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Active Power Loss Minimization Using Simultaneous Network Reconfiguration and DG Placement with AGPSO Algorithm

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Abstract-* This paper presents a new approach has been proposed to solve network reconfiguration in the presence of distributed generation (DG) in distribution system with an objective of minimization real power loss and improving voltage profile of the consumers connected to radial distribution network. Improper allocation of DG sources in power system would not only lead to increase power losses, but can also jeopardize the system action. The finest position of DG is needed for the minimization of losses and improving reliability and stability in power system. In order to overcome the drawbacks of mathematical optimization practices, soft computing algorithms have been actively introduced during the past decade. In this paper AGPSO algorithm is proposed to solve the network reconfiguration problem which gives optimal switching combination and also the same used to calculate the optimal size of DG to minimize power loss in the distribution system. Sensitivity study is used to recognize corresponding optimal location for installation of distributed generation (DG). The proposed method was examined on distribution network consisting of 33 and 69- bus radial distribution systems at different load levels to verify efficacy of the planned method, the outcome shows that the planned method is fast and effective.
***Keywords* – Distributed Generation, Reconfiguration, Harmony Search Algorithm, Sensitivity Analysis, Autonomous Groups Partical Swarm Optimization**

I. INTRODUCTION

As distribution systems are growing large and being stretched too far, which leads to higher system losses and poor voltage regulation. This means that distribution systems are divided into subsystems of radial feeders, which contain a number of normally closed switches and a number of normally open switches. Due to uncertainty of system loads on different feeders, the loss minimum reconfiguration problem in the open loop radial distribution system is basically one of the complex combinatorial optimization; there is need for reconfiguration of the network from time to time. It is known that distribution network are built as interconnected harmonized networks, while in the process they are prearranged into a radial tree arrangement. Distribution systems are configured radiating. Their configurations may be assorted with manual or automatic switching operations so that all the loads are supplied with electric power. This results in reduced power loss, increased system security and enhancement of power quality. The change in network configuration is performed by opening sectionalizing and closing tie switches of the network under normal and abnormal operating conditions. Reconfiguration also relieves the over loading of the network components but voltage profile will not be improved to the required level. In order to meet energy demand distributed generation devices can be strategically placed in power systems for grid reinforcement, reduction of power losses and on-peak operating costs, improvement of voltage profiles and also load factor of the system. Distributed power generation is a technology that could help to enable efficient, renewable energy production both in developed and developing world. Distributed generation is an electric power source connected directly to the distribution network or on the customer site of meter. DG technologies include diesel engines, heat combustion engines, small wind turbines, fuel cells and photovoltaic system. DG technologies can run on renewable energy possessions, relic fuels or dissipate heat. The size of DG equipment ranges from less than a KW to tens of MW. DGs are actually replacing the more costly grid electricity. DG can be rotating devices directly coupled to the network, or they can be rotating or static devices interfaced via electronic converters Inappropriate DG placement may increase system losses, network capital and operating costs. Optimal DG placement can improve network performance in terms of voltage profile, reduced system losses and improvement of power quality and reliability of supply. Depending on the number of DGs to be installed, the optimal DG placement problem is classified as single DG or multiple DG s installation. Optimal DG placement problem is very interesting in the smart grid system, where the usage of

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renewable energy is expected to increase. It is interesting to investigate network reconfiguration with simultaneous placement of DGs, which are dependent on each other. Such a coordinated planning can provide maximum benefits for the network owner and/or the network users. A heuristic iterative search technique is developed that optimizes the weighting factor of the objective function and maximizes the potential benefit to the optimal DG placement.

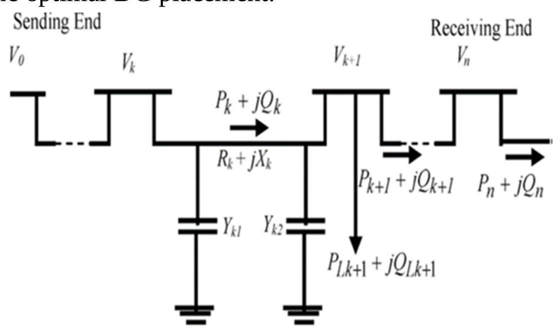

Fig. 1. Single-line diagram of a main feeder.

