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RESEARCH ARTICLE OPEN ACCESS

Impact of Dispersed Generation on Optimization of Power Exports

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ABSTRACT

Dispersed generation (DG) is defined as any source of electrical energy of limited size that is connected directly to the distribution system of a power network. It is also called decentralized generation, embedded generation or distributed generation.

Dispersed generation is any modular generation located at or near the load center. It can be applied in the form of rechargeable, such as, mini-hydro, solar, wind and photovoltaic system or in the form of fuel-based systems, such as, fuel cells and micro-turbines.

This paper presents the impact of dispersed generation on the optimization of power exports. Computer simulation was carried out using the hourly loads of the selected distribution feeders on Kaduna distribution system as input parameters for the computation of the line loss reduction ratio index (LLRI).

The result showed that the line loss reduced from 163.56MW to 144.61 MW when DG was introduced which is an indication of a reduction in line losses with the installation of DG at the various feeders of the distribution system. In all the feeders where DG is integrated, the average magnitude of the line loss reduction index is 0.8754 MW which is less than 1 indicating a reduction in the electrical line losses with the introduction of DG.

The line loss reduction index confirmed that by integrating DG into the distribution system, the distribution losses are reduced and optimization of power exports is achieved

The results of this research paper will form a basis to establish that proper location of distributed generation units have significant impact on their effective capacity.

Keywords: Dispersed generation, Line loss reduction ratio, Simulation, Optimization, Thermal losses, Penetration level, Dispersion level.

I. INTRODUCTION

Distribution generation may have a significant impact on the system and equipment operation in terms of steady-state operation, dynamic operation, reliability, power quality, stability and safety for both customers and electricity suppliers. This impact may manifest itself either positively or negatively, depending on the distribution system, distribution generator and load characteristics [[5], [9]].

DG placement impacts critically the operation of the distribution network. Inappropriate DG placement may increase system losses and network capital and operating costs. Optimal DG placement (OPDG) can improve network performance in terms of voltage profile, reduced flows and system losses, and improve power quality and reliability of supply [[11], [16]].

Installation of DG is a way to improve the power quality allowing customers and utility equipment more years of usage [[17], [18]].

The main aim of any utility is to increase overall efficiency from fuel to power delivery. Any new source of generation should increase the overall generation efficiency. [[19], [20]].

The method minimizes system losses during periods of high power transfer.

DG involves the interconnection of small-scale distributed energy resources with the main power utility at distribution voltage level. DG mainly constitutes non-conventional and renewable energy sources like solar PV, wind turbines, etc [8].

By producing power from distributed renewable sources and also reducing the distribution losses will help to reduce the output requirements from conventional a plant which in turn reduces the greenhouse gas emissions. Since DGs are placed near to the load centre, appropriately placing DGs in the distribution network will contribute to reduction of power losses [[4], [14]].

Installing DG units at no optimal places may result in an increase in system losses, costs, and therefore, having an undesired effect on the system. There may be many locations that do not have overload or voltage problems, where the DG can be located and provide the necessary control. As a result, using an optimization method capable of indicating the best solution for a given distribution network can be very useful for system planning engineers [[15],[6]].

DG plays an important role in the electric power system organization and market. Unlike traditional generation, the aim of dispersed generation is to generate part of required electrical energy on small scale closer to the places of consumption and interchanges the electrical power with the network [[1], [3]].

An increasingly widespread use of DG can be as a result of the following:

- It may be more economical than running a power line to remote locations
- It provides primary power with the utility providing backup and supplementary power
- It provides backup power during utility system outages for facilities requiring uninterrupted services.
- It provides higher power quality for electronic equipment
- For reactive supply and voltage control of generation by injecting and absorbing reactive power to control grid voltage
- For network stability in using fast response equipment to maintain a secured transmission system [7].

DG has some advantages and disadvantages.. Some of the advantages include the following [[10], [13]]:

- Improvement of energy reliability and system security,
- Prevention of investment in distribution and transmission infrastructure,

Some of disadvantages of DGs are [12]:

- Decentralizing and increasing transaction costs
- High investment cost which causes less competition compared to conventional systems,
- Operation and maintenance systems need new methods,

B. Thermal losses

Electrical power systems losses depend on the line resistance and currents and are usually referred to as thermal losses. The line resistances are fixed, the currents are a complex function of the system topology and the location of generation and load [2].

