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# Studying Effect of Unbalanced Load on Three Phase System

**Solomon Feleke***

**Department of Electrical and computer Engineering, Debre Berhan University Debre Berhan, Ethiopia.**

**Abstract**

**(In this paper, the effect of balanced and unbalanced loads on three-phase systems** was **studied. In the study, a model of an automatic load balancing system for three-phase power systems using MATLAB Simulink is developed, and the effect of time response parameters such as settling time, rise time, undershoot, and overshoot for line voltages and load currents in two scenarios is analysed. In the first scenario, three equal balanced loads are considered; in the second scenario, the load in line 2 was doubled to make the system unbalanced. In the simulation result, it is observed that with unbalanced loads, overshoot and undershoot are recorded for both voltage and load current measurements, indicating that the unbalanced loads disturb or distort the system.**

**Keywords: Three phase load balancing and unbalancing; settling time; rise time; undershoot; overshoot.**

## 1. Introduction

As the growing population of human race widens the gulf between energy supply and energy demand, the imbalance in energy availability sent researchers into excavating for a way of settling this age long squabble. A lasting solution is vested on alternative use of the renewable energy source, a project that is yet to be widely applied. Hence, the continuation of the unsettled yearns for sufficient power. Consequently, the power lines are frequently over loaded resulting to a trip of power by the action of switch gears or by the load shading process undertaken by the distribution authorities [1].A three-phase load is an electrical load that requires three alternating currents, each with a phase difference of 120 degrees, to operate. This type of load is commonly found in industrial and commercial applications where high power is required, such as in motors, pumps, compressors, and large industrial machinery. In a three-phase system, the load is distributed across all three phases, with each phase carrying a portion of the total power. The load is balanced when each phase carries an equal amount of power, which is important for ensuring the stability and efficiency of the power system [2]. Three-phase loads can be resistive, inductive or capacitive, or a combination of these. Resistive loads, such as heaters and incandescent lamps, consume power in phase with the voltage. Inductive loads, such as motors and transformers, consume power that is out of phase with the voltage, while capacitive loads, such as capacitors and some types of lighting systems, consume power that leads the voltage [3].Load balancing is important in three-phase systems to ensure that the load is distributed evenly across all three phases, which can help to reduce the risk of voltage fluctuations, equipment damage, and downtime. This is typically achieved using various techniques such as phase shifting transformers, capacitors, and inductors, or by using electronic control systems to monitor and adjust the power supply to each load.An automatic three-phase load balancing system is a power distribution system that automatically balances the load across all three phases to ensure that each phase carries an equal amount of power. This is achieved using electronic control systems that monitor the current and voltage on each phase and adjust the power supply to each load accordingly. The system typically includes current sensors and voltage sensors that are installed on each phase of the power distribution system [4]. These sensors measure the current and voltage on each phase and send the data to a central control unit, which uses this information to calculate the power demand on each phase.Based on this information, the control unit can adjust the power supply to each load in real-time to balance the load across all three phases. This is typically done using electronic switches or relays that can be used to divert power from one phase to another as needed. Some automatic three-phase load balancing systems also include backup power supplies, such as

*Corresponding author: sole12@dbu.edu.et/solomonfelek1888@gmail.com.
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batteries or generators, to ensure that the system can continue to operate even in the event of a power outage or other disruption to the power supply. The benefits of an automatic three-phase load balancing system include improved power efficiency, reduced equipment damage, and increased system reliability. By balancing the load across all three phases, the system can reduce the risk of voltage fluctuations, which can damage equipment and reduce efficiency. Additionally, by automatically adjusting the power supply to each load, the system can ensure that the power demand is always met, even during periods of high demand, which can help to reduce downtime and improve productivity [5].Three-phase load balancing is the process of distributing electrical power evenly across all three phases of a three-phase power system. In a balanced three-phase system, the three phases of power are equal in voltage amplitude and have a 120-degree phase shift from each other. However, in practical applications, the power demands of different loads may vary, resulting in an imbalance in the three phases. Load balancing is important for several reasons. First, it helps to prevent overloading of any one phase, which can lead to voltage drops and potential equipment damage. Second, it helps to ensure that the power demand is met efficiently, which can reduce energy costs and improve system performance. Third, it can help to improve the overall power quality of the system, reducing the risk of voltage fluctuations and other power quality issues and investigation of three-phase balancing techniques was discussed in [6]

There are several methods for achieving three-phase load balancing, including:

***Static Load Balancing*****:** This involves manually connecting loads to different phases of the system to achieve a balanced load distribution. This is a simple and low-cost method, but it can be time-consuming and may not be suitable for applications with changing loads discussed in [7].