II. FORMULATION OF OPTIMIZATION PROBLEM

A. Power Flow Equations

The power losses in the distribution systems are real power loss and reactive power loss. The total real power loss (I^2R loss) in a balanced distribution system consisting of *b* branches can be written as

$$P_{LT} = \sum_{i=1}^{b} I_i^2 R_i \qquad (1)$$

Where I_i is the branch current and *R* is the resistance of the i^{th} branch of the network.

$$I_i = I_a + j * I_r \qquad (2)$$

The branch current I_i is the active part of the branch Current I_a and reactive part of branch current I_r in the network can be obtained from the load flow solution of the network. The total I^2R loss P_{LT} can be separated in to two components P_{LA} and P_{LR} based on the active and reactive components of branch currents. The power loss components can be defined as

$$P_{LA} = \sum_{i=1}^{b} I_{ai}^2 R_i \qquad (3)$$

$$P_{LA} = \sum_{i=1}^{b} I_{ri}^2 R_i \qquad (4)$$

The power loss in the line section connecting buses and *k+1* may be computed as

$$P_{Loss}(k, k+1) = R_k \cdot \frac{(P_k^2 + Q_k^2)}{|V_k|^2} \qquad (5)$$

The network reconfiguration problem in a distribution system is to find a best configuration of radial network that gives minimum power loss while the imposed operating constraints are satisfied, which are voltage profile of the system, current capacity of the feeder and radial structure of distribution system.

B. Power Loss Using Network Reconfiguration

The network reconfiguration plays a vital role in finding the radial operating structure in order to minimize the system power losses and at the same time maintaining operating constraints, such as voltage profile of the system, current carrying capacity of the feeder and radial structure of distribution system. After reconfiguration, the power loss in the line section with buses k and k+1 is calculated as follows

$$P'_{Loss}(k, k+1) = R_k \cdot \frac{(P_k'^2 + Q_k'^2)}{|V_k'|^2}. \qquad (6)$$

The total real power loss of the all lines sections in n bus system ($P_{T,Loss}$) is calculated by adding up the losses of all line sections of the feeder, which is described as,

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$$P'_{T,Loss} = \sum_{k=1}^{n} P'_{Loss}(k, k+1). \qquad (7)$$

C. Loss Reduction Using Network Reconfiguration

Net power loss reduction in the system is the variance of power loss before and after reconfiguration, that is equations (5) − (7) and is given by

$$\Delta P_{Loss}^{R} = \sum_{k=1}^{n} P_{T,Loss}(k, k+1) - \sum_{k=1}^{n} P'_{T,Loss}(k, k+1). \qquad (8)$$

D. Power Loss Reduction Using DG Installation

Distributed generation units' installation in optimal location of a distribution system results in various benefits. These contain Supplying peaking power to reduce the cost of electricity, reduce environmental emissions through clean and renewable technologies (Green Power), combined heat and power (CHP), high level of reliability and quality of supplied power and deferral of the transmission and distribution line investment through improved load ability are the major applications of the DG. Other than these applications, the major application of DG in the deregulated environment lies in the form of ancillary services.

The power loss when a DG is installed at an arbitrary location, the power loss is given by,

$$P_{DG,Loss} = \frac{R_k}{V_k^2}(P_k^2 + Q_k^2) + \frac{R_k}{V_k^2}(P_G^2 + Q_G^2 - 2P_kP_G - 2Q_kQ_G)\left(\frac{G}{L}\right). \qquad (9)$$

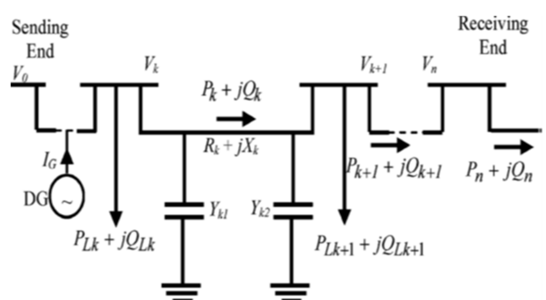

Fig. 2. Distribution system with DG installation at an arbitrary location.

Net power loss reduction is the variance of equations (9) and (16) is given by,

$$\Delta P_{Loss}^{DG} = P_{DG,Loss} - P_{line\ loss}$$

$$\Delta P_{Loss}^{DG} = \frac{R_k}{V_k^2}(P_G^2 + Q_G^2 - 2P_kP_G - 2Q_kQ_G)\left(\frac{G}{L}\right). \qquad (10)$$

The positive sign of ΔP_{Loss}^{DG} indicates that the system loss reduces with installation of DG. In difference the negative sign of ΔP_{Loss}^{DG} denotes that DG origins the higher system loss.