The complex power

$$S_i = P_i + i_J Q_i \tag{1}$$

$$P_i = V_i \sum_{j=1}^{n} Y_{ij} V_j cos(\delta i - \delta j - Yij) \tag{2}$$

$$Q_i = V_i \sum_{j=1}^{n} Y_{ij} V_j sin(\delta i - \delta j - Yij) \tag{3}$$

Where Y_{ij} is the magnitude of the i-j^th^element of the bus admittance matrix, V_i is the voltage magnitude at the i^th^bus, $Y_{ij}$is the angle of thei-j^th^element of the bus admittance matrix, and δi is the phase of the voltage $V_{i.}$

The system losses can be expressed as

$$P_l = \sum_{i=1}^{n} P_{Gi} - \sum_{i=1}^{n} P_{Di} \tag{4}$$

Where P_i= real power loss
P_{Gi}= real power generated at the i^{th}bus
P_{Di}= real power required at the i^{th} bus.

Penetration Level

The penetration level (%DG level) is defined as the ratio of the total DG power to the peak load demand P_{load} expressed on a percentage.

$$\% \text{ DG level} = \frac{P_{DG}}{P_{load}} \times 100\% \tag{5}$$

The following scenarios can be considered for penetration level indication [1].

-- Low penetration scenario:

The penetration level here is below 30 % i.e. $P_{DG}< 0.3\ P_{load}$.

- Semi-Ideal penetration scenario:

Distributed generation capacity in this scenario corresponds to half of load demand. Liberalized market will be adequate to this penetration level i.e. $P_{DG}< 0.5\ P_{load}$.

- Ideal Scenario: This considers complete penetration of DG ($P_{DG} = P_{load}$). This scenario minimizes power production by centralized generator. Completely open market will be able to make possible high penetration level.

Dispersion Level

- Dispersion level of DG (%DG dispersion) is ratio of number of nodes in which there is DG (Number of bus DG) and the number of nodes in which consumption exists (Number of bus load).

$$\% \text{ DGdispersion} = \frac{nunber\ \ of\ BusDG}{number\ \ of\ Busload} \times 100\% \tag{6}$$

100% DG dispersion means all nodes with load have a DG (Number of bus DG = Number of bus load). The following DG scenarios are considered [1].

-- Low dispersion scenario: It considers a level below 30%. i.e(Number of bus DG = 30% Number of bus load.).

- Semi-Ideal Dispersion scenario: DG is installed on half of load buses.In this scenario, (Number of bus DG = 50% Number of bus load).
- Ideal Dispersion Level: This scenario considers total dispersion of DG unit. i.e Number of bus DG = Number of bus load).

Review of related works.

[8] developed a new algorithm for allocating multiple distributed generations units based on load centroid concept., The paper explained that distributed generation (DG) involves the interconnection ofsmall-scale distributed energy resources with the main powerutility at distribution voltage level.

[11] presented a comparative study of two meta-heuristic algorithms with their applications to distributed generation planning

In this paper, a distributed micro-grid planning model was presented to optimize the location and the unit capacities within DG micro-grid, in which wind power and photovoltaic power were taken into consideration.

[4] presented the Impact of DG on power distribution systems

This paper modeled the IEEE 34 Node distribution test feeder using the commercial software package DIgSILENT power factory version 14. Solar photovoltaic generators were introduced as distributed generators (DGs) at various nodes and the impacts that DG produced on real and reactive power losses, voltage profile, phase imbalance and fault level of distribution system were studied. Simulated results obtained using load flow and short circuit studies were presented and discussed.

[12] presented an optimal placement and sizing of distributed generation for power loss reduction using particle swarm optimization.

Single DG placement was used to find the optimal DG location and its size corresponding to the maximum loss reduction.

[11] presented an optimal placement and sizing of distributed generators in radial system

In this paper, the optimum size and location of distributed generation was defined so as to minimize total power loss by an analytical method based on the equivalent current injection techniques without use of admittance matrix, inverse of admittance matrix or Jacobian matrix which were proved to be problematic for the radial systems.

[2] worked onoptimal distributed generation placement and sizing for loss reduction and voltage profile improvement in distribution systems using particle swarm optimization and sensitivity analysis.

[13] presented an optimal sizing and location of distributed generation using improved teaching-learning based optimization algorithm.