***Dynamic Load Balancing*****:** This involves using control algorithms to monitor the current and voltage on each phase and adjust the power supply to each load accordingly. This method can achieve more precise load balancing and can adapt to changing loads, but it can be more complex and costly to implement was explained in [8].

***Phase Conversion*****:** This involves converting single-phase loads to three-phase loads and connecting them to different phases of the system to achieve a balanced load distribution. This method can be useful when there are only a few single-phase loads in the system, but it can be costly and may require additional equipment was discussed in [9].

***Transformer Tapping*****:** This involves adjusting the taps on a transformer to redistribute the load between different phases. This method can be used to achieve relatively simple load balancing, but it may not be suitable for applications with highly variable loads explained in [10].Overall, the choice of load balancing method will depend on the specific requirements and constraints of the application. In some cases, a combination of methods may be used to achieve the desired level of load balancing. The design of an automatic three-phase load balancing system typically involves the selection of appropriate sensors, switches, and relays, as well as the development of control algorithms that will be used to balance the load. The system may be tested and validated using simulations or experimental tests to ensure that it meets the desired performance specifications. Based on this project is to make this balancing system automatically controllable. So we assessed different papers, journals, conferences and other related materials discussed in [11].

In [12] an intelligent consumer's load transfer scheme is proposed that dynamically reduces voltage unbalance (VU). In this scheme to minimize VU in the distribution feeders, consumer's loads are transferred from one phase to another without disconnection of phases. In [13] Scott transformers are used in a low voltage radial feeder to balance the distribution system. In this scheme, unbalanced 3 phase power supply is converted to unbalanced 2 phase supply and then converted back to a balanced 3 phase power supply using Scott transformers. In [14] a new method is proposed for equal sharing of load and balancing the three phases in a 0.4 KV distributions grid. They also simulated daily load flow using MATLAB/Simulink models,a new phasing identification system is proposed that measures voltage phase of underground distribution transformers at the secondary side to determine the phase load and indicate unbalancing. However, no proposal is given to reduce the unbalancing. In [15] a new technique is developed for identifying automatically the phase each domestic loads is connected to, this information can be used by the distribution systems for phase rebalancing.

In this technique voltage information from the energy meters and phase information from the transformers is collected over time and then correlated to determine each customer's phase. In [16] a stochastic method is proposed to calculate the increasing of a single-phase photovoltaic inverter (PVI) to voltage unbalancing in LV distribution networks. The ambiguity in location and phase is included in a serial number of stochastic indicators. This technique is used in induction motors, electric vehicle charging (EVC) and single-phase loads. In real world, a distribution feeder is usually a three-phase, four wire system.single phase loads to phases along a radial feeder should also be recognized in [17].

Studying the effect of an automatic three-phase load balancing system is used to develop a control mechanism that can monitor the load on each phase and redistribute it evenly, ensuring forr optimal operation of the power system

## 2. Methodology

Assume four groups of loads and each group of loads have contains different types of electrical equipment's or appliance like: Light load, Computer, Stoves, Fan loads are considered in **scenario-1**. In the first scenario three group of loads have total connected loads of 4500 watt with each line contains equal load of 1500 watt with total powers in three phase feeders are;

3*1500watt = 4500 watt.