E. Objective Function Of The Problem

The objective function of the problem is expressed to maximize the power loss reduction in distribution system while subjected to power balance constraints and power generation limit. Which is given by

$$\text{Maximize the } f = \max\cdot(\Delta P_{Loss}^{R} + \Delta P_{Loss}^{DG}) \qquad (11)$$

The bus voltage magnitudes are to be kept within acceptable operating limits throughout the optimization process, as follows, that means voltage constraints should be satisfied, as given below, subjected to

$$V_{min} \leq V_k \leq V_{max}$$

And feeder capability limits

$$|I_{k,k+1}| \leq |I_{k,k+1,max}| \quad \} \quad (12)$$

Generator operator constraints

$$\sum_{k=1}^{n} P_{Gk} \leq \sum_{k=1}^{n} (P_k + P_{Loss,k})$$

Radial structure of the system

$$\det(A) = 1 \; or -1 \; (radial\ system)$$
$$\det(A) = 0 \; (not\ radial) \quad \} \quad (13)$$

Where the lower bound of bus voltage limits is V_{min} and V_{max} is the upper bound of bus voltage limits.

III. SENSITIVITY ANALYSIS FOR DG INSTALLATION

Sensitivity factor method is based on the principle of linearization of original nonlinear equation around the initial operating point, which helps to reduce the number of solution space. Loss sensitivity factor method has been widely used to solve the capacitor allocation problem [12]. Sensitivity factors [13] are evaluated at each bus to install DG units, firstly using the values obtained from the base case power flow. The fig shows a line impedance of $R_K + jX_K$ between k-1 and k buses connected to the load of$P_{LK,eff} + jQ_{LK,eff}$. The active power loss in kth line as shown in equation [1].

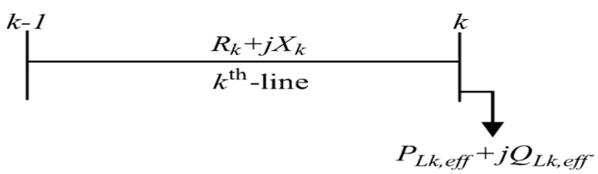

Fig.3. connected line between bus k-1 and k

$$P_{Loss} = [I_k^2] \times R_k \quad (14)$$

Where the branch current is I_k and R is the resistance of line. In addition,

$$I_k = \left[\frac{P_{Lk,eff} + jQ_{Lk,eff}}{V_{Lk,eff}}\right]^* \quad (15)$$

Where P, Q, V are the real power load and reactive power load, voltage at the receiving end. By substituting equation (15) in (14) as given follows, Active power loss in the k^{th}-line between k-1 and k buses is given by,

$$P_{lineloss} = \frac{(P_{Lk,eff}^2 + Q_{Lk,eff}^2)R_k}{V_k^2} \quad (16)$$

The sensitivity factor of real power loss is obtained by differentiating equation (16) with respect to real power injection from DG at bus k which is given by as follows,

$$\frac{\partial P_{lineloss}}{\partial P_{LK,eff}} = \frac{2 * P_{LK,eff} * R_K}{V_K^2}. \quad (17)$$

Using above equation (17), LSFs are computed from load flows and values of the buses are ranked in descending order of the values of their sensitivity factors to form a priority list. The top-ranked buses in the priority list are most sensitive to DG placement in order to have the best effect on loss reduction.

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IV. AUTONOMOUS PARTICLES GROUPS FOR PARTICLE SWARM OPTIMIZATION

In this paper, a modified particle swarm optimization (PSO) algorithm called autonomous groups particle swarm optimization (AGPSO) is projected to further improve the two problems of trapping in local minima and slow convergence rate in solving high-dimensional problems.

The main proposal of AGPSO algorithm is inspired by individual's diversity in bird flocking or bug swarming. In natural colonies, individuals are not basically fairly parallel in terms of intelligence and ability, but they all do their duties as members of a colony. Each individual's capability can be useful in a particular state. In this paper, a mathematical model of diverse particles groups called autonomous groups is proposed. In other words different functions with diverse slopes, curvatures, and interception points are employed to tune the *group and cognitive* parameters of the PSO algorithm to give particles different behaviors as in natural colonies. The results show that PSO with autonomous groups of particles outperforms the conventional and some latest modifications of PSO in terms of avoidance local minima and convergence speed. The results also show that dividing particles in groups and allowing them to have different individual and social thoughts can improve the performance of PSO considerably.