In this paper, a method which employed improved teaching–learning based optimization (ITLBO) algorithm was proposed to determine the optimal placement and sizing of distributed generation (DG) units in distribution systems.

II. MATERIALS AND METHOD

Mathematical Model of Line Loss Reduction Index (LLRI)

Line Loss Reduction Index (LLRI) is defined as the ratio of the total line losses in the distribution system with the use of DG to the total line loss in the distribution system without DG.

$$\text{LLRI}=\frac{LL_{w/DG}}{LL_{wo/\,DG}} \qquad (7)$$

Where $LL_{w/DG}$ is the total losses in the distribution system with the use of DG.

$LL_{WO/DG}$ is the total line loss in the distribution system without DG.

When:

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

This index (LLRI) is used to identify the best location to install DG so as to minimize the line loss reduction.

The minimum value of LLRI corresponds to the best DG location scenario in terms of line loss reduction.

Assumptions Made in the Work:

- The configuration of the network changes and the power factor increases.
- The network operates at a power factor of 0.8 lagging without DG.
- The DG considered are synchronous generator that will supply real power when located at the substation bases.
- The DG units operate at a lagging power factor throughout.

III. SIMULATION

Distributed generation units were placed on the ten selected feeders of Kaduna distribution systems while computer simulation was carried out using the hourly loads record of the selected distributed generation units for the computation of the line loss reduction index. The simulation parameters used for the study are shown in Tables 1 and 2

Simulation Parameters.

Table 1: Load parameters for Kaduna distribution system without distributed generation.

S/N	Feeders Names	Load (MW)
1	FDR 3	55
2	FDR 2	51
3	FDR 1	64
4	Arewa	62
5	Kujama	73
6	Dawaka	63
7	Tundun-Wads	60
8	St Gorald	57
9	Junction Road	61
10	Constitution Road	53

Table2: Load parameters for Kaduna distribution system without distributed generation.

S/N	Feeders Names	Load (MW)
1	FDR 3	57
2	FDR 2	52
3	FDR 1	65
4	Arewa	67
5	Kujama	76
6	Dawaka	64
7	Tundun-Wads	62
8	St Gorald	59
9	Junction Road	63
10	Constitution Road	55

Analysis of the Line Loss:

Loss reduction (LR) is the difference between the loss with and without DG. Thus:

$$LR=\frac{LL_{w/DG}}{LL_{wo/\,DG}} \quad (\mathbf{8})$$

Where $LL_{W/DG}$ = line loss with DG.
$LL_{WO/DG}$ = line loss without DG.

$$\%\,LR =\frac{LR}{LLw\,/DG} \times 100 \quad (9)$$

This is the benefit of DG in normalized form.

IV. DISCUSSION OF RESULTS

The computer simulations for the work are presented in Figures 1 to 7.

Figure 1 shows how the line loss reduction varies with the feeder names while Figure 2 illustrates the correspondence between the line loss reduction index and the names of feeders. The line loss reduction indices for FDRR 3, FDR 2 and FDR 1 feeders of Kaduna distribution system are 0.8751, 0.8577 and 0.8475 respectively suggesting a reduction in the line losses with the introduction of DGs for the feeders. Arewa, Kujama, Dawaki and Tundun Wada feeders also had loss reduction indices of 0.9388, 0.8779, 0.8541 and 0.8818 respectively indicating a reduction in the line losses of these four selected feeders on Kaduna distribution system. St. Gorald, Junction road and Constitution road feeders also recorded loss reduction indices of 0.8662, 0.8673 and 0.8871 respectively justifying appreciable reduction in the line losses of the feeders on the distribution system.

The percentage variation in the line loss reduction with the feeders is illustrated in Figure 3. FDR 3 feeder had a percentage line loss reduction of 12.49% while FDR 2 and FDR 1 feeders had percentage line loss reduction of 14.22% and 15.24% respectively even though AREWA feeder with a percentage loss ratio of about 6.11% appeared to have the least percentage line loss reduction of all the selected feeders on Kaduna distribution systems.

Figure 4 illustrates the correspondence between the line loss with the incorporation of DG and the line loss without the incorporation of DG for the selected feeders of the distribution system.

For FDR 3 feeder, the line loss with the introduction of DG was 12.52 MW which corresponds to line loss of 14.3136 MW without the incorporation of DG.

