# IMPORTANCE OF BALANCED VOLTAGES IN FACILITIES EXPLAINED

Innovative Facilities Solutions

## What is unbalance Voltage

- Any deviation in voltage and current waveform from perfect sinusoidal, in terms of magnitude or phase shift is termed as unbalance

- In ideal conditions the phases of power supply are 120 degree apart in terms of phase angle and magnitude of their peaks should be same. On distribution level, the load imperfections cause current unbalance which travel to transformer and cause unbalance in the three phase voltage. Even minor unbalance in the voltage at transformer level disturbs the current waveform significantly on all the loads connected to it

- If three phase voltages have the same magnitude and are in exactly 120deg phase displacement, then the Three-phase voltage is called balanced, otherwise, it is unbalanced.

- There are no negative- and zero-sequence voltages in a balanced system, only positive-sequence components of balanced three-phase voltage exist. On the contrary, if the system is unbalanced, negative-sequence components or zero-sequence components or both may exist in the system.

## Causes of unbalance Voltage

- Switching of three phase heavy loads results in current and voltage surges which cause unbalance in the system.

- Unequal impedances in the power transmission or distribution system cause differentiating current in three phases.

- Any large single phase load, or a number of small loads connected to only one phase cause more current to flow from that particular phase causing voltage drop on line

- With continuous operation of motor’s in various environment cause degradation of rotor and stator windings. This degradation is usually different in different phases, affecting both the magnitude and phase angel of current waveform

- A three phase equipment such as induction motor and Transformer with unbalance in its windings. If the reactance of three phases is not same, it will result in varying current flowing in three phases and give out system unbalance.

- A current leakage from any phase through bearings or motor body provides floating earth at times, causing fluctuating current.

- Unbalanced incoming utility supply

- Unequal transformer taps settings
- Large single phase distribution transformer on the system
- Open phase on the primary of a 3 phase transformer on the distribution system
- Faults or grounds in the power transformer
- Open delta connected transformer banks
- A blown fuse on a 3 phase bank of power factor improvement capacitors
- Unequal impedance in conductors of power supply wiring
- Unbalanced distribution of single phase loads such as lighting
- Heavy reactive single phase loads such as welders

## How to calculate unbalance

- **%voltage unbalance= 100x (maximum deviation from average voltage) / (average voltage)**
- Example: With phase-to-phase voltages of The System is 430V, 435V, and 400V.
- The average Voltage=(430+435+400)/3=421V.
- The maximum Voltage deviation from Average Voltage=435-421=14V
- %voltage unbalance=14×100/421=3.32%
- The permissible limit in terms of percentage of negative phase sequence current over positive sequence current is 1.3% ideally but acceptable up to 2%.

## Effects of unbalance Voltage on System and Equipment:

- The factors for voltage unbalances can be classified into two categories: normal factors and abnormal factors.
- Voltage imbalances due to normal factors, such as single-phase loads and three-phase transformer banks with open star-open delta connections, can generally be reduced by properly designing the system and installing suitable equipment and devices.
- Abnormal factors include series and shunt faults of circuits, bad electrical contacts of connectors or switches, asymmetrical breakdown of equipment or components, asynchronous burnout of three phase power fuses, single-phase operation of motors, etc. The abnormal factors just mentioned above might result in critical damage of systems and equipment.

### Increase Neutral Return Current

- The unequal distribution of loads between the three phases of the system cause the flow of unbalanced currents in the system, that produce unbalanced voltage drops on the electric lines. This increase in neutral current which cause line losses.

- If the system has balanced phase then Neutral current flow will be less on a system. We can save thousands to millions of rupees money by reduce losses be the reducing the neutral current flow in the system

- Thus unbalance in LV distribution network resulting in increase of neutral current.

## Voltage or Current Shift

- If the system is unbalanced, negative-sequence components or zero-sequence components or both may exist in the system.

- The resistance for negative sequence current is 1/6th of the positive sequence current, which means a small unbalance in voltage waveform will give more current and thus losses.

## Excessive power loss

- The unbalance Voltage always causes extra power loss in the system. The higher the voltage unbalance is the more power is dissipated means higher power bills.

- The imbalance of current will increase the I2R Losses

- Let's look at a simple exercise, In balance System The Load current in R Phase=200A, Y Phase=200A,B Phase=200A and in Unbalance System The Load current in R Phase=300A, Y Phase=200A,B Phase=100A,Consider Resistance of line are same in both case and all phases.

- In Balanced System:

- Total Load current =R+Y+B = 200+200+200=

- Total Losses =R(I2R)+Y(I2R)+B(I2R)=40000+40000+40000=**120,000Watt.**

- In Un Balanced System:

- Total Load current =R+Y+B = 300+200+100=

- Total Losses =R(I2R)+Y(I2R)+B(I2R)=90000+40000+10000=**140,000Watt.**

- Here Total Load current is same in both case but Losses in unbalance system is more than balance system.

- An unbalance of 1% is acceptable as it does not affect the cable. But above 1% it increases linearly and at 4% the de-rating is 20%. This means – 20% of the current flowing in the cable will be unproductive and thus the copper losses in the cable will increase by 25% at 4% unbalance.

## Motor failure

- In general, a three-phase motor fed by a balanced three-phase voltage with only positive-sequence component which produces only positive-sequence torque.

- **Reduce Motor life by heating:** Extra loss due to voltage imbalance will heat the motor windings, by increasing the operating temperature of Motor leads to the breakdown of winding insulation and might finally in motor failure. This may also decompose the grease or oil in the bearing and de-rate the motor windings. The voltage unbalance of 3% increases the heating by 20% for an induction motor.

- Winding insulation life is reduced by one-half for each 10°C increase in operating temperature

- **Vibration of Motor:** The negative-sequence voltage caused by voltage imbalance produces opposite torque and leads to motor vibration and noise. Severe voltage imbalance may even result in motor collapse.

- **Reduce Motor Life:** Heat generated by Unbalance Voltage may also reduce the Motor life

- **Reduce Efficiency:** In induction motors connected to unbalanced supply, the negative sequence currents flow along with positive sequence current resulting in decreased percentage of productive current and poor motor efficiency. Any unbalance above 3% hampers the motor efficiency.

| **Motor Efficiency %** | | | |
|---|---|---|---|
| **Motor Load % Full** | **Voltage Unbalance** | | |
| | **Nominal** | **1%** | **2.5%** |
| 100 | 94.4 | 94.4 | 93.0 |
| 75 | 95.2 | 95.1 | 93.9 |
| 50 | 96.1 | 95.5 | 94.1 |

- Assume that the 100-HP motor tested was fully loaded and operated for 800 hours per year with an unbalanced voltage of 2.5%. With energy priced at 23Rs/KWH. the annual energy and cost savings calculation are

- With Normal Voltage

- Annual Energy Consumption=100HPx0.746X800X(100/94.4)x23=1454068Rs

- With Unbalanced Voltage

- Annual Energy Consumption=100HPx0.746X800X(100/93)x23=1475957Rs

- Annual Cost Savings = 1475957-1454068=21889Rs

- Overall savings may be much larger because an unbalanced supply voltage may power numerous motors and other electrical equipment.

- **Tripping of Motor:** Negative phase sequence current flowing due to unbalance can cause faults in the motor, resulting in, tripping or permanent damage of the electrical equipment

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- **Reduce Capacity:** For motors, an unbalance of 5% will result in capacity reduction by 25%.

- **Tripping of VFD Drives:** The variable frequency or speed drives connected to an unbalanced system can trip off. VFD treats high level unbalances as phase fault and can trip on earth fault or missing phase fault.