V. SIMULATION RESULTS FOR AGPSO ALGORITHM

The main idea is to get best combinations of open/closed switches and place an optimal size of DGs at sensitive buses so that the combined network must give minimum real power loss and improve the voltage profile in the system. The algorithm was developed in MATLAB and simulations are carried out. AGPSO algorithm with, and without for light and nominal, heavy load for IEEE 33 and 69-bus systems for improving voltage profile and loss reduction.

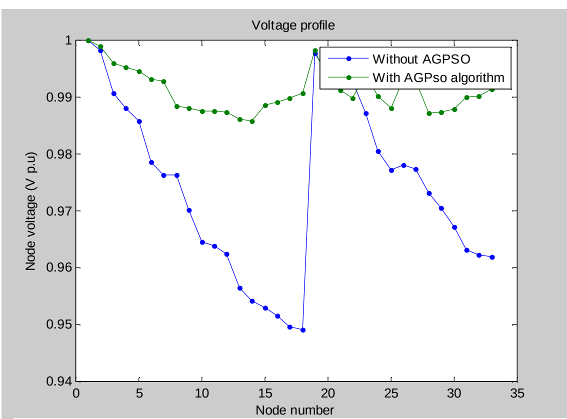

Figure 4: voltage profile of the 33-bus test system for light load(0.5) using with and with out AGPSO

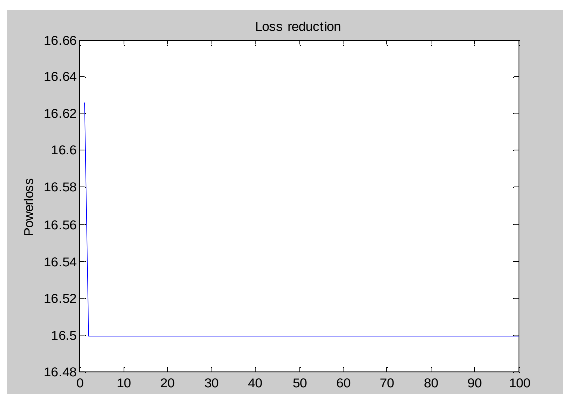

Figure 5: loss reduction for 33bus test system for light load (0.5) using AGPSO algorithm

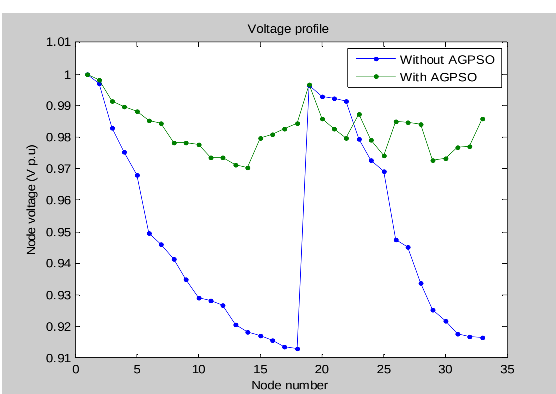

Figure 6: voltage profile of the 33-bus test system for nominal load(1.0) using with and with out AGPSO

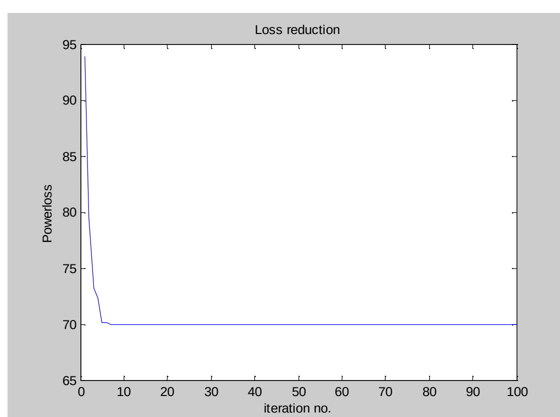

Figure 7: loss reduction for 33bus test system for nominal load (1.0) using AGPSO algorithm