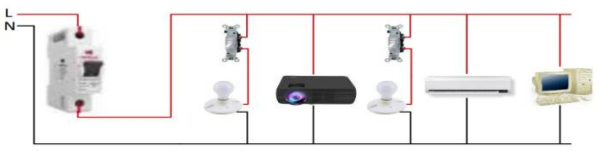


**Figure.1.** Group of electrical loads of a consumer for a single line to neutral connection

In scenario-2 three group of loads have total connected loads of 6000 watt with unbalanced load in line-1 and Line-3 a load of 1500 watt and in Line-2 a load of 3000 watt with total powers in three phase feeders 3*1500watt = 4500 watt were considered.

### 2.1. Load current calculation of each phase

Current flow in 1500watt of equal load cases = 1500/220 = 6.82 Ampere
Current flow in 3000watt of un equal load cases = 3000/220 = 13.64 Ampere
By considering the two scenarios simulation with Matlab Simulink was done and the time response parameters such as rise time, settling time, overshoot and undershoot are compared and analyzed.

### 2.2. Distribution transmission line models

A short transmission line is modeled as having only a resistance and inductance in series with each other. This model is commonly applied to distribution networks since the distance between connecting lines are relatively short.

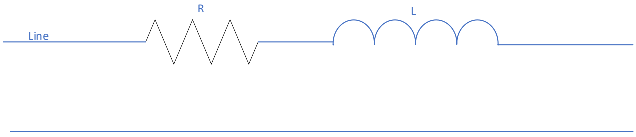


Figure 2 short transmission model

### 2.3. Source voltage modeling

Input voltage for three phase source is 380V for loaded and 400V for unloaded cases were considered. Each phase have 120 degree phase shifting.

### 3.1.5 Design of the study system model using MATLAB Simulink

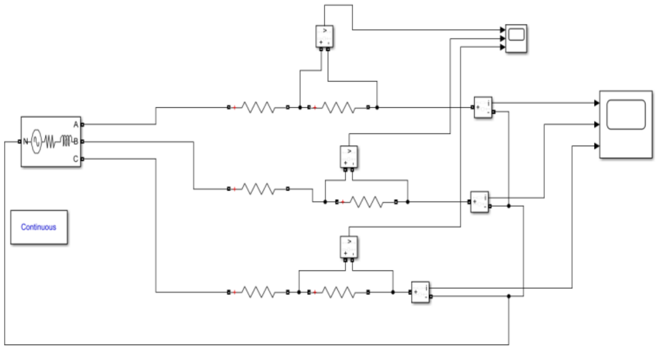


**Figure. 3.** system modeling under study with resistive load connected.

## 3. Result and discussion

Scenario.1

If all three phases have equal loads having 1.5kW each phase and the Simulink graph shows its result as follow. In a balanced three-phase power system, the voltages and currents in each phase are equal in magnitude and 120 degrees out of phase with each other. This results in a smooth and efficient power transmission. The simulation result of voltage and current for the system in scenario-1 at equal load is given in Figure 4 and Figure 5 respectively, similarly the time response output results such as rise time, settling time, overshoot and undershoot for equal load cases for voltage and current measurement is also given in table 1 and table 2 respectively, from the result it is observed that at equal loads the output of the measured parameters from all the three lines for both load current and voltages are almost equal with no voltage drop in each line. On the other hand in scenario-2 in unbalanced load case the measured parameters of voltage and currents in the three lines are not equal and it was shown in the figures 6-7 and in table 3-4 for voltage and current respectively.

First scenario: Balanced or equal loads in all the three phase lines

Load on line-1   1500 watt
Load on line-2   1500 watt
Load on line-3   1500 watt

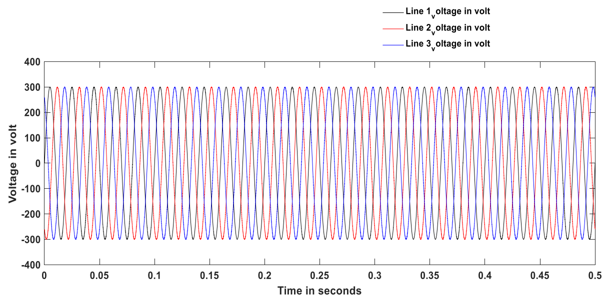


**Figure. 4.** showing voltage in volt at equal load

Table 1 voltage in volt at equal loads

| Phases | Rise time | Settling time | Overshoot | Undershoot |
|---|---|---|---|---|
| Line 1 | 2.2701e-07 | 0.4999 | 300.2666 | -300.2080 |
| Line 2 | 3.4309e-07 | 0.4998 | 300.3540 | -300.3541 |
| Line 3 | 7.0817e-07 | 0.4997 | 300.3537 | -300.3443 |

