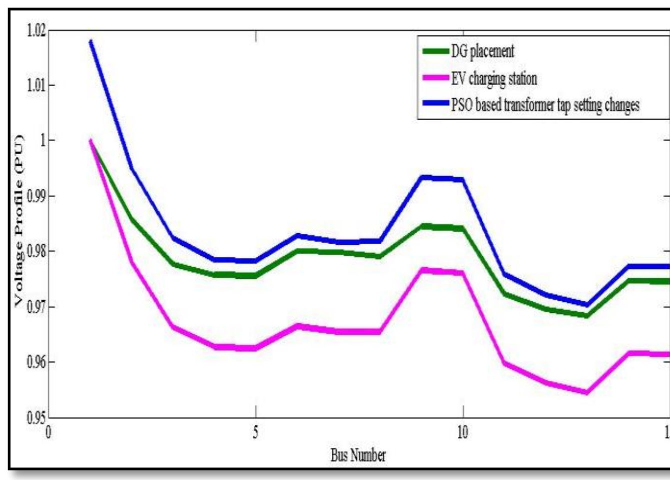

FIGURE 7: COMPARISON OF VOLTAGE PROFILES IN VARIOUS CASES.

Fig.7 shows the voltage profile improvement in the distribution system after applying the PSO algorithm. It clearly shows the change in voltage profile of the buses represented as EV charging station and PSO based transformer tap settings change.

Table 2 shows the real and reactive power loss minimization in various cases. The PSO based OLTC delivers the best value of the distribution transformer and it helps to reduce the power losses and improves the minimum bus voltage levels in the distribution system.

TABLE 2: COMPARISON OF POWER LOSSES, MIN & MAX VOLTAGES

Case	Real power losses	Reactive power losses	Minimum voltage(p.u.)	Maximum voltage (p.u.)
Base Case (constant power load model)	61.7873	57.2905	0.9445 & 13	0.9712 & 2
Voltage dependent load model	56.0592	44.497	0.9506 & 13	0.9743 & 2
DG placement	20.1442	19.4661	0.9688 & 13	0.9858 & 2
Placement of EV charging Station	43.6357	32.5599	0.9530 & 13	0.9761 & 2
PSO based OLTC with EV charging station	46.3826	30.2400	0.9702 & 13	0.9954 & 2

CONCLUSION

This paper discussed about the constant power and constant voltage load modelling for minimization of real and reactive power losses and improvement of voltage profile. Voltage profile improvement observed in the constant voltage load modelling and real & reactive power losses are also minimized. Randomly placed PV system (DG system) to compensate the real power and to reduce the power losses & both AC and DC EV charging stations are placed in various locations in the standard 15 bus system. After placing of various levels of EV charging stations in the distribution system the power losses are increased due to loading effect on the system and voltage profile also reduced slightly at EV charging station bus numbers. Distribution transformer tap settings are changed using PSO algorithm and it helps adjust the tap settings to minimize the power losses and improve the voltage profile. The results are compared with other conditions i.e., DG & EV placement in the distribution system under constant voltage load modelling. It shows the satisfactory results and average voltage value in the distribution system also improved.

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