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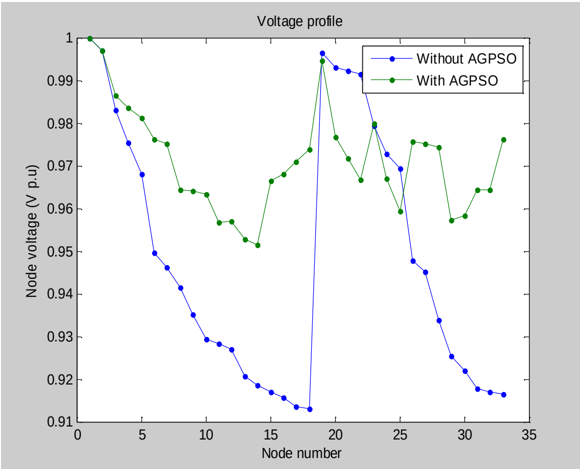

Figure 8: voltage profile of the 33-bus test system for heavy load(1.6) using with and with out AGPSO

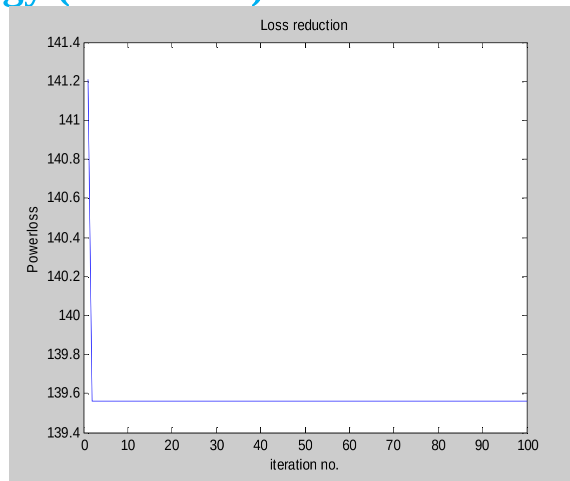

Figure 9: loss reduction for 33bus test system for heavy load (1.6) using AGPSO algorithm

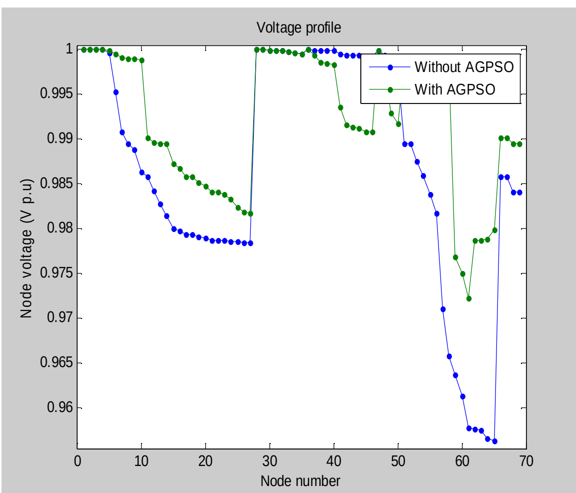

Figure 10: voltage profile of the 69-bus test system for light load(0.5) using with and with out AGPSO

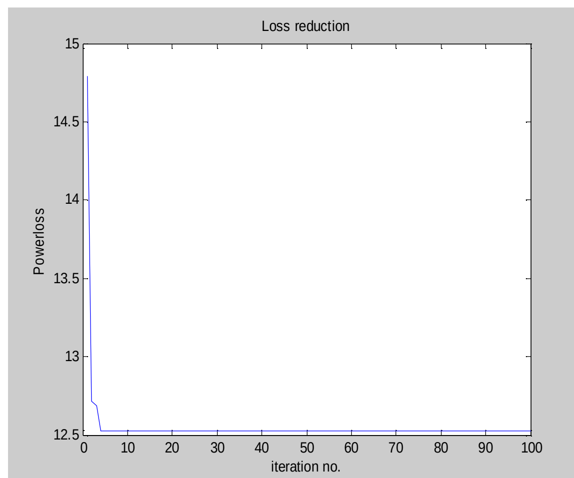

Figure 11: loss reduction for 69-bus test system for light load (0.5) using AGPSO algorithm

