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Minimization of Power Loss in Distribution System by Tap Changing Transformer using PSO Algorithm

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ABSTRACT- Energy is a primary requirement for everyone and it is available in different forms in nature, in all forms of energy "Electrical Energy" is the most significant and useful in the daily life of humans. In the last two decades, the usages of electrical & electronic devices are rapidly increased and technology modernizes lifestyles as well as simplified their lives. In this way, the load demand also significantly increased and leads to an imbalance between generated power and load demand. Load uncertainty also increased with the rise of load demand; it leads higher power losses & poor voltage in distribution system (DS). The main objective of this paper is going to discuss the minimization of losses by adjusting tap settings of the distribution transformer with the help of particle swarm optimization (PSO) algorithm. The proposed approach verified on 15 bus distribution system using MATLAB. Electric vehicle charging stations are located in the distribution system to represent the load uncertainty.

Keywords: SCSA, BP, Photo plethysmography, CNN, Non-invasive, Cuff-les Distributed Generation, Distribution transformer, EV Charging Stations, Radial Distribution System (RDS), Voltage Profile.

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1. INTRODUCTION

More nonlinear loads are connected to the distribution system, these nonlinear loads cause and inject harmonic currents into the power system, which reflects the quality of the power system [1]. Nowadays consumer satisfaction would be maximized; customers are expecting high power quality but in the distribution system, 10-13% of generated power is dissipated as I^2R losses [2] and 20-25% distribution losses present [3]. Normally the distribution system is a radial structure because of the simplicity, it has mainly feeders and distributors, and the main feeders originate from the substation and pass-through different consumer loads, these systems are facing a problem with high resistance to reactance ratio problem [4]. For solving this problem system should upgrade by providing DG and capacitors [5]. DG units are expanded day by day as it advances in innovation [6].

In DG technology nearby load side small generating units are connected, DG's are both renewable and non-renewable. As fossil fuels are depleted day by day reflects renewable-based generating units are the top priority [3]. There is no. of renewable technologies in DG such as fuel cells, photovoltaics', wind, etc. In all those wind is going to dominate the electricity because of their environmentally friendly and abundantly available resource [8]. Using wind power minimizes some losses, but some losses have existed in the power system even after placing DG. In this project, the PSO method is implemented by controlling transformer tap settings in the distribution system. Losses are moving with the forward-backward sweep technique. The transformer plays a key role in the distribution system as well as transmission. It is intermediate to transmission and distribution, the transformer tap changing's of two types one is off circuit tap changing and on-circuit tap changing. Under normal load conditions, the transformer tap changes within an acceptable range from 0.95 to 1.05 p.u., if indicates below 0.95p.u means poor voltage. In this case, the transformer tap settings are changed from 0.80 to 1.20 p.u. with step 0.01. In this way, the losses will be minimized, and improve system voltage profile.

2. LITERATURE SURVEY

In [9], determines the minimum investment required to satisfy the reactive device's suitable reactive constraints. For this problem, capacitor placement is the solution, implemented the capacitor allocation solution with a deterministic and genetic algorithm. The proposed algorithm was tested on SICILY and CIGRE Networks. In [10], uses a combinatorial search algorithm with alternative combinatorial approaches to examine location of the capacitance placement. In [11], power losses are minimized and energy costs are minimized by the perfect location of capacitors. When tested on 22,69,85, and 141 bus systems, the teaching-learning based optimization (TLBO) algorithm and results shows outperforms compared with GA, PSO, DS, and mixed integer linear programming approach. In [12], clustering-based optimization is used to solve the shunt capacitor problems like position, estimating, etc., the proposed

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approach is verified on buses 22, 34, 69, and 85 of the distribution system. The CBO results are compared with fuzzy genetic algorithms, direct search algorithms, teaching learning-based optimization, cuckoo search, self-adaptive harmony search algorithms, and artificial bee colonies. In [13], based on sensitive analysis solves the accurate solution to identify the capacitor locality and capacitor values by gravitational search algorithm. These methods were tested on 33, 69, and 85 buses. Shown better results compared with analytical interior point technique. In [14], capacitor arrangement and sizing of capacitors are determined by using a fuzzy expert system and Dragonfly algorithm methods. 69-bus system considered for verification of proposed approach and the results are compared with existing optimization techniques. In [15], discusses an Integer genetic algorithm for shunt capacitor placement and capacitor bank sizing based on load flow calculations. This proposed algorithm is performed on the IEEE 34 bus system. In [16], deals two objectives optimization of capacitor placement and conductor gradation problem with MINLP solvers and it is tested on 117 bus systems. Load uncertainty and dynamic allocation of capacitor banks constraints considered in the objective function. In [17], minimizes losses by the finest capacitor position in radial distribution systems with a line-wise model (LWM) of power balance equations, tested on 69-bus and 136-bus, and results are compared with BFM-based formulation. In [18], perfect location of capacitors was introduced to improve the power quality and reliability based on the application of Shannon's Entropy. To fix this problem particle swarm optimization algorithm is used and tested on IEEE 12, 34-bus, and 108 buses. The obtained results are compared with previously published methods. After this extensive literature survey many researchers addressed the individual optimal placement of DG & capacitors in RDS to improve the system performance by minimization of losses. But very few authors addressed the integrated CB and DG placement in the RDS in the view of power loss minimization. Here in this paper placement of CB & DG is not optimized, they're located based on the low voltage profile of the buses in RDS. Further the losses are minimized by changing the distribution transformer tap settings using particle swarm optimization.

