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# Over Voltage Fault due to Disconnection of Consumer’s Transformer Neutral Wire

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**Abstract:** Practically, the load currents in three phases are asymmetric in the power system. It means that the impedances are different in all three phases. If the consumer’s transformer neutral cut off and/or was disconnected from the neutral of power supply source, then there will be some trouble and failure occurred. The current in the neutral wire drops down to zero when the neutral wire is cut off and the phase currents of all three-phase equal to each other since there was no return wire. The currents are equal but the voltages at the phase consumers are different. Especially for residential single-phase consumers, the voltage at the consumers of the phase varies differently for three phase systems when the neutral wire was disconnected at consumer side and even the voltage at the consumers one or two of those three phases becomes over nominal voltage or reaches nearly line voltage. In this case, the electronic appliances in that phase will be fed by high voltage than the rated value and they can be broken down. In the power system of UB (Ulaanbaatar) city, there are some occasional such kind of failures every year. Obviously, many electronic appliances were broken down due to high voltage and the electricity utility companies respond for service charge of damaged parts.

**Key words:** Neutral connection and neutral wire, phase and line voltage, single-phase residential consumer, transformer neutral cut off, asymmetric load current, protective earth.

## 1. Introduction

The 6-10 kV medium voltage isolated neutral power distribution network distributes power to the residential consumers. At the consumer or receiving end, the 6/0.4 kV and 10/0.4 kV substation powers the residential single-phase consumers.

There are about 7,800 sub stations with over 10,000 transformers of the 6-10/0.4 kV for power supply of the residential consumers in UB (Ulaanbaatar) including suburb and suburban little towns.

The total installed capacity of those transformer substations is 4,042.6 MBA [1].

In Mongolia, the 0.4 kV low voltage power distribution network has deeply grounded neutral as like as in Russia. It means that at the 35/0.4 kV, 10/0.4 kV and 6/0.4 kV sub stations with the transformer’s neutral of the low voltage side or secondary winding are almost directly grounded to the ground or earth.

Therefore, 0.4 kV distribution network has 3 hot lines and 1 neutral line. The line-to-line voltage is 380 V or 0.4 kV and line to neutral voltage is 220 V.

Today, more than 60% of UB’s population, some 750,000 people at last official count, live in poorly serviced ger districts. Many ger residents have little access to basic services and infrastructure provisions such as electricity, sanitation, water, solid waste management, roads, public transportation, or street lighting and drainage [2].

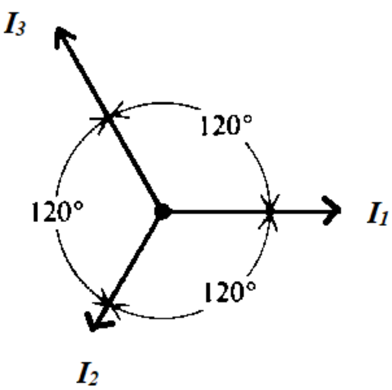


**Fig. 1 Magnitude and angle of phase currents.**

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Especially for the ger districts, the load currents in phases are completely different to each other and several hundreds of gers get their power from each phase of single transformer. Usually there are outdoor transformer substations and also there is no PE wire separately for residential low voltage network or grounding system is entirely insufficient in ger district power supply. Practically, the power factor is almost unity for residential consumer and the phase angle between three phases is nearly 120°.

But the currents in phases are unequal to each other and the neutral current returns to generator or power source neutral point as shown in Fig. 1. The magnitude of current in neutral wire is exceedingly high due to unequal phase currents and heat generated by this current is higher than calculated or designed volume. The contact of the neutral point becomes worse due to extra heating. When the transformer's neutral is disconnected at the consumer side then the neutral current becomes zero and phase currents in each phase become automatically equal to each other.

Accordingly, the phase voltages will be changed to equalize the phase currents.

## 2. Analysis of the Fault Current and Voltage

*2.1 Analysis of the Fault Current*

The current in the neutral wire is sum of the phase currents of the receiving end and returns to the armature winding of the power source or secondary winding of the transformer.

If the impedances in phase A, B and C are as follows:

$$Z_A < Z_B < Z_C$$

The magnitudes of the currents in the phases are shown in Fig. 2.