The line loss with the introduction of DG for FDR 2, FDR 1 and Constitution road feeder are 7.8092 MW, 10.8931 MW and 6’4297 MW respectively which corresponds to line losses of 9.1044 MW, 12.8523 MW and 7.2482 MW respectively without the introduction of DG.

The relationship between the line loss with the distributed generation incorporated and the line loss ratio is shown in Figure 5. FDR 3, FDR 2, FDR 1 and Arewa feeders of Kaduna distribution system had line losses of 12.5258 MW, 7.8092 MW, 10.8931 MW and 33.7042 MW respectively with the incorporation of DG with line loss reduction of 1.7878 MW, 1.2952 MW, 1.9592 MW and 2.195 MW.

Figure 6 shows the variation of the line loss without the incorporation of DG with the line loss reduction for the feeders of the distribution system. The line losses without the DG incorporation for FDR 3, FDR 2, FDR 1 and AREWA feeders at line loss reduction of 1.7878 MW, 1.2952 MW, 1.9592 MW and 2.195 MW are 14.3136 MW, 8.1044 MW, 12.85233 MW and 35.8992 MW respectively.

The relationship between the line loss reduction index and the loss ratio is shown in Figure 7. FDR 1 feeder had the least line loss reduction index of 0.8475 MW with a percentage line loss reduction of 15.24% which appeared to be the least figure recorded among all the selected feeders. AREWA distribution feeder had the line loss reduction index of 0.9388 MW with a percentage line loss reduction of 6.11% which appeared to be the only feeder with the highest line loss reduction index.

It also showed that the values of the line loss reduction indices were lesser than 1 for each of the feeders of the distribution system suggesting an appreciable level of electrical power loss with the incorporation of the DGs.

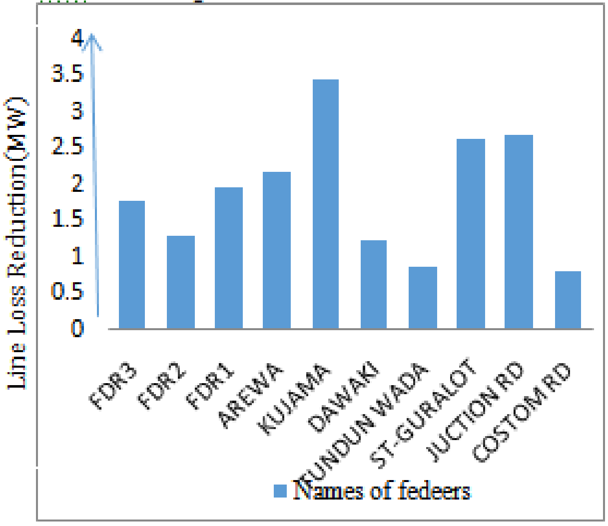

Figure 1: Computer simulation of line loss reduction.

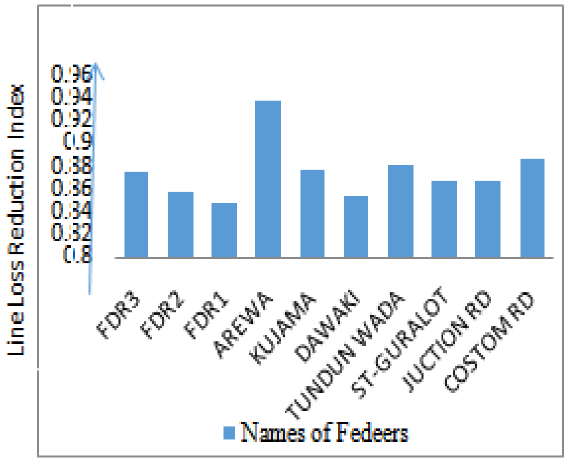

Figure 2: Computer simulation of line loss reduction index.

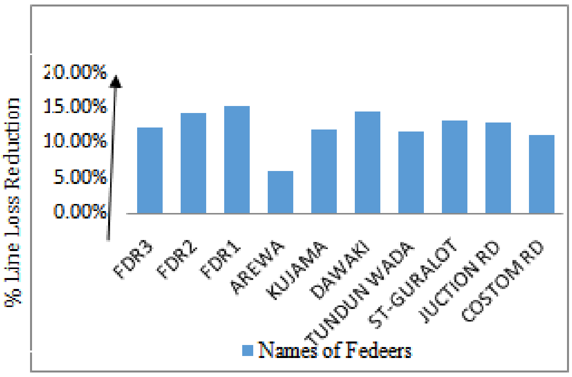

Figure 3: Computer simulation of the percentage line loss reduction.

