10 ohm Neutral Grounding Resistance in 30kV Western Libyan Network and Effects

Eng. Hasan Z. Al-Amari
Ministry of Electricity and Renewable Energy, Libya
hasan_zawam@yahoo.com

Dr. Abdallah I. Fadel
University of Tripoli, Libya
fadel.abdalla@icloud.com

***Abstract*- Direct Grounding of the transformer neutral point leads to single line to ground fault current with a high-value, which may reach the value of the three-phase fault current or more. This high fault current causes destruction of fault locations (equipments and operators), and raises the ground voltage that increases the high step and touch voltages, which is dangerous to humans and animals, causes destruction of communications equipment and can be of great danger to the users. Those high fault currents can be reduced by inserting resistance to the neutral point of injection feeding transformer.**

In this research, the importance and effect of neutral grounding resistance in 30kV system network and its impact in the determining and limiting of the single line to ground fault currents for a network fed by a single or multi sources will be addressed. Also, the characteristics of the neutral grounding resistance installed in 220/30 kV transformer will be determined and discussed.

According to the historical data, two events of tripping happened in 30kV transformer substation in Tripoli area network, due to high single line to ground fault.

The behavior of single line to ground fault current for the above mentioned tripping events in Tripoli area were measured, and this will be compared to the simulated results of the same cases and discussed.

The ATP (Alternative Transient Program) and Neplan software programs are used for simulation of such events [5] [6].

Finally, the effect of the Temporary Over Voltage (TOV), which is also called Power Frequency Over Voltage, on the healthy phases during the single line to ground fault current occurs will be discussed, as well as the effect of the neutral grounding point.

***Key Words*- Neutral Grounding Resistance (R_N), Single Line to Ground Fault current (I_f), Temporary Overvoltage, Short-time Rating, Alternative Transient Program (ATP).**

I. INTRODUCTION

The 66kV and 30kV networks of the Libyan electrical systems are the link between the high voltage (220kV) and the low voltage (11kV) networks; they are, also, known as the medium voltage (or sub- transmission) networks. Libya is one of the largest countries in North Africa; its area is about 1.76 million km², with a coastline stretching in the south of the Mediterranean Sea for about 2,000 km. The country's population is about 6 million inhabitant, most of them live in the coastal cities. The electric load demand dramatically increased over the past three decades at an average growth rate (8-10 %) per annum. Accordingly, the generation and network expansions to meet the requirement of this growth have always been a consequent result. The number of substations installed in 30kV network is 355, and are based in coastal cities. In the 66Kv network, there are 175 substations, and are based in the Central and South cities. The total capacity of all substations, constituting a ratio of almost 1:2, is 13,539 MVA. The cables and overhead lines for power transmission are 22,258 km long, whereas the length of the overhead lines for the medium voltage electric power transmission network is approximately 90% of the total length of the medium voltage circuits [1].

The Libyan electric network is divided into six areas for the operation and maintenance of stations and transmission lines. Each area contains a set of electrical rings separated from each other. It is worth mentioning that the term ring denotes a 220/66kV or a 220/30kV transformer that feeds a 66kV or 30kV network; it is called the main Injection point. Figure 1 and Figure 2 show the geographical division of the six operation and maintenance areas and the main injection point, respectively [1].

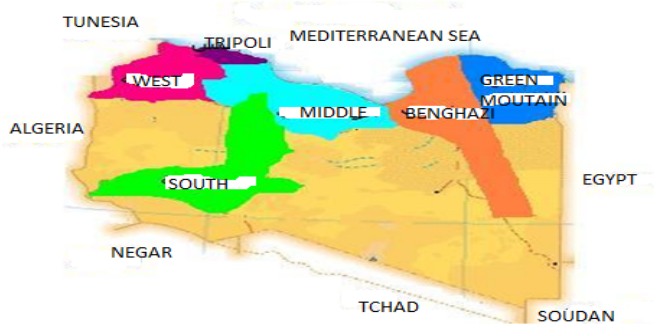

Fig. 1. Division of Geographical Regions of the Six Electric Operating Areas