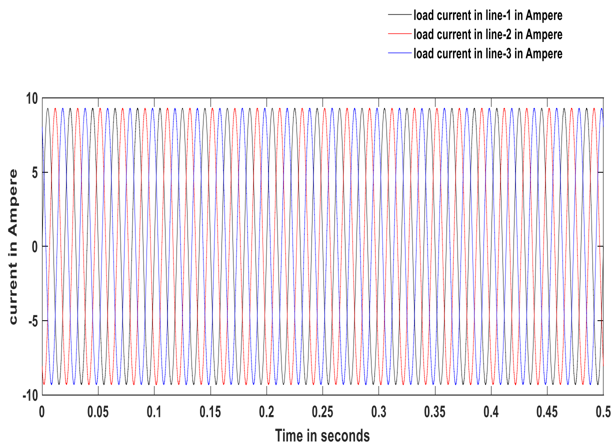


**Figure. 5.** showing current in ampere at equal load

**Table .2.** current in ampere at equal load

| Phases | Rise time | Settling time | Overshoot | Undershoot |
|---|---|---|---|---|
| Line 1 | 2.2701e-07 | 0.4999 | 9.3058 | -9.3040 |
| Line 2 | 3.4309e-07 | 0.4998 | 9.3085 | -9.3085 |
| Line 3 | 7.0817e-07 | 0.4997 | 9.3085 | -9.3082 |

Second scenario: Unbalanced or unequal loads in all the three phase lines
Load on line-1   1500 watt
Load on line-2   3000 watt
Load on line-3   1500 watt

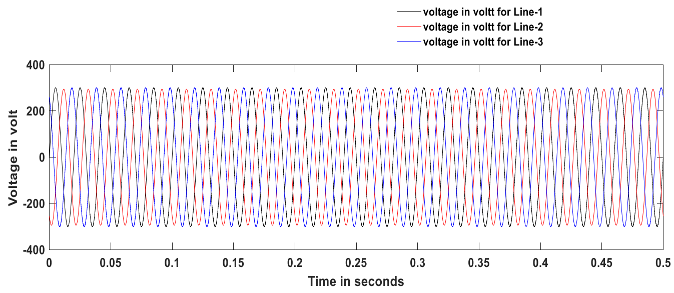


**Figure. 6.** showing voltage in volt at un equal load

**Table. 3.** voltage in volt at scenario 2 with unequal load

| Phases | Rise time | Settling time | Overshoot | Undershoot |
|---|---|---|---|---|
| Line 1 | 6.6196e-08 | 0.4999 | 300.3540 | -300.3540 |
| Line 2 | 1.2613e-12 | 0.4998 | 294.2203 | -294.2203 |
| Line 3 | 7.0785e-08 | 0.4997 | 300.3540 | -300.3540 |

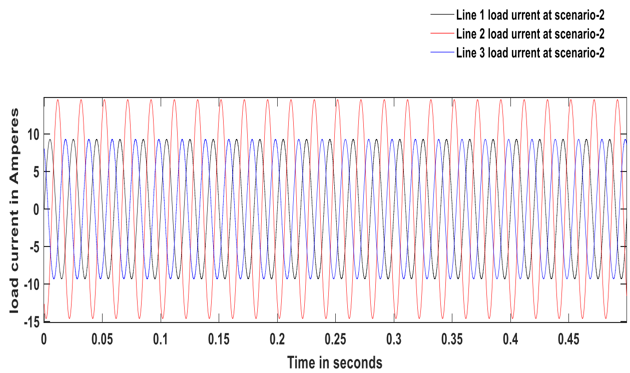


**Figure.7.** load current in ampere at scenario -2 with unequal load

**Table. 4.** load current in ampere at scenario -2 with unequal load

| Phases | Rise time | Settling time | Overshoot | Undershoot |
|---|---|---|---|---|
| **Line 1** | 6.6196e-08 | 0.4999 | 9.3085 | -9.3085 |
| **Line 2** | 1.2613e-12 | 0.4998 | 14.5894 | -14.5894 |
| **Line 3** | 7.0785e-08 | 0.4997 | 9.3085 | -9.3085 |

