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Impact of Distributed Generation in power system using Particle Swarm Optimization

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ABSTRACT

Distributed generation (DG) is a new trend of technology that can enhance the availability of power, and improve the quality of power supply to consumers. This paper present particle swarm optimization (PSO) methodology to assess the impact of DG on losses and voltage profile in Port Harcourt 33kV Power Distribution System. The load flow analysis using Newton Rapshson Method in Etap software identified weak buses and thus helps in reducing the search space for the algorithm, making it to converge faster. PSO algorithm identified the optimal placement of DGs which resulted in the improvement of voltage profiles and losses. The Line Loss Reduction Index (LLRI) and Voltage Profile Improvement Index (VPII) were the indices used to attest PSO result. Results show that with PSO, LLRI is (0.464MW and 0.499Mvar) and VPII is greater than 1.07 in all the buses. This indicates that DGs has reduced electrical line losses, improved the voltage profile of the system and impacted positively in the network.

Keywords: Distribution generation, Voltage profile improvement index, Line loss reduction index, Particle Swarm Optimization.

INTRODUCTION

Power availability is a big determinant and key indicator to a nation's growth due to its use in almost every area of the nation's development. Nigeria as a nation has been experiencing a lot of setbacks in its economy due to unavailability of power. The power problems had led to business collapses, loss of jobs and lack of investors. In a bid to improve the power situation in Nigeria, the power sector is increasing the number of generating stations and upgrading the transmission and distribution infrastructure which can be seen as a long term capital intensive. Distributed generation implies the use of small, modular, decentralized, off- grid or grid connected generators placed at various locations in the distribution network providing the electricity locally to consumers. The purpose of these small- scale power plants is to deal with the growing demand for electricity especially in areas not covered by the national grid and areas where the power system is overstressed.

Optimization is the act of obtaining the best results under given circumstances. In design, construction and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function. Optimization can be viewed as a process that searches methodically for better answers, better solutions, or better designs that a human being may not be able to find through experience, intuition, or courageous trial-and-error. Optimization can be defined as the art of making things better. Interestingly, optimization very often does not simply allow one to do something better, but it may also make it possible to do something that one did not otherwise know how to do. To take full advantage of the power of optimization in practice, there is no choice but to use a computer. The study of optimization typically takes a theoretical and/or computational approach. The theoretical approach is highly useful when the objective is to develop new optimization methods or to assess how the current methods work additionally; the study of optimization often focuses on the understanding of various search algorithms for optimization.

There is no single method available for solving all optimization problems efficiently. Hence a number of optimization methods have been developed for solving different types of optimization problems. The optimum seeking methods are also known as mathematical programming techniques. Mathematical programming techniques are useful in finding the minimum of a function of several variables under a prescribed set of constraints. Numerical methods can be used to solve highly complex optimization problems of the type that cannot be solved analytically. The discipline encompassing the theory and practice of numerical optimization methods has come to be known as mathematical programming. During the past 40 years, several branches of mathematical programming have evolved, such as: Linear programming, Integer programming, Quadratic programming, Nonlinear programming and Dynamic programming. Each one of these branches of mathematical programming is concerned with a specific class of optimization problems.

In recent years, some optimization methods that are conceptually different from the traditional mathematical programming techniques have been developed. These methods are labelled as modern or non-traditional methods of optimization. Most of these methods are based on certain characteristics and behaviour of biological, molecular, swarm of insects, and neurobiological systems.

The methods are: Genetic algorithms, Simulated annealing, Particle swarm optimization, Ant colony optimization, Fuzzy optimization, Neural-network-based methods. Most of these methods have been developed only in recent years and are emerging as popular methods for the solution of complex engineering problems. Most require only the function values (and not the derivatives). The genetic algorithms are based on the principles of natural genetics and natural selection. Simulated annealing is based on the simulation of thermal annealing of critically heated solids. Both genetic algorithms and simulated annealing are stochastic methods that can find the global minimum with a high probability and are naturally applicable for the solution of discrete optimization problems. The particle swarm optimization is based on the behaviour of a colony of living things, such as a swarm of insects, a flock of birds, or a school of fish. Ant colony optimization is based on the cooperative behaviour of real ant colonies, which are able to find the shortest path from their nest to a food source. In many practical systems, the objective function, constraints, and the design data are known only in vague and linguistic terms. Fuzzy optimization methods have been developed for solving such problems. In neural-network-based methods, the problem is modelled as a network consisting of several neurons, and the network is trained suitably to solve the optimization problem efficiently.

