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# Power Quality Improvement in Electrical Distribution Network

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***ABSTRACT:*** *The introduction of Distributed Generation (DG) in a distribution system offers several benefits to utilities, customers and society. However, the integration of these sources into the networks can cause some challenges regarding their expected impacts on the security and the dynamic behaviour of the entire network. This paper presents the Modified Particle Swarm Optimization algorithm (MPSOA) to determine the optimal location and size of Distributed Generation and Capacitor banks to maximizing the power quality by reducing the line losses and increasing the voltage stability of the various buses. The adaptive feature of Swarm particles in search space at each iteration is employed to determine the particles' exploration and exploitation capacity at successive iterations. This guaranteed convergence at global optimum rather than the local minimum. The proposed algorithm was developed and implemented on Matlab software with performance analysis using standard IEEE 33-bus radial distribution system. The results show a better improvement when the network was reconfigured with both DG and capacitor banks.*

***Keywords:*** *Distributed generation, Particle Swarm Optimization, Capacitor Banks, Power quality*

## I. INTRODUCTION

The current electric power industry is undergoing major changes from being centralized into decentralized generation. The advances in technology have created rapid growth in the utilization of distributed generation (DG) which leads to energy market becoming more attractive and competitive. The industry has been experiencing many changes leading to increasing complexity, interconnectivity and uncertainties [1]. Thus the grid system has become a focus of technological innovation, resulting in the emergence of new topologies that are envisaged to be so smart as to be resilient to the major shortcomings of conventional power system by being intelligent and self-healing. The rapid rise on the issue is leading to the fast growth in DG technology markets such as in fuel cells (FC), photovoltaic (PV), wind turbine (WT), small-scale hydro plant and energy storage (ES) [2]. Consequently, the trend will have profound impact on future electricity technology which allows advanced power electronic devices to be installed and embedded throughout the network. This is the challenge where current bulk generation and DG will co-exist with higher power reliability and quality.

Conventionally, shunt capacitors are used as reactive power compensators in electrical networks. The main benefits of their utilization are to minimize the power and energy losses, improve power factor and maintain best voltage regulations for all load buses [3]. The problem of the optimal placement and sizing of capacitors in electrical networks appears generally in radial distribution systems. Therefore, defining the optimal number, location and size of capacitor banks to maximize the voltage profile, while maintaining required high quality operating condition is imperative. Power quality (PQ) is a term that refers to maintaining the near sinusoidal waveform of power distribution bus voltages and currents at rated magnitude and frequency. It is often used to express voltage quality, current quality, reliability of service etc. However, voltage quality and power losses form the fundamental upon which others are influenced [4].

Different methods and algorithms had been employed by authors on power quality improvement with DG and capacitor banks on electrical distribution system. In [5] analytical approach was presented which has limitation in handling a large network [6], numerical programming and heuristic methods demonstrated in [7,8]. Generally, in most formulations, the objective function is to minimize the real power losses and improve voltage while abiding into both equality and inequality constraints equations in terms of voltage and power. The drawback of their work is the lengthy process of finding candidate locations and the fact that they sought to optimize only DG without considering any conventional devices. In this paper, a coordinated framework that exploited the benefit accrued to DG and Capacitor banks as a way of expansion planning in radial distribution network is considered. This involved modelling the DG, capacitor and formulation of nonlinear multi-objective optimization based on MPSO for the minimization of power losses and maximization of voltage stability.

## II. PROBLEM FORMULATION

The problem to select the best places for installation and the preferable size of DG unit and Capacitor banks is a complex discrete optimization problem. The first step in an optimization procedure is to define the objective function. A multi-objective function is stated on the basis of power loss indices and voltage stability index as follows:

The power loss index (PIL) = $ILP = \frac{|P_L| - |P_{LDG\&Cap}|}{|P_L|}$ (1)

$P_L$ is the real power losses without any compensating devices and $P_{LDG\&Cap}$ is the real power losses after the addition of DG and capacitor banks. The voltage stability index which incorporates correctly the effect of real and reactive power increase scenario is mathematically expressed as:

$$\boldsymbol{LS1} = \frac{2\frac{B}{A}\sqrt{(P_m^2 + Q_m^2}}{\frac{V_k^2}{A^2} - 2\frac{B}{A}P_m \operatorname{Cos}(\beta_1 - \alpha_1) - 2\frac{B}{A}Q_m Sin(\beta_1 - \alpha_1)} \le \mathbf{1} \tag{2}$$

