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Determining the Optimal Location and Amount of Distributed Generation Sources in an Unbalanced Radial Distribution Grid

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Abstract

Optimal placement of scattered generator sources in the main and secondary feeders of radial grid reduces energy losses, releases the capacity of existing feeders and improves the existing voltage profile. In this project determine the location and suitable for the production of production resources S cattered in radial feeders of unbalanced distribution networks, a new formulation solution is proposed. The application of scattering generation sources proposed in this project is independent of the voltage level of the system under study and its limitation is radial and unbalanced distribution system under study.

Keywords: disperse production resources, distribution grid, Unbalanced
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1. Introduction

With the growth of industry and the increasing need for electricity in recent years, the creation of large power plants is not economically and environmentally justified [1, 2]. By creating and operating a small grid-connected power plant that is simply renewable energy based on the needs of the electricity industry. Scattered generation (DG) generally refers to the generation of electricity at the point of consumption of livestock information. According to the IEEE definition, electricity generation is by equipment that is a sufficient candidate for smaller central power plants and is able to install and operate at their point of use to use existing compounds. Electricity supply companies have a duty to provide the required power to the grid in all circumstances. The use of distributed generation resources allows power companies to supply energy in proportion to the load connected to the grid. On the other hand, these resources can be used as backups in the network that enter the circuit when necessary and reduce the number of consumers who leave the circuit in the event of a breakdown or disruption of the network [4]. Research shows that the connection of distributed generation units in some grid substations can improve the power transfer imbalance due to the difference in power transfer coefficient of different parts of the network by adjusting the direction of flow and load distribution [5]. The use of distributed generation sources will reduce the load seen by the manufacturer and consequently reduce the voltage drop across the transmission lines. Reducing voltage drop is one of the most important factors in increasing the life of grid equipment and heat loss in them. Utilization of distributed generation resources reduces power losses in the grid due to reduced transmission current from large generators to distribution transformers and reduced voltage drop in transmission lines. This advantage will have other side effects such as reduced production and related costs [5].

A) The effect of distributed generation sources on the distribution system voltage

According to various standards, certain limits are allowed for the distribution grid voltage, in most of which this value is between 10% of the nominal voltage. In distribution systems, by passing current through the resistance and impedance of the lines, it causes power losses and voltage drops, which will be more acute at the end points of the grid with increasing load and due to the radial structure of this system. To control the voltage of the distribution system, there are two traditional methods of control by pulse changers in transformer substations and control of reactive power with shunt capacitors [6]. In the presence of DG in the distribution grid, if the DG output changes in harmony with the load (DG output increases with increasing load and decreases with decreasing load), then DG will act as a negative load and reduce voltage changes. However, in some types of distributed generation sources such as photovoltaics and wind power plants, this is not possible and the voltage changes in the grid increase. In general, the presence of DGs to control voltage can cause it to be confronted with traditional voltage control equipment such as pulsators, which indicates the need for new methods to control the voltage in the presence of DGs in distribution networks. Of course, DG connection technology to the distribution network will be very effective in controlling the grid voltage [2, 6, 7]. As mentioned, the presence of DG, provided proper placement, reduces the post-load flow. Therefore, the current passing through the line resistance is reduced and the losses (RI2) are reduced [1, 8].

The LLRI line loss reduction index is defined as follows:

$$LL_{W/DG} = 3\sum_{I=1}^{M} I_{A,i}^{2}\, RD_i \quad (1)$$

Where LLW / DG and LLWO / DG are the line losses in the two modes of connection and non-connection of DG to the grid, respectively, which are obtained from the following relations:

$$LL_{W/DG} = 3\sum_{I=1}^{M} I_{A,i}^{2}\, RD_i \quad (2)$$

$$LL_{WO/DG} = 3\sum_{I=1}^{M} I_{L,i}^{2}\, RD_i \quad (3)$$

Where IA, i, line prionite current in a grid supplied by DG, and IL, i, line prionite current in a device without DG, line resistance R in terms of Di, Pu / km, distribution line length, and M, number of lines Is the system. Therefore, the following states can be defined in the grid:

- Increasing line losses with the presence of DG (LLRI <1)
- No effect on line losses in the presence of DG (LLRI = 1)
- Reduction of line losses with the presence of DG (LLRI> 1)

B) Unbalanced consequences

Increase of power losses: Power losses in low voltage grid include two categories of power losses in phases and power losses in neutral wire. Assuming that the total current of the three phases is constant, the power losses in the phases in the load imbalance state are more than the losses in the load equilibrium state, to which the losses in zero are added. Phases and therefore the ohmic resistance of the neutral wire is about twice the resistance of the phase wires, the losses are still noticeable even in the case of low currents. Voltage drops due to unbalance: Even assuming that the phase wires in the grid have the same cross-sections and therefore the same impedance, due to unequal current flow, the phase wires have different voltage drops and therefore have unbalanced voltage on the consumers side, especially the most sensitive consumers. they will be. This will have adverse effects on three-phase consumers. Dangers due to neutral current: With the current unbalanced in the three-phase system and the current passing through the neutral wire, it has a voltage relative to the ground, which is undesirable in terms of safety if it exceeds the allowable limit, and if the consumer contacts the neutral wire Slowly, there will be a possibility of electric shock. In addition to the mentioned issues, the unbalanced high load of the grid will cause unfavorable situation in other components of the grid, including transformers.

C) Modeling of transformers under abnormal operating conditions -Modeling in non-sinusoidal load conditions:

In this case, the single-line diagram of the transformer in the nominal mode and the net resistance load are shown in Figure 1. R1 and R2 in the external circuit section correspond to the primary and secondary windings. The RC resistor is modeled for transformer core losses.

- R1 Primary winding resistance
- X1 Primary winding inductance
- Xm core magnetic inductance
- RC core resistance
- R2 Resistance of secondary winding
- X2 Secondary winding inductance
- RLoad load resistance Are.

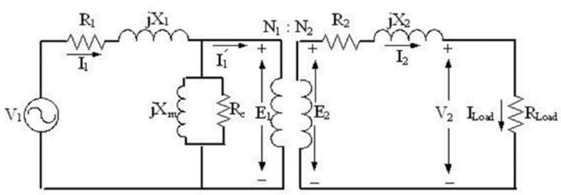

Fig. 1. Single-line diagram of transformer in nominal mode and net resistance load

Transformer core losses include hysteresis losses and Foucault losses. In this software, the complete cycle of the core magnetization curve is not considered, so the hysteresis component of the core losses is ignored and only Foucault losses are considered as core losses. The magnetic inductance of the Xm core is automatically calculated by the software and taken into account in the FEM calculations according to the magnetic curve defined for the core and the type of transformer power supply in the external circuit part of the software. V1 The transformer supply voltage is supplied through the supply drive. In the drive section, there are various functions for powering the transformer. Among these functions, we can mention sine, cosine, step, exponential, and so on. Each of these functions is defined by assigning a value to its principal attribute. According to the sine power supply, a sine function is used as the supply voltage of the three-phase transformer in its primary. The frequency characteristic and phase angle of the sine function in the drive section are applied to the first three phases and the voltage range is considered in terms of its maximum value in the external circuit section. Since nonlinear load modeling is not possible through harmonic current sources, an alternative method is considered for this purpose. The following model is the best alternative to nonlinear load modeling through harmonic current sources:

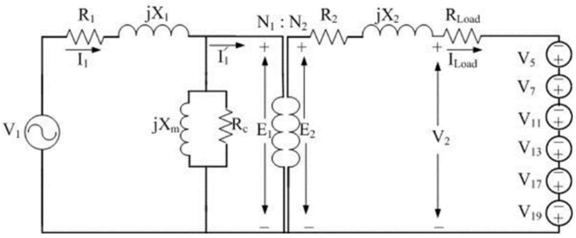

Fig. 2. Single-line diagram of a transformer modeled with nonlinear load

As shown in Figure (2), harmonic voltage sources are used to model the nonlinear load. For phase A we will have a transformer:

$$V_2 = v_{2m}\, sin(\,\omega t + \theta_a) \tag{4}$$

$$V_k = v_{km}\, sin(\,k\omega t + \theta_a)k = 5; 7; 11; 13; 17; 19 \tag{5}$$

v_{2m} is the maximum value of the induced voltage range at both ends of the load V_{km} The maximum value of the amplitude of the harmonic voltage source km Thus, the load current is equal to:

$$I_{Load} = \frac{v_{2m}\, sin(\omega t+\theta_a)}{R_{Load}} + \frac{v_{5m}\, sin(5\omega t+\theta_a)}{R_{Load}} + \frac{v_{7m}\, sin(7\omega t+\theta_a)}{R_{Load}} + \frac{v_{11m}\, sin(11\omega t+\theta_a)}{R_{Load}} + \frac{v_{13m}\, sin(13\omega t+\theta_a)}{R_{Load}} + \frac{v_{17m}\, sin(17\omega t+\theta_a)}{R_{Load}} + \frac{v_{19m}\, sin(19\omega t+\theta_a)}{R_{Load}} \tag{6}$$

$$I_{Load} = i_{1m}\, sin(\,\omega t + \theta_a) + i_{5m}\, sin(\,5\omega t + \theta_a) + i_{7m}\, sin(\,7\omega t + \theta_a) + i_{11m}\, sin(\,11\omega t + \theta_a) + i_{13m}\, sin(\,13\omega t + \theta_a) + i_{17m}\, sin(\,17\omega t + \theta_a) + i_{19m}\, sin(\,19\omega t + \theta_a) \tag{7}$$

According to Equation (7) the load current is non-sine. Since the value of R_{Load} is equal to 1/3 ohm, for each time with a certain harmonic content (known values i_{5m}, i_{7m}, i_{11m}, etc.) can be unknown values v_{5m}, v_{7m}, v_{11m} and .... And included in the transformer model. The main difference between a single-line diagram in Figure 1 and a single-line diagram in Figure 2 (transformer in nominal mode and net resistance load) is in the harmonic voltage sources added to the circuit.

D) Load unbalanced state modeling

Load inequality is defined as the amplitude, phase, and combination of the two. In this section, only the load amplitude imbalance is discussed. Modeling a transformer under load imbalance is exactly the same as modeling it in the nominal mode. For this purpose, all the steps mentioned in section 1-4-1 are repeated. The only major difference between the two is in the external circuit applied to the transformer model. To account for load unbalance, the R_{Load} load resistance is determined in terms of the unbalanced load percentage of each phase and placed in the external circuit. The one-line diagram of the transformer in the unbalanced state of the load and according to the nominal state of Figure 1 is given below:

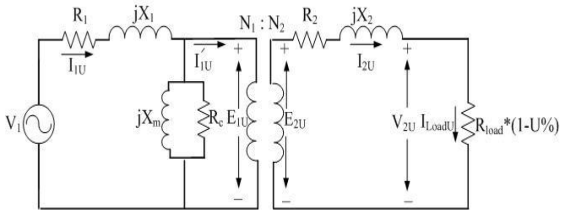

Fig. 3. One-line diagram of an unbalanced load transformer

U is the percentage of unbalanced load resistance. This diagram is the equivalent of a single-phase transformer circuit. For each phase, by changing the load resistance (R_{Load}) according to the unbalanced amount of load, we achieve different values of primary, secondary currents, induced voltage between the two ends of the primary winding and induction voltage between the two ends of the secondary winding.