## Conclusion

In this study the basic concept described was how unbalanced loads in a three-phase power system can cause voltage and current waveform distortions, leading to less efficient power transmission and potentially damaging equipment. On the other hand for balanced load the simulation result using Matlab software also showed that the voltage and the current measurements output is at equal wave amplitude at 120 degree phase shift i.e with less undershoot and overshoot at the comparison of each phases. In unbalanced load case voltage in line-2 drops from 300.3540 to 294.2203,but the load current was increased from 9.3085 to 14.5894.In future the work also can be extended analysed by considering un equal loads at all phases and by considering some optimization mechanism.

## References


1. Ibraheem w: Design and construction of automatic phase selector and changeover switch for 3-phase power supply (doctoral dissertation).
2. https://agrilinks.org/sites/default/files/resources/e4as_brief_1_powering_three_phase_with_single_phase_final.pdf
3. Chen CS, Ku TT, Lin CH: Design of phase identification system to support three-phase loading balance of distribution feeders. *In2011 IEEE Industrial and Commercial Power Systems Technical Conference* 2011, 1-8.
4. Perepichka IF, Bai J, Hu D, Xu X, Liu M, Wang T, Zhao C., Meng, H., Huang, W: Three-phase electric power driven electroluminescent devices. *Nature communications* 2021. 12(1):54
5. Katiraei F, Iravani MR: Power management strategies for a microgrid with multiple distributed generation units. IEEE transactions on power systems 2006, **21**(4):182-131.
6. Mahdee M: Investigation of Three-Phase Balancing Techniques. *A Comparative Study of Different Solutions With Respect to Telecom Industry Needs*.
7. Chakrabarti A, Halder S: Power system analysis: operation and control. *PHI Learning Pvt. Ltd.* 2022.
8. Patel SN: Power load balancing using fuzzy logic.
9. Jimenez VA, Will AL, Lizondo DF: Phase reassignment for load balance in low-voltage distribution networks. *International Journal of Electrical Power & Energy Systems* 2022, **137**:107-691.
10. Gao D, Lu Q, Luo J: A new scheme for on-load tap-changer of transformers. *InProceedings. International Conference on Power System Technology IEEE* 200, 2: 1016-1020.
11. Grigoraş G, Neagu BC, Gavrilaş M, Triştiu I, Bulac C: Optimal phase load balancing in low voltage distribution networks using a smart meter data-based algorithm. *Mathematics* 2020, **8**(4):549.
12. Shahnia F, Wolfs PJ, Ghosh A: Voltage unbalance reduction in low voltage feeders by dynamic switching of residential customers among three phases. *IEEE Transactions on Smart Grid.*, 2014. **5**(3):131-827.
13. Li Y, Crossley PA: Voltage balancing in low-voltage radial feeders using Scott transformers. IET Generation, Transmission & Distribution 2014, **8**(8):148-998.
15. Haq SU, Arif B, Khan A, Ahmed J: Automatic three phase load balancing system by using fast switching relay in three phase distribution system. *In2018 1st International Conference on Power, Energy and Smart Grid (ICPESG)* 2018. 1-6, IEEE.
16. Jimenez VA, Will A: A new data-driven method based on Niching Genetic Algorithms for phase and substation identification. *Electric Power Systems Research*, 2021. 107-434.
17. Schwanz D, Möller F, Rönnberg, SK, Meyer J: Bollen MH. Stochastic assessment of voltage unbalance due to single-phase-connected solar power. *IEEE Transactions on Power Delivery* 2016.,**32**(2): 852-61.
18. Alhmoud L, Nawafleh Q, Merrji W: Three-phase feeder load balancing based optimized neural network using smart meters. Symmetry, 2021, **13**(11):2195.