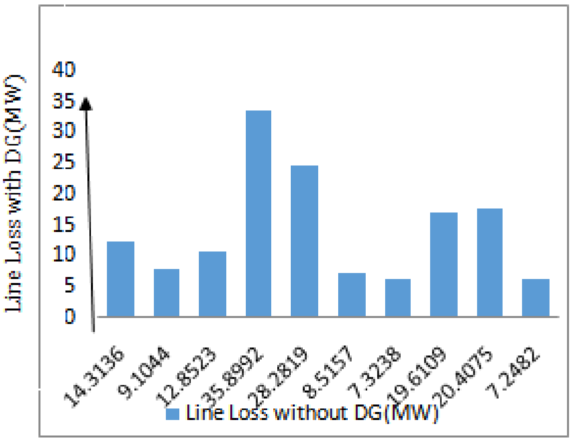

Figure 4: Computer simulation of line loss with DG versus the line loss without DG.

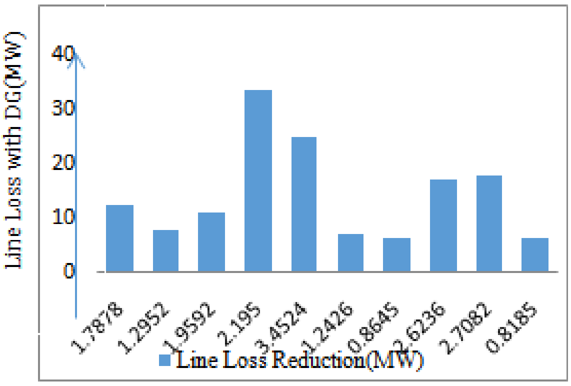

Figure 5: Computer simulation for the line loss with DG versus the line loss reduction.

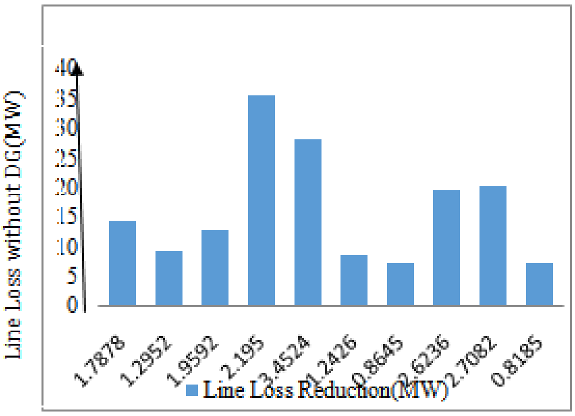

Figure 6: Computer simulation of the line loss without DG versus the line loss reduction.

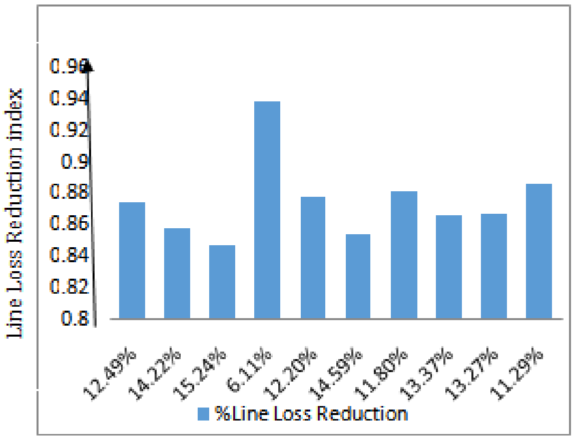

Figure 7: Computer simulation of the line loss reduction index versus the percentage line loss reduction.

V. Conclusion

The impacts of dispersed generation on optimization of power exports has been investigated.

It addressed the placement of DG units on selected distribution feeders of Kaduna distribution system to obtain the greatest reduction in losses based on simulations of the line loss reduction index model for the distribution system feeders.

Thermal losses arising from different placement varies greatly, and that one must consider the transmission and distribution effect when determining appropriate location.

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