E) Unbalanced supply voltage modeling

Voltage imbalance is the amplitude, phase and combination of the two. The definition of voltage imbalance and its occurrence factors were studied in detail in the second chapter. In this section, only the unbalance of the supply voltage amplitude will be investigated. For modeling a transformer under unbalanced supply conditions, all the steps mentioned in section 3-3-1 are repeated, and the only fundamental difference between this mode and the nominal mode is the voltage applied to the transformer supply circuit. For this purpose, according to the unbalanced percentage of supply voltage, the applied voltage to the high voltage windings (primary windings) is determined and in the external circuit section, circuits 1, 2 and 3 (high voltage windings) are inserted. It is possible to select the type of supply voltage in the software drive section. The supply voltage is sinusoidal and is determined by assigning the values of frequency and phase angle in the drive section and the maximum amplitude in the external circuit section. The single-line diagram of the transformer on phase in unbalanced voltage is shown in Figure 3-13: Note that the diagram drawn is the equivalent circuit of a single-phase transformer. For each phase, depending on the voltage imbalance, the supply voltage applied to the equivalent circuit will be different. U is the percentage of unbalanced voltage.

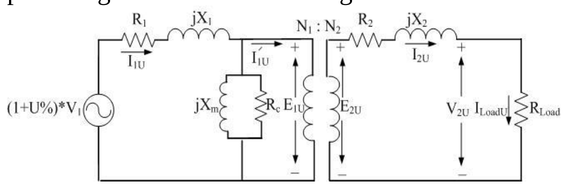

Fig. 4. Single-line diagram of transformer under unbalanced voltage supply

2. Modeling

Methodology in determining the optimal location of distributed generation sources: Optimal placement of distributed generation sources in the main and secondary feeders of radial grid leads to reduction of energy losses, release of capacity of existing feeders and improvement of voltage profile. In this project, the problem of determining the optimal location and capacity of distributed generation resources in radial feeders of unbalanced distribution grid is formulated and a new solution is presented to solve the problem. The application of scatter generation generation method proposed in this project is independent of the voltage level of the system under study and its limitation is radial and unbalanced distribution system under study.

A) Loss modeling:

$$P_{Loss}^{active} = \sum_{i=1}^{nl} Re(I_i)^2 \times R_i \quad (8)$$

$$P_{Loss}^{reactive} = \sum_{i=1}^{nl} Im(I_i)^2 \times X_i \quad (9)$$

B) Voltage deviation modeling:

Another goal of this project is to reduce the voltage deviation in the unbalanced distribution network when determining the capacity and optimal location of distributed generation sources and Statcom. The value of the voltage deviation is obtained from Equation (10) as follows.

$$F_V = \left(\sqrt{\sum_{i=1}^{n}(1-V_i)^2}\right)_{Phase\ A} + \left(\sqrt{\sum_{i=1}^{n}(1-V_i)^2}\right)_{Phase\ B} + \left(\sqrt{\sum_{i=1}^{n}(1-V_i)^2}\right)_{Phase\ C} \quad (10)$$

C) Problem constraints:

$$Vi_{max_{min}} \quad (11)$$

$$Ii_{max_{min}} \quad (12)$$

The first calculation (required condition) is that the number of lines in thegrid circuit should be one number less than the number of busbars. Shown in Equation (13).

$$det(A) = 1\ or -1 \quad (13)$$

$$det(A) = 0 \quad (14)$$

$$P_{T,i}^{min_{T,i}{}_{T,i}^{max}} \quad (15)$$

D) Objective system function:

In this section, in order to achieve the objectives stated at the beginning of the third chapter, it is necessary to define the objective function to solve the problem in such a way that during optimization, while reducing losses, voltage deviation is reduced and the voltage profile is improved. Therefore, first a suitable function is determined as a cost function that includes all these constraints, then this function is optimized using a genetic algorithm and the optimal capacity and location of the distributed generation source is determined. Therefore, according to the objective functions that were introduced in the previous sections, respectively; The cost function of the whole system is defined as relation (16):

$$F_{System} = P_{Loss} + F_v \quad (16)$$

3. Simulation

In this section, the location and capacity of the distributed generation source in standard and unbalanced networks and 123 IEEE buses will be discussed using a genetic algorithm.