LITERATURE REVIEW

Different studies are presented in the literatures on the impact of DG placement in power system.

Chaw et al. (2015) presented a voltage stability based approach to determine the effect of distributed generation on Berlin distribution system with the aim of reducing power losses and improving voltage profile.

Hadi et al. (2011) presented an introduction of DGs and an overview of the impacts of DGs on system protection relay co- ordination. Increased fault current contribution and load flow changes are the major two impacts on utility system and should be taken into consideration when planning DG interconnection.

Rugthaicharoencheep et al. (2012) presented the technical and economic impacts of distributed generation on distribution system.

Basudev et al. (2013) presented a paper on the impact of distributed generation on reliability of distribution system. After penetration of DG, the passive distribution system becomes an active system. The reliability improvement is maximum if the DG is connected at a location from where it can meet the highest load demand.

Nigam et al. (2016) investigated the optimal location of distributed generation and its impacts on voltage stability. The disturbance in the voltage profile is improved by minimizing the real and reactive power losses with the help of STATCOM.

Quezada et al. (2006) investigated the impact of different DG technologies, penetration, and concentration levels on the energy losses of distribution network based on the different load flow methodologies. Ayres et al presented in (2009) a sensitivity-based methodology for evaluation the influence of DG integration on the power loss. The evaluation process is conducted for different penetration levels, different numbers of DG units, and the different operating modes of DG.

Atthapol et al. (2013). Investigated a reliability impact and assessment of Distributed Generation Integration to Distribution System. Both the location of DG and the capacity of DG was taken into account to reach optimal condition in order to create the suitability and fairness for both utility and DG.

Particle Swarm Optimization (PSO) Model

The PSO model consists of a number of particles moving around in the search space, each representing a possible solution to a numerical problem. Each particle has a position vector (X_i) and a velocity vector (V_i), the position pbest_i is the best position encountered by the particle (*i*) during its search and the position gbest is that of the best particle in the swarm group. A swarm consists of a number of particles "or possible solution" that proceed (fly) through the feasible solution space to explore optimal solutions. In each iteration the velocity of each particle is updated according to its best encountered position and the best position encountered among the group, using the following equation:

$$v_i^{(k+1)} = wv_i^{(k)} + c_1 r_1 (\text{pbest}_i - s_i^{(k)}) + c_2 r_2 (\text{gbest} - s_i^{(k)}) \quad (1)$$

The position of each particle is then updated in each iteration by adding the velocity vector to the position vector

$$s_i^{(k+1)} = s_i^{(k)} + v_i^{(k+1)} \quad (2)$$

Where:

$s_i^{(k)}$ is the current position of particle *i* at iteration k

$s_i^{(k+1)}$ is the modified position of particle *i* at iteration k+1

$v_i^{(k)}$ is the current velocity of particle i at iteration k

$v_i^{(k+1)}$ is the modified velocity of particle i at iteration k+1

pbest_i is the personal best of particle i

gbest is the global best of the group.

C_1, C_2 are acceleration coefficient

r_1 , r_2 are random numbers between 0 and 1

w is inertia coefficient.

METHODOLOGY

The Port Harcourt 33kV distribution network diagram, line data and bus data for the impact analysis is drawn from (Esobinenwu et al., 2019).