3. PROPOSED METHODOLOGY

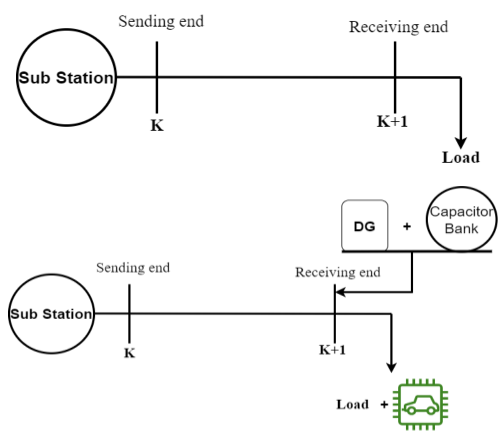

Figure 1: EV charging station with integrated DG &Capacitor Bank in radial distribution system

From the radial distribution system,

$$V_{k+1} = V_k - I_k Z \tag{1}$$

$$|I_k| = \frac{\sqrt{P_k^2+Q_k^2}}{V_k} \tag{2}$$

Where, V_k represents the voltage across the sending end,
V_{k+1} Represents the voltage across the sending end,
I_k Represents the line current,
P_k Represents the sending end active power,
Q_k Represents the sending end reactive power,
P_{k+1} Represents the receiving end active power,
Q_{k+1} Represents the receiving end reactive power.

Radial distribution system power losses will be expressed as:

$$P_{Loss(k,k+1)} = \frac{(P_{k+1}^2+Q_{k+1}^2)}{|V_{k+1}|^2} * R \tag{3}$$

$$Q_{Loss(k,k+1)} = \frac{(P_{k+1}^2+Q_{k+1}^2)}{|V_{k+1}|^2} * X \tag{4}$$

Let us assume power injected by placing the DG & CB in RDS is represented by P_{DG}, Q_{DG} & $P_{CB} Q_{CB}$. Then the following equations represent the power injection to the RDS

$$P_{inj} = P_{k+1} - (P_{DG} + P_{CB}) = P_{k+1} - P_{int} \tag{5}$$

$$Q_{inj} = Q_{k+1} - (Q_{DG} + Q_{CB}) = Q_{k+1} - Q_{int} \tag{6}$$

Where

$$P_{int} = (P_{DG} + P_{CB})$$

$$Q_{int} = (Q_{DG} + Q_{CB})$$

Equation (7)-(9) shows the Voltage across the receiving end, real power & reactive power losses after consideration of integrated DG with capacitor bank is

$$|V_{k+1}| = \frac{|V_k|+(|V_k|^2-4\left((P_{int}^2+Q_{int}^2)^{1/2}\right)(R^2+X^2)^{1/2}}{2} \tag{7}$$

$$P_{Loss(k,k+1)}^{DG} = \frac{((P_{k+1}-P_{int})^2+(Q_{k+1}-Q_{int})^2)}{|V_{k+1}|^2} * R \tag{8}$$

$$Q_{Loss(k,k+1)}^{DG} = \frac{((P_{k+1}-P_{int})^2+(Q_{k+1}-Q_{int})^2)}{|V_{k+1}|^2} * X \tag{9}$$

3.1 Forward/Backward Sweep Technique:

Further expansions of existing system need to calculate the system losses. Here Forward/Backward Sweep technique adapted to calculate the system losses.

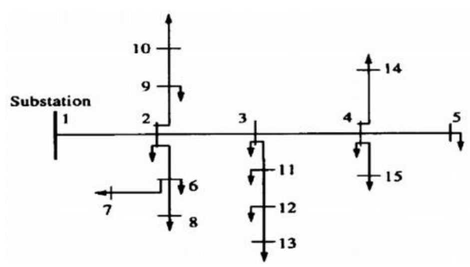

Figure 2: IEEE 15 bus test system

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The line currents are calculated by backward technique and are represented as I_1, I_2…I_n.