Where $LS_1$ is termed as voltage stability index of the $i^{th}$ value, $P_m$, $Q_m$ are the real and reactive power at receiving end respectively in p.u. and $\mathbf{V}_K$ is the voltage magnitude at sending end in p.u. $A < \alpha_1$ $and B < \beta_1$ are transmission line constraints. As long as the above index is less than unity, the system is stable. However, at collapse point it will be unity. The objective function is set up considering power losses and voltage stability respectively:

$$\min\ f_1 = \sum_{i=1}^{N} I_i^2 R_i \qquad i \in 2,\ldots,N \tag{3}$$

$$\max\ f_2 = \frac{1}{LS_1} \qquad i \in 2,\ldots,N \tag{4}$$

Where $f_1$ and $f_2$ are the factors considered. The objective function is subject to standard power balancing equality constraints as well as the following additional inequality constraints: Bus voltage magnitude, real and reactive power output limits are given below respectively:

$$V_{i\min} \le V_i \le V_{i\max} \tag{5}$$

$$P_{i\min} \le P_i \le P_{i\max} \tag{6}$$

$$Q_{i\min} \le Q_i \le Q_{i\max} \tag{7}$$

### 2.1 Optimal siting and sizing of DG and capacitor banks

The optimal sitting and sizing problem of distributed generation and capacitor banks are formulated as a multi-objective constrained optimization problem. This paper uses novel combination of linearly decreasing inertial weight strategy with particle adaptability in search space to overcome the weakness of premature convergence to local minimum. Shi and Eberhart (2) presented constant inertia weight (IW) and established that large inertia weight facilitates global search while small inertial weight facilitate a local search. Other researchers work on dynamically adjustable IW, random inertia strategy, linearly decreasing and linearly increasing strategy. The present work employed the linearly decreasing IW starting with large inertial value and subsequent introduction of particle adaptability based on success rate in search space of 50% and above of the total iteration. The success rate of the particles is expressed as:

$$S(i,it) = \begin{Bmatrix} 1, if\ pbest_i^{it} > pbest_i^{it-1} \\ 0, \quad otherwise \end{Bmatrix} \tag{8}$$

$$P_s(it) = \frac{\sum_{it}^{n} s(i,it)}{n} \tag{9}$$

Where s(i,it) is success of particle i at iteration it, $p_s(t)$ is percentage of particle that move towards optimum solution. The percentage of particle success is fed back from 50% and above of total iteration as:

$$iw(t) = (w_{\max} - w_{\min})P_s(t) + w_{\min} \quad (10)$$

## III. METHODOLOGY

The power flow analysis of the proposed network using Newton-Raphson method was carried out incorporated with developed modified particle swarm optimization algorithm. The searching technique developed was for optimal sitting and sizing of DG and capacitor banks. Results for the DG and capacitor banks were computed using Matlab software in term of voltage stability and power losses with comparative analysis between DG and capacitor banks integration. PSO has the fast convergence ability which is a great attractive property for a large iterative and time consuming problem. The computation flow chart is represented in figure 1.