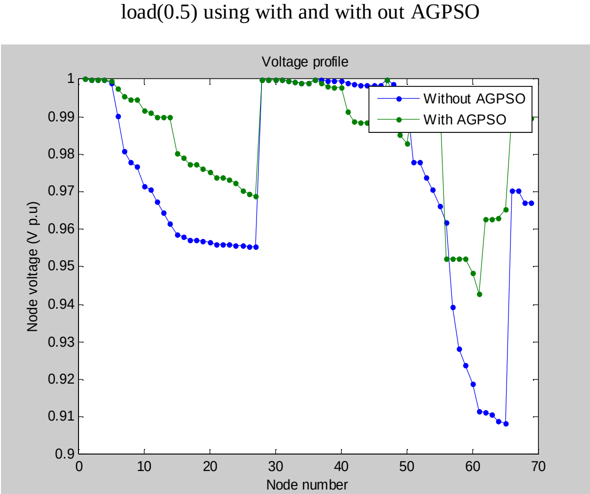

Figure 12: voltage profile of the 69-bus test system for nominal load(1.0) using with and with out AGPSO

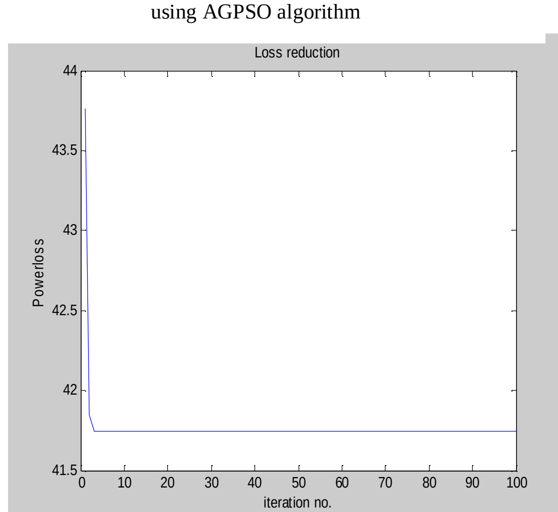

Figure 13: loss reduction for 69-bus test system for nominal *load (1.0) using AGPSO algorithm*

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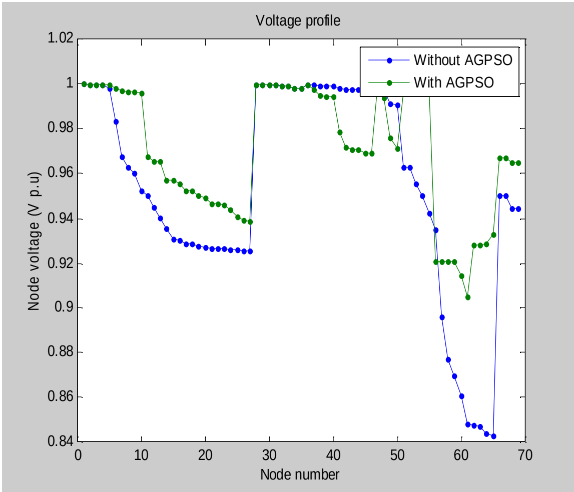

Figure 14: voltage profile of the 69-bus test system for heavy load(1.6) using with and with out AGPSO

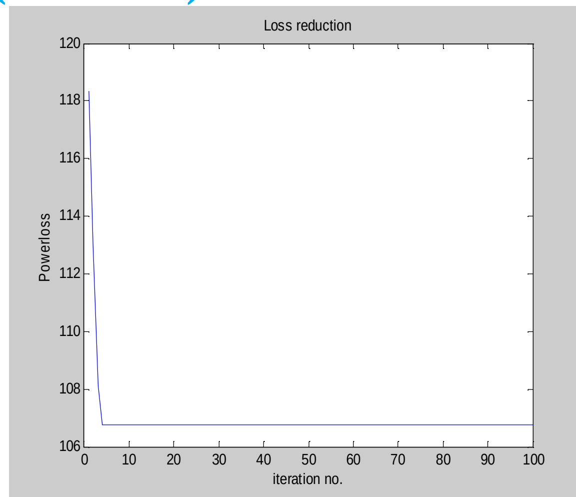

Figure 15: loss reduction for 69-bus test system for heavy load (1.6) using AGPSO algorithm

VI. CONCLUSION

A new algorithm has been presented to solve the network reconfiguration problem in the presence of distributed generation (DG) for minimizing the real power losses. An AGPSO algorithm is used in the optimization process of the network reconfiguration and DG installation. The proposed method is tested on an IEEE test systems at different load levels, light, nominal and heavy. The results show that simultaneous network reconfiguration and DG installation method is more effective in reducing power loss and improving the voltage profile compared to other methods. The ratio of percentage loss reduction to DG size is highest when number of DG installation locations is three. In earlier approaches, network reconfiguration and DG placement in distribution networks are considered independently. However, in the proposed method network reconfiguration and DG installation are dealt simultaneously for improved loss minimization and voltage profile.