Load Current: $I = \frac{P_k - jQ_k}{V_k^*}$ (10)

Load Current: $I_{n-1} = I_n + \sum K = nI_K$ (11)

$V_{n+1} = V_n - Z_n * I_n$ (12)

3.2 Modified Distribution System

In addition to increasing actual and reactive power losses, the distribution system's low voltage profile is caused by the exponential growth of load uncertainty and power consumption. In order to maintain the voltage stability for reliable amount of power supply to the stack holders, the distribution generation (DG) portion of energy generation rose. In the radial distribution system, placement of DG helps to boost the buses' range voltage and lowers power losses.

The following equations depict the real and reactive power demands using voltage-dependent load modeling, taking into account voltage variations with respect to time. [14]

$P_{d,k}(t) = P_{d,k(0)} * V_{k(t)}^{\propto}$ (13)

$Q_{d,k(t)} = Q_{d,k(0)} * V_{k(t)}^{\beta}$ (14)

3.3 DG & EV Charging Stations Modeling [19]

In this case, real and reactive power correction is done using Capacitor Bank and wind systems.

3.4 Modeling of distribution generation

Synchronous generators or wind farm

$P_{di,new} + jQ_{di,new} = (P_{di,new} - P_{DG,i}) + (Q_{di,new} \pm Q_{DG,i})$ (15)

3.5 Modeling of the Wind system

$P_{spv}^{rated} * \frac{G_t}{1000} = P_{spv}$ (16)

Where G_t : Global irradiance incident on the tilted plane (W/m^2)

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

Table 1: Details of Modified RDS

Bus No.	Category	Wind	EV Stations
1	-	-	-
2	Commercial	50%	-
3	Commercial	-	-
4	Industrial	50%	DC3
5	Industrial	-	-
6	Industrial	-	DC2
7	Industrial	-	DC2
8	Residential	-	-
9	Residential	-	-
10	Residential	-	-
11	Residential	-	-
12	Residential	-	-
13	Residential	-	-
14	Residential	-	-

3.6 Objective Function

Power losses in the RDS directly depend on the system voltage profile. Lower voltage profile in the RDS leads to higher losses in general. In this paper, the system voltage levels are improved by adjusting the distribution transformer tap settings using PSO algorithm. Here, minimization of power losses are considering as an objective and it is represented as

$$\min F(x) = \frac{1}{f(x)}; f(x) \neq 0$$

Here line current, bus voltage, real & reactive powers are treated as variables.

Transformer tap settings upper and lower limits are 0.9 and 1.10 P.U.

Table 2: Rating & Levels of EV Charging Station

Source	Level	Power (KW)	Supply
DC	Level 1 (DC 1)	36	200-450V, 80A
	Level 2 DC 2)	96	200-450V, 210A
	Level 3 DC 3	200	200-600V, 210A

4. RESULTS AND DISCUSSION

Here the result shows the minimized power losses in RDS. The voltage dependent load modeling is considered as the base case in further cases after comparison of constant power model. The standard IEEE 15 bus test system is modified by considering the EV charging station in the RDS based on the voltage profile. But the load uncertainty introduced by the EV charging stations with two different levels in the form of DC source.

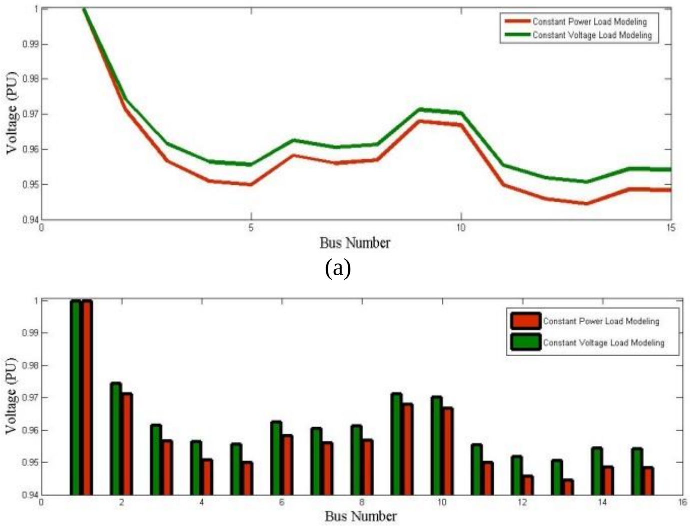
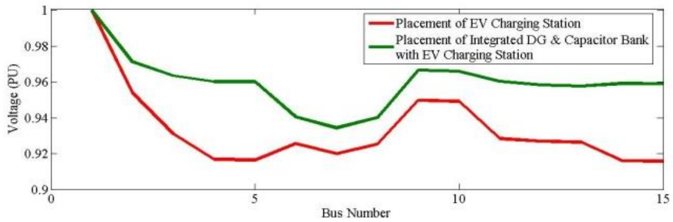
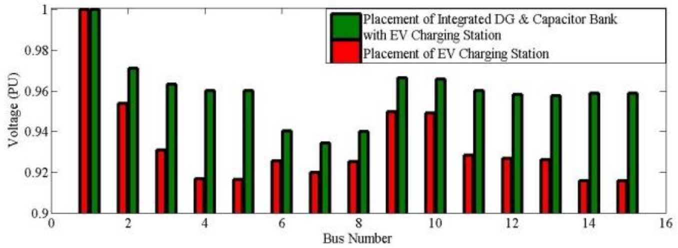