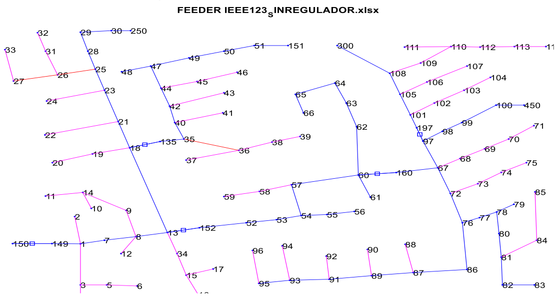

Fig. 5. Grid structure 123 bushes

After running the program using the genetic algorithm, the optimal location and value of the distributed generation source is shown in Table (1). Also, the optimization process of the objective function, the amount of voltage deviation and the amount of losses during optimization are shown in Figures (5) to (6), respectively, as seen in these figures. The values of voltage deviation and mains losses during optimization and the steps of locating and determining the optimal capacity are greatly reduced and the objective function is reduced according to Figure (6). The final values of mains voltage deviation and the amount of losses before and after placement are shown in Table (2).

Table.1.
Optimal location and amount of distributed generation resources

Type of equipment	***Optimal installation location (bus number)***	***The desired phase***	***Optimal value (kW)***
Scattered production source	3	3	139600

Table.2.
Loss values and voltage deviations before and after locating the distributed generation source

	Losses (kilowatts)	***Voltage deviation***
Before placement	97.3858	18.3911
After placement	81.9864	18.3856

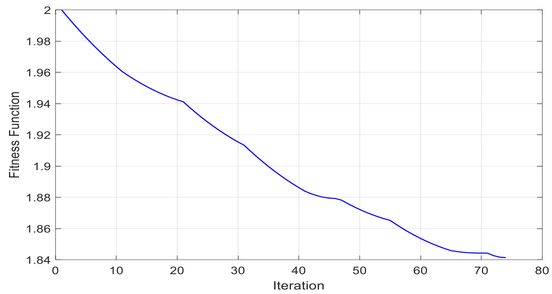

Fig. 6. Objective optimization process

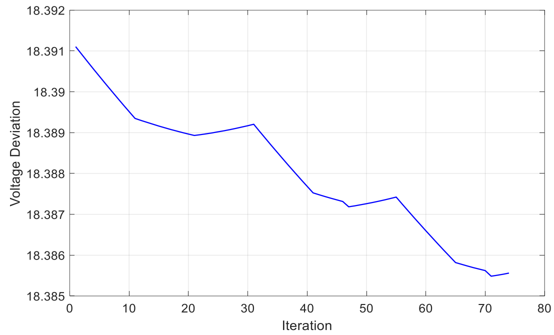

Fig. 7. Voltage deviation changes in the process of optimizing the objective function

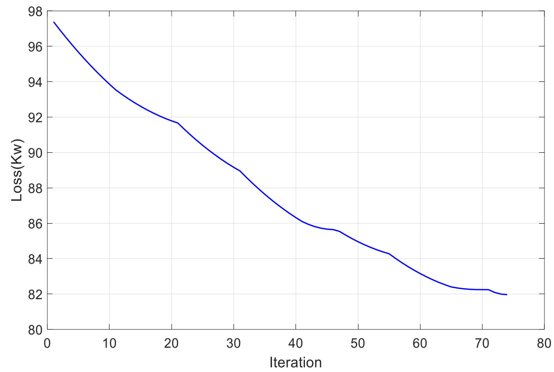

Fig. 8. Loss changes in the objective function optimization process

As can be seen in Table (2), the final values of voltage deviation and losses have been significantly improved so that the losses have been almost halved.

4. Conclusion

For proper placement of distributed generation sources in power networks, many parameters must be considered. In this project, to determine the optimal amount and location of distributed generation source in unbalanced power networks in order to improve voltage profile and reduce losses and voltage deviation using genetic algorithm. paid. The simulation results show an improvement in the voltage profile and a reduction in losses as well as a reduction in voltage deviation.

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