The angle and magnitude of the neutral current send messages to the winding of the power source to send more charges from the power source to the terminal of receiving end which dissipate more charges comparatively. It means that the terminal which dissipates more charges or the phase has more load current can receive more charges from the power source.

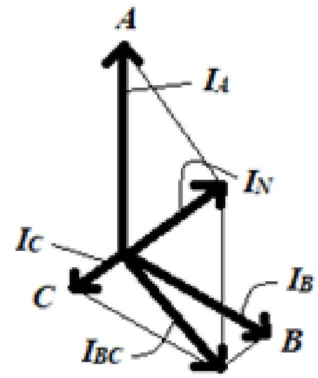



**Fig. 2 Vector diagram of the currents.**

In other word, the neutral current can contribute to or take part in controlling the sending charges from the power source to the receiving end. These extra charges can cause to keep the magnitude and angles of the phase voltages relatively equal to each other. The phase voltage which has higher load current can be decreased, but the extra charges delivered to this terminal can increase the potential of this phase.

If suddenly the neutral wire is disconnected at the receiving end, then the magnitude of the currents will become equal to each other or it is fault current of disconnecting neutral wire. However, the angles between the currents will be changed due to the angles between phase voltages. Obviously, the angle between voltage and current in each phase can be caused character of the load in this phase [3].

*2.2 Analysis of the Fault Voltage*

Since the currents in phases can be equalized to each other by causing the disconnection of neutral wire, according to Ohm's law, the voltages in each phase will be product of impedance and current in each phase. In previous section, we noticed that the currents in phases are completely different even the phase voltages are equal to each other due to different value of the impedances for normal working state.

It can be explained by using a simple model of the impedances of the phases as mentioned above.

$$Z_A < Z_B < Z_C$$

According to Ohm's law:

$$V = I \times Z$$

For the disconnection of neutral wire, the phase current is equal to each other and the phase voltage will depend on the phase impedance.

$$V_A = I \times Z_A \quad (1)$$

$$V_B = I \times Z_B \quad (2)$$

$$V_C = I \times Z_C \quad (3)$$

$Z_A < Z_B < Z_C$ for this case:

$$V_A < V_B < V_C$$

The summation of the phase impedance:

$$Z_A + Z_B + Z_C = Z_\Sigma \quad (4)$$

Fraction of each phase impedance in summation of impedance is as follow:

$$C_A = Z_A/Z_\Sigma \quad (5)$$

$$C_B = Z_B/Z_\Sigma \quad (6)$$

$$C_C = Z_C/Z_\Sigma \quad (7)$$

When:

$$C_A = (1/3) \times Z_\Sigma \quad (8)$$

then:

$$V_A = V_\Phi \quad (9)$$

here: $V_\Phi$ = phase voltage.

General equations for determination of the phase voltages when there occurred disconnection of neutral wire are as follows:

$$V_A = V*_A \times \frac{V*_B + V*_C}{V_N} \quad (10)$$

$$V_B = V*_B \times \frac{V*_A + V*_C}{V_N} \quad (11)$$

$$V_C = V*_C \times \frac{V*_A + V*_C}{V_N} \quad (12)$$

here: $V_N$ = voltage of floating neutral point V.

$V*_A = 3 \times C_A \times V_\Phi$

$V*_B = 3 \times C_B \times V_\Phi$

$V*_C = 3 \times C_C \times V_\Phi$

Then the phase voltage after the fault of disconnecting the neutral wire is shown in Fig. 3.

Here the voltage of the phase C is largest one due to impedance in this phase.

If the impedance in phase A and B is negligible than the impedance in phase C, then the voltage of the phase C will be larger than the voltages in phases A and B. The phase voltages are shown in Fig. 4.