Figure 3: Comparison of constant power & Voltage load modeling voltage profile

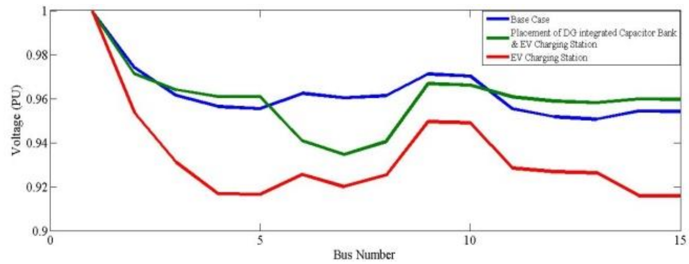


(a)

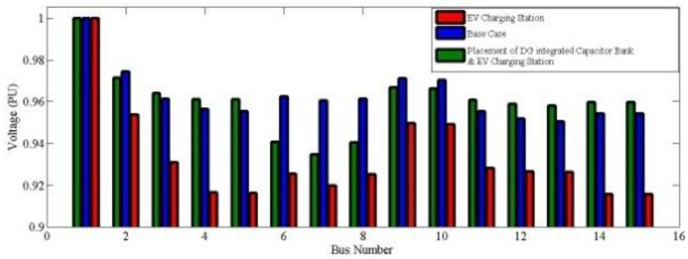


(b)

Figure 4: response of distribution system voltage profile after placement of EV charging station & Integrated DG with capacitor



(a)



(b)

Figure 5: Comparison of Distribution system bus voltage profile

Two types of static load models *i.e.*, constant power & voltage load models are considered, with help of forward backward sweep technique the losses and voltage magnitude of the each bus in the DS are calculated. Constant voltage model offers the low power losses (both active and reactive power) and healthy voltage profile when compared with constant power load model as shown in *figure 3*. Constant voltage load model is considered as base case, the distribution system is modified by adding 296 KW amount of load in the name of EV DC type charging stations in the RDS on bus numbers 4, 6,7 based on the voltage profile. The EV charging station offers the load uncertainty and it leads to increase the both real and reactive power losses. To avoid the voltage collapse and voltage instability integrated DG & CB combination is considered, located in the distribution system. It results improvement of voltage profile and reduction of power losses in the distribution system as observed in *figure 4*.

Table 3: Comparison of Power losses & Voltage levels in Distribution System

	Constant Power Modelling	Constant Voltage Modeling (Base Case)	EV Charging Station Placement	EV Charging Station & Integrated DG with CB	PSO based Distribution Transformer Tap Settings
Real Power loss (KW)	61.7873	56.0592	271.87	115.40	110.56
Reactive Power loss (KVAr)	57.2905	44.4975	249.68	96.905	90.761
Max. Voltage	0.97128 & 2	0.97260 & 2	0.95490 & 2	0.97138 & 2	0.99138 & 2
Min. Voltage	0.94451 & 13	0.94722 & 13	0.917205 & 15	0.93515 & 7	0.94515 & 13

Table 2 shows the proposed approach i.e., PSO based changing of tap settings of distribution transformer, this approach helps improve the minimum voltage value in distribution system and this better voltage profile helps to reduce the losses. Proposed approach shows the improvement of poor voltage profile and reduction of both real and reactive power losses in the RDS and it is shown in *figure 5*.

5. CONCLUSION

This paper discussed about power loss reduction in RDS using PSO based distribution transformer tap settings. The IEEE 15 bus system modified by placement of EV charging station to represent load uncertainty and integrated DG & CB combination helped to maintain the balance the RDS by maintaining acceptable voltage levels. The proposed approach examined on IEEE 15 bus distribution system & superior results obtained. These results are compared with and without optimizing transformer tap settings, by optimizing transformer tapings nearly 10% power loss reduction observed and also shown improvement in voltage levels of the various buses. The load uncertainty due to EV charging stations in the RDS is balanced by optimizing the tap settings.

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