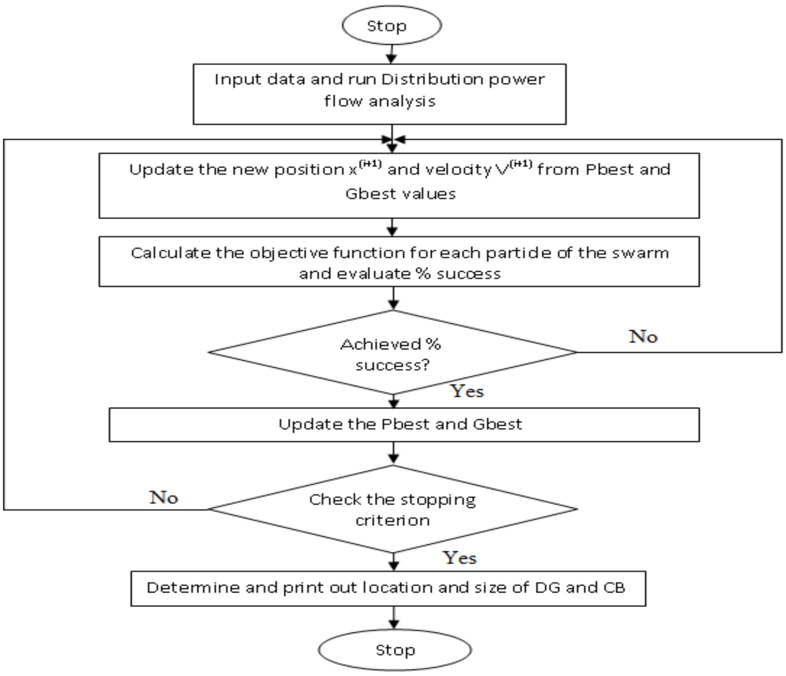


**Figure 1:** Modified PSO flow chart

## IV. RESULTS AND DISCUSSION

The presented algorithm was implemented and coded in Matlab computing environment. In order to evaluate the proposed algorithm, the 33kV 33-bus IEEE distribution system is such that the objective function is minimized. The DG was first introduced after which the network was reconfigured with capacitor banks and a comparative analysis was made. Figure 2 shows the power loss reduction with and without installation of DG using modified PSO. It was observed that the highest percentage reduction was at $27^{th}$ bus with 75.61%. Figure 3 shows the power loss without and with capacitor banks configuration. The highest loss reduction was at $18^{th}$ bus with 75.1%

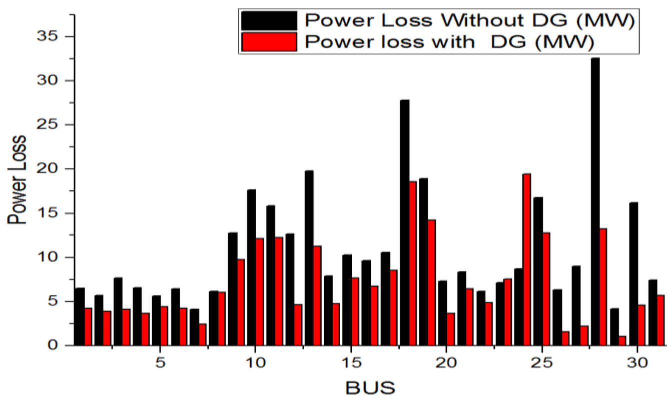


**Figure 2:** Power loss without and with DG installed

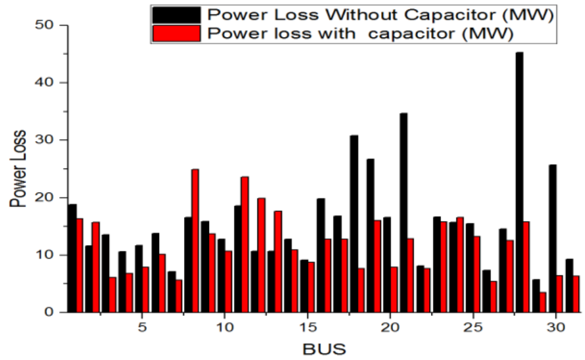


**Figure 3:** Power loss without and with Capacitor banks installed

The stability index profile produced a better performance with capacitor banks compare to the use of DG as presented in figure 4.

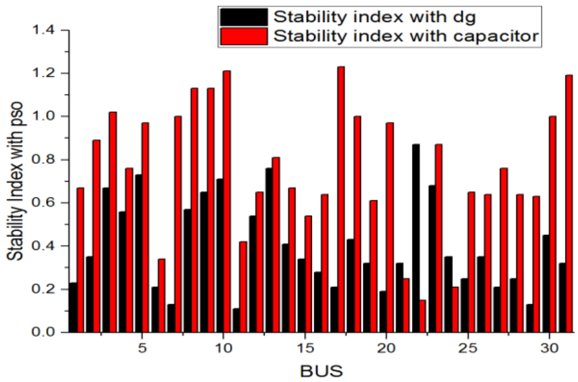


**Figure 4:** Voltage stability index with DG and Capacitor banks

The overall power loss improvement with the use of DG is 33.4% compare to 26.0% when Capacitor banks were installed.

## V. CONCLUSION

The study shows the application of the Modified Particle Swarm Optimization method to solve the problem of optimal placement and sizing of multiple DG and capacitor on power network. The algorithm is able to find the optimal solutions with a relatively small number of iterations, hence with a reasonable computational effort. The simulation results show that multiple DG and capacitor can be used for improving voltage profile as well as reducing the losses by leaving sufficient amount of reactive reserves at generator buses.

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