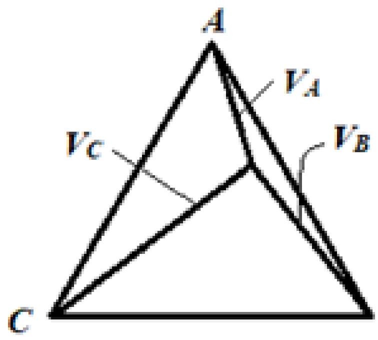



**Fig. 3 Vector diagram of voltage after fault of disconnecting the neutral wire.**

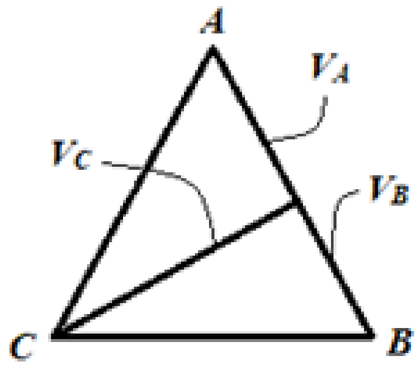
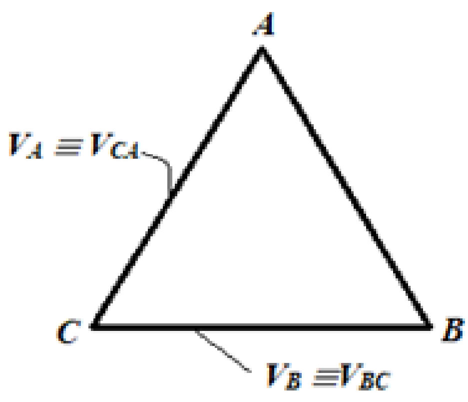



**Fig. 4 The phase voltage in phases for *Z*.**

Otherwise, the impedance in the phase C is negligible than the impedances of phases A and B, then the phase voltage in the phase C is almost equal to zero and the vector diagram of the phase voltages is shown in Fig. 5.

In this case, the phase voltage in the phase C is almost equal to zero. Since the impedance in the phase C is exceedingly small and then the phase voltage is also equal to zero. However, the phase voltages in the phase A and B are nearly equal to line-to-line voltage.




**Fig, 5 Vector diagram of the phase voltages for $Z_C \equiv 0$.**

## 3. Explanation on Over Voltage due to Disconnecting Neutral Wire

When the neutral wire is disconnected from the neutral point of the power source, then it is dangerous for single phase dominant transformer substation.

First of all, the return current to equalize the neutral point potential between consumer and power source becomes zero or potential of those points differs and the neutral point position on the vector diagram moves to another position.

Since there is no return way, the currents in all three phases become equal automatically and accordingly, the phase voltages are changed in frame from zero to line-to-line value due to its impedance.

If one or two of phase voltage become over rated value, then electronic appliances in this phase will be down broken immediately.

Several hundred single phase consumers are powered from single transformer substation and many of the parts of the electronic appliances are broken down due to over voltage of the phase.

The electricity utility company has to respond for charges of those damaged parts indeed.

Usually, for constructing the grounding system of the low voltage power supply system is used first: ПУЭ which is used as the rule or regulation of Russia and second: БД 43-101-03 which is used as the rule and regulation of Mongolia [4, 5].

Both of those regulations do not clearly and detailly explain how to construct the grounding facility in the low voltage power supply network system of the ger district.

It means that there is no official regulation for constructing the grounding system for the low voltage power supply network in the ger district in Mongolia.

## 4. Conclusions

It is necessary to strengthen the regular checking of the contact connecting condition of the neutral point at the consumer side transformer substation and to improve grounding system in the low voltage power network in the ger district in UB city.

Accordingly, it is needed to develop the regulations and rules for constructing grounding facility especially in the ger district power supply network system in Mongolia.

The grounding facility must be particularly related with feature of the ger district area.

## References


[1] Technical Information of Ulaanbaatar Electricity Distribution Company. https://www.tog.mn/une/1.

[2] Carlisle, S., and Pevzne, N. 2019. *Mongolian Energy Futures: Repowering Ulaanbaatar Challenges of Radical Energy Sector Decarbonization.*

[3] Parmar, J. 2012. "Impact of Floating Neutral in Power Distribution." Presented at the 2012 Electrical Notes and Articles.

[4] правила устройства электроустановок Седьмое издание, Дата введения 2003-01-01. (in Russian)

[5] БД 43-101-03. 2003. *The Mongolian Regulations for Design and Maintenance of Electrical Installations.*