The Impact Of Distributed Generation On Power Distribution System

Distributed generation (DG) can be interconnected at the distribution substation bus that can increase power output in response to an increase in load demand. It can also boost the voltage at the substation bus thereby improving the voltage profile and improving the power quality of the network. A method to assess the impact of DG in distribution system is to investigate the behaviour of an electric distribution system, with and without the presence of DG. The difference between the results obtained in these two operating conditions, gives important information for both, companies in the electric sector and customers. These impacts could be positive or negative and are considered as the benefits and drawbacks of the distributed generation.

Line Loss Reduction Index (LLRI)

Another major benefit offered by installation of DG is the reduction in electrical line losses (Chiradeja, 2005). By installing DG, line currents can be reduced, thus helping to reduce electrical line losses. The proposed line loss reduction index (LLRI) is defined as:

LLRI = $\frac{LL_{W/DG}}{LL_{WO/DG}}$ 3

Where $LL_{W/DG}$ is the total line losses in the distribution system with the employment of DG and $LL_{WO/DG}$ is the total line loss in the distribution system without DG.

$LL_{W/DG} = 3\sum_{i=1}^{M} I_i^2 R D_i$ 4

Where, Ii is the per unit line current in distribution line i with the employment of DG, R is the line resistance (pu/km), D_i is the distribution line length (km), and M is the number of lines in the system. Similarly, $LL_{WO/DG}$ is expressed as

$LL_{WO/DG} = 3\sum_{i=1}^{M} I_i^2 R D_i$ 5

Where, Ii is the per unit line current in distribution line i without DG. Based on this definition, the following attributes are:
LLRI < 1 DG has reduced electrical line losses,
LLRI = 1 DG has no impact on system line losses,
LLRI > 1 DG has caused more electrical line losses.

Voltage Profile Improvement Index (VPII)

The inclusion of DG results in improved voltage profile at various buses. The Voltage Profile Improvement Index (VPII) quantifies the improvement in the voltage profile (VP) with the inclusion of DG (Joss et al., 2000). It is expressed as:

VPII = $\frac{VP_{w/DG}}{VP_{WO/DG}}$ 6

Based on this definition, the following attributes are used:
VPII<1, DG has no benefit
VPII = 1, DG has no impact on the system voltage profile,
VPIII > 1 DG has improved the voltage profile of the system.
Where, $VP_{W/DG}$, $VP_{WO/DG}$ are the measure of the voltage profile of the system with DG and without DG respectively.

RESULTS

Table 1: Line Loss Reduction Index (LLRI) with PSO

LOSSES	LLRI
LOSS(MW)	0.464
LOSS (MVar)	0.499

Table 2: Voltage Profile Improvement Index with PSO

Bus No	PSO	Bus No	PSO
BUS 7	1.13	BUS 51	1.16
BUS 9	1.09	BUS 52	1.16
BUS 16	1.08	BUS 53	1.16
BUS 20	1.16	BUS 54	1.18
BUS 21	1.19	BUS 55	1.16
BUS 25	1.10	BUS 56	1.16
BUS 26	1.09	BUS 57	1.18
BUS 27	1.08	BUS 58	1.19
BUS 28	1.18	BUS 59	1.06
BUS 31	1.06	BUS 63	1.09
BUS 37	1.08	BUS 64	1.09
BUS 39	1.13	BUS 65	1.10
BUS 41	1.08	BUS 66	1.18
BUS 42	1.17	BUS 67	1.20
BUS 44	1.08	BUS 68	1.20
BUS 48	1.16	BUS 69	1.19
BUS 49	1.16	BUS 71	1.15
BUS 50	1.08		

DISCUSSION

The installation of DGs resulted to a positive impact on the power system by improving the voltage profile and reducing losses. To achieve the benefit of DG, an optimization method capable of assessing the impact is a panacea. Particle swarm optimization is an artificial intelligent approach and a new trend of research methodology gaining global acceptance because of its reliability and convergence

CONCLUSION

The result of the line loss reduction index (LLRI) and Voltage profile improvement index (VPII) with PSO shows that DG impacted positively in the network and should be adopted by utility company for sustainable power supply to consumers.

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