Investigating the Effects of Electric Load Imbalance on Increasing Losses in the Electricity Distribution Network and Ways to reduce it

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Abstract

One of the factors that cause energy losses in distribution networks is unbalanced loads. These losses, which weigh billions of afghanis on the country's economic charter, although impossible to completely eliminate, but its study can be the beginning of inventing ways to reduce it in different categories of the system. The phase between the feeder phases and the other is the random and asynchronous behavior of the customers is one phase. In load distribution networks, load imbalance has two important features, one variable with the amount and severity of load imbalance and the other its dispersion along the circuit.

The purpose of this study is to investigate the losses due to load imbalance in the electricity distribution network.

A large part of the nationwide network losses is generated in the secondary distribution network, part of which is due to load imbalance in distribution networks. In this paper, first the various problems that cause load imbalance are described, and then the calculations of energy losses and voltage drop due to unbalanced load are performed, and in the third stage, the status of a transformer with unbalanced load is investigated. Finally, practical solutions have been proposed to reduce losses due to unbalanced electrical load in the distribution network

Keywords: Feeder, Load imbalance, Distribution network, Energy losses, Voltage drop

Introduction

In the current distribution network, a three-phase system with four lines is used to supply electricity to the customers, three of which are phase lines, and the fourth line is used as a zero line that is connected to the transformer start point, which is used as a current return line (Alabi & Jayaweera, 2021).

If the system is balanced, the set of three-phase currents passing through the zero line will be equal to zero, but if the load is unequal and the system is unbalanced, the set of currents passing through the zero line will not be zero (Golshan & Mehdi, 2012).

In the distribution network, most of the time, it is one phase and it is connected between one of the phase lines and the zero line. Because the number of branches is often not equal in each of the phases, and if the number is equal, a current usually passes through the zero-line due to the different uses of single-phase consumers. Unbalanced load in distribution networks has many complications and adverse effects. Today the amount of load imbalance is one of the indicators of the quality of electrical energy (Siti et al., 2007).

For this reason, the distribution network is generally an imbalance network. Load imbalance creates various problems, which are first described and finally discussed in detail in endurance injuries, which is the main problem (Kashem et al., 2000).

Research goal: - The purpose of this field study is to investigate the losses due to load imbalance in the electricity distribution network.

Research method

The present research is applied research in terms of purpose and descriptive-analytical research in terms of method.

Effects of load imbalance:

1-1 **Increase of endurance losses**

Endurance losses due to network load imbalance should be searched in two separate cases, namely endurance losses in phases and endurance losses in zero line. The losses are loaded in equilibrium, to which the loss in the zero line will be added. Also, most of the sections of the lines in the zero line are half of the sections of the phase lines. Due to this, the ohmic resistance of the zero line is about twice the resistance of the phase lines and the losses are still significant in the event of low currents passing through it (Lin, 2003).

1-2 **voltage drop due to load imbalance**:

In case of load imbalance and as a result of current passing through the zero line, in addition to fuzzy voltage loss, we will also have zero voltage loss, which causes the low voltage at both ends of the consumer (Augugliaro et al., 2003).

As a result of an unbalanced current passing through the phase line, if we assume that the sections of the phase lines in the network are the same, which will have equal impedance, due to unequal current flow, the loss phase lines have different voltage, and as a result have unbalanced voltage on consumers, especially three motors. Will be a phase. This will have adverse effects on three-phase consumers (Das, 2006).

1-3 Dangers of electrification of the null line:

When the current in the three-phase system becomes unbalanced and the current passes through the neutral line, the neutral line has a voltage relative to the ground which is undesirable in terms of safety, and if the consumer comes in contact with the neutral line, it will probably cause electric shock. will be (Homaee et al., 2019).

In addition to the above issues, high network load imbalance will cause an unfavorable situation in other network components, including transformers. For example, due to load imbalance, the load of one of the transformer phases may increase from the nominal load. This will cause the transformers to not be economically exploited even when the load of the transformer is less than its nominal load, and the transformers will overheat and wear out, resulting in premature damage to the transformers (Ukil & Siti, 2008).