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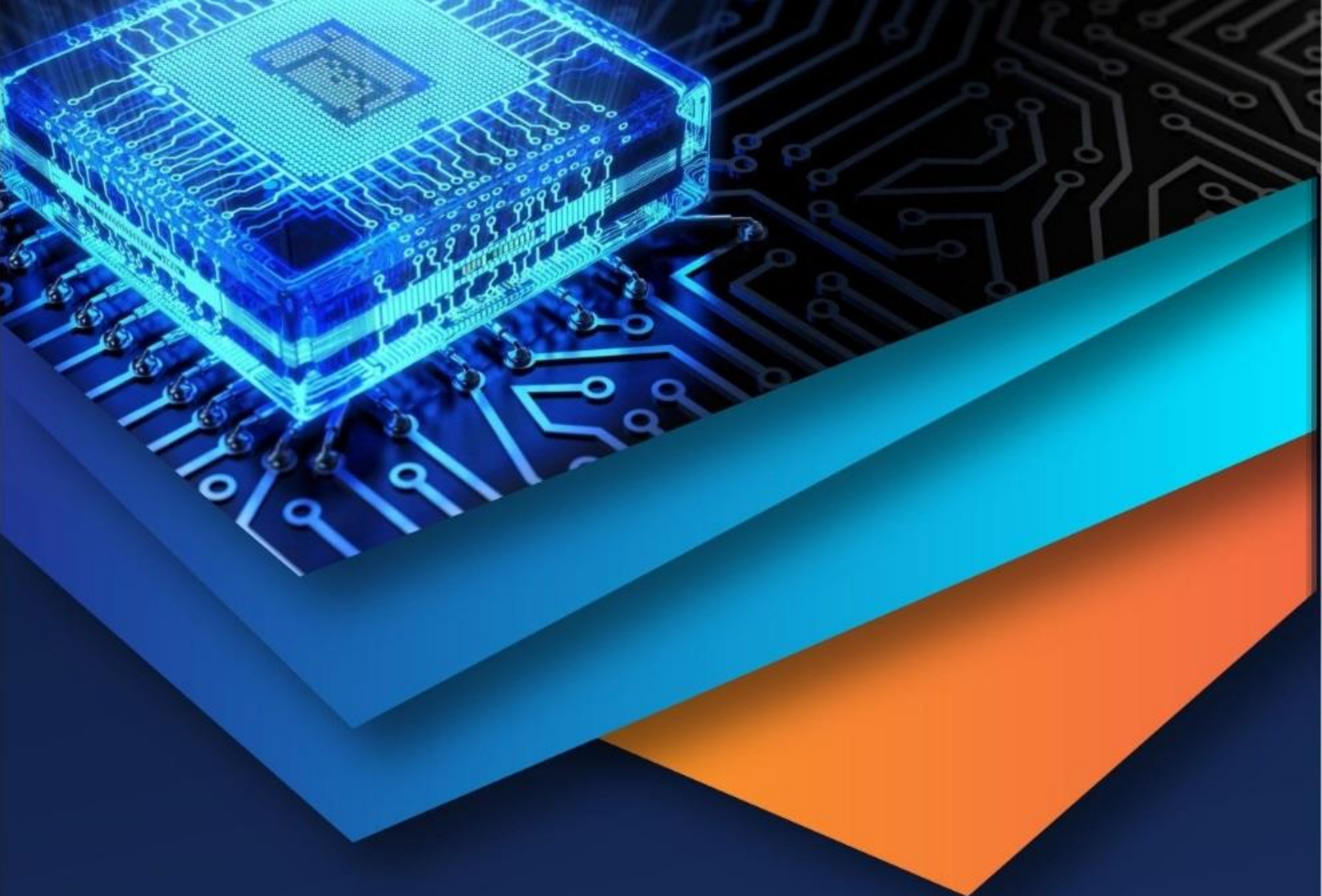

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