2- Unbalance mode calculations

To perform the equilibrium calculations on the complete ohmic networks, consider Figure (1), which shows a power source (secondary to a 20.04 kV transformer) and a low voltage line with loads Load1, Load2, and Load3: (Ciric et al., 2003).

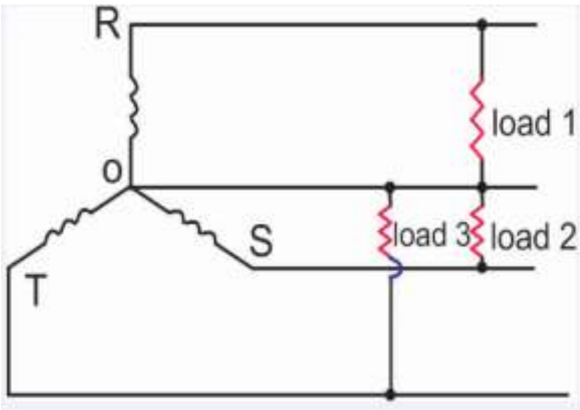

Figure (1) Equivalent circuit of a low voltage distribution line

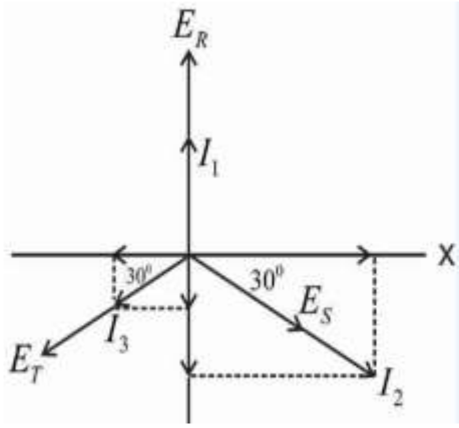

Figure (2) Vector diagram of voltage and currents

We know that for a pure ohmic load the coefficient of strength is one. After the three-phase lines, currents I1, I2, and I3 pass, and the vector diagram of voltage and currents are shown in Figure (2) below.

$$I_n(X) = I_2 \cos 30^\circ - I_3 \cos 30^\circ = \frac{\sqrt{3}}{2}(I_2 - I_3) \quad (1)$$

$$I_n(y) = I_1 - I_2 \sin 30^\circ - I_3 \sin 30^\circ = I_1 - \frac{1}{2}(I_2 + I_3) \quad (2)$$

$$I_n = \sqrt{\left[I_n^2(X) + I_n^2(Y)\right]} = \sqrt{\left[(I_1^2 + I_2^2 + I_3^2) - (I_1 I_2 + I_1 I_3 + I_2 I_3)\right]} \quad (3)$$

2-1 Calculate the line zero current

The flow inline zero according to the above vector diagram and the position of the currents on the x and y axes is done as follows. If it is related, we will see In = 0.

2-2 Comparison of lesions in balanced and unbalanced states

The losses of the phase lines will be in an unbalanced state, through which currents and flows will be equal, respectively (Ciric et al., n.d).

$$P_{Lub} = R.I_1^2 + R.I_2^2 + R I_3^2 \quad (4)$$

In this case, we assume that all three times they enter the same place from the line and the cross-section of the phase lines is the same. The ohmic resistance of all three phases will be equal to R. Now, if we assume that the above three times were equilibrated in equilibrium between the three phases, then the three phases of equal current (I), which is the middle of the three currents and, would be passed.

$$I = \frac{I_1 + I_2 + I_3}{3} \text{..}(5)$$

As a result, the phase losses in equilibrium are equal to:

$$P_{L.b} = 3.RI^2 = R.\frac{(I_1 + I_2 + I_3)^2}{3} \text{...}(6)$$

According to the above, the difference between unbalanced and balanced loss is equal to:

$$\Delta P = P_{L.u.b} - P_{L.b}$$
$$\Delta P = \frac{2}{3} R(I_1^2 + I_2^2 + I_3^2 - I_1 I_2 - I_1 I_3 - I_2 I_3) \text{..}(7)$$

Due to Cauchy inequality which is as follows:

$$I_1^2 + I_2^2 + I_3^2 \geq I_1 I_2 + I_2 I_3 + I_1 I_3 \text{.......................................}(8)$$

As a result, the losses in the unbalanced state will always be more than the losses in the balanced state. This is where one of the unfavorable and uneconomical effects of load imbalance becomes apparent, and this is just without calculating the null zero.

2-3 Losses in zero line:

According to the value of in mentioned in equation (1) and also assuming Rn for the resistance of the null line, the losses in the null line can be obtained from equation (9):

$$P_{L.n} = R_n . I_n^2$$
$$P_{L.n} = R_n (I_1^2 + I_2^2 + I_3^2 - I_1 I_2 - I_1 I_3 - I_2 I_3) \text{..........................}(9)$$

Calculation of total imbalance losses

According to the above, the amount of total loss in the unbalanced state can be obtained as follows: (Yu Li et al., 2019).

$$P_L = P_{L.Ub} + P_{L.n} \text{...}(10)$$

By placing prices in relation (8), the number of total losses can be obtained in two different modes, namely from relations (11) and (12).

$$P_{L1} = R.(2I_1^2 + 2I_2^2 + 2I_3^2 - I_1I_2 - I_1I_3 - I_2I_3)........................(11)$$
$$P_{L2} = R.(3I_1^2 + 3I_2^2 + 3I_3^2 - I_1I_2 - I_1I_3 - I_2I_3)......................(12)$$

And the difference of losses in the equilibrium state of the resistance of the neutral line phase lines is equal to:

$$Increase\ in\ casualties\ (\Delta P) = \frac{5}{3}R(I_1^2 + I_2^2 + I_3^2 - I_1I_2 - I_1I_3 - I_2I_3)...(13)$$

If the resistance of the null line is twice that of the phase line, the amount of loss increase is equal to:

$$Increase\ in\ losses\ (\Delta P) = \frac{8}{3}R(I_1^2 + I_2^2 + I_3^2 - I_1I_2 - I_1I_3 - I_2I_3).....(14)$$

In other words :

Increase in casualties $= \frac{4}{3}$ (Losses in Line Null)

Now that we are somewhat familiar with the calculations of losss inline zero, we realized that due to the load imbalance in the network, the phase losses will be added to it, and we knew that the losses are in an unbalanced state since the line zero cross-section is half the phase line cross-section of the formula. $\Delta p = \frac{4}{3}$ (Losses in zero line) Will be calculated. So, we can calculate the losses in line zero by the load measurement method.

Voltage drop due to load imbalance

If the voltage of the power supply is E relative to the ground, the current path for one of the loads is as shown in the figure below (Siti et al., 2007).

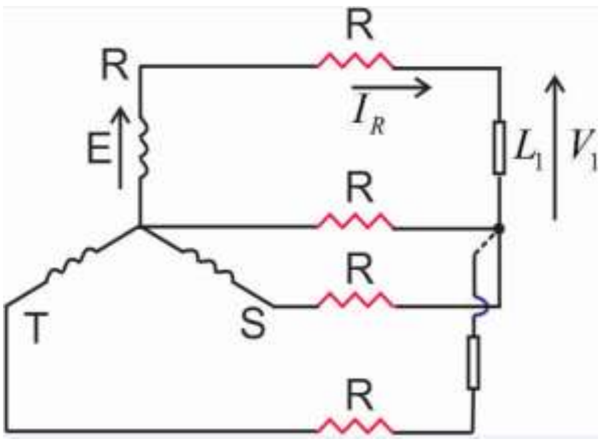

Figure (3) Equivalent to the circuit of a power supply and power load

From the KVL(Kirchhoff voltage law) rule in the above-closed loop we can write:

$$E = R.I_R + V_1 + RI_n \qquad (15)$$
$$V_1 = E - R(I_R + I_n) \qquad (16)$$

Of course, it should be noted that in the above calculations, the reactance of the line is neglected and if the reactance of the line is considered, the voltage drop will increase comes:

$$V_1 = E - R(I_R + 2I_n) \qquad (17)$$

As the calculations show, the zero line voltage can be equal due to the load imbalance RI_n In the case where the line-zero cross-section is equal to the phase cross-section, and in the case where the line-zero cross-section is half the phase cross-section, the line-zero voltage $2RI_n$ If this voltage exceeds the voltage limit of about (60V) AC voltage, there will be life-threatening risks for people who come in contact with the neutral line (Golshan & Mehdi, 2012).

CASE STUDY

To check the practicality, a 250kVA Qaleh Qadam hill substation with two aluminum-steel sections with a cross section of 70mm2 and a length of 600m was considered as a sample in the 0.4kV distribution network of Ghazni city. We got Breshna with the cooperation of Ghazni department. Initially, loading was done in the mentioned network (peak consumption time). The network load at the inputs and outputs was as follows:

$$\text{Input}\begin{bmatrix} Phase\ A = 125A \\ PhaseB = 75A \\ Phase\ C = 30A \\ Phase\ N = 75A \end{bmatrix} \qquad \text{First out put}\begin{bmatrix} Phase\ A = 90A \\ Phase\ B = 65A \\ Phase\ C = 25A \end{bmatrix}$$

$$\text{Second output}\begin{bmatrix} Phase\ A = 55A \\ Phase\ B = 25A \\ Phase\ C = 25A \end{bmatrix}$$

It should be noted that in the network above the Qala-e-Qadam hill substation with a capacity of 250 kVA, the number of customers on the three phases was as follows:

$$\begin{bmatrix} Phase\ A = 150 \\ Phase\ B = 109 \\ Phase\ C = 66 \end{bmatrix} Customer$$

$$\Delta P = \frac{4}{3}(Losses\ \ in\ \ the\ \ zero\ \ line)$$

$$Losses\ \ in\ \ the\ \ zero\ \ line = I^2 R$$

$$R = \frac{1}{3} \times \frac{600}{36 \times 70} = 0.081\Omega$$

$$\Delta P = \frac{4}{3}(0.081.75^2) = 612W$$

3. Conclusion and discussion

The studies conducted in this article show have that part of the loss of the secondary distribution network is due to the imbalance of the network rainfall, which unfortunately is not taken into consideration and is not taken seriously, and this has increased the current costs of distribution networks. It has and still has adverse effects on consumers. Load imbalances in distribution networks not only increase energy loss but also cause vibration in three-phase motors, reducing their life and strength. In terms of protection, electrification of the null line is also dangerous and has human casualties. Voltage is also one of the basic parameters of the regime in electrical cycles that must be kept constant for the customer to the required extent.

Studies show that the amount of voltage drops due to the imbalance of the electric load. Excessive voltage fluctuations cause great damage to consumers.

Imbalances often increase network loss, wasting the production capacity of stations and capital, resulting in a decrease in system efficiency. By balancing loads and reducing loss, more electricity can be provided to customers.

Therefore, to solve this problem, the following ways can be used:

1- If the currents of the three phases are equal in appearance, but the ohmic and inductive loads are not divided into equilibrium on the phases, which creates a kind of imbalance. To balance such a network, the use of voltage regulating capacitors in distribution towers are used to keep the three-phase phase angle at a certain level and thereby modify the mains voltage.

2- Ghazni Breshna should an office called "Load Balancing Management" This management in electricity distribution affairs should consist of one electrical engineer, one technician and several service employees and take action to eliminate the load imbalance. However, due to the lack of personnel in the formation, it is possible to give overtime to electrical engineers by giving a calculation plan during non-business hours, which helps to create balance in the network and increases all financial incentives in the company's employees. It is suggested that a thorough and comprehensive study be done in this regard by allocating sufficient budget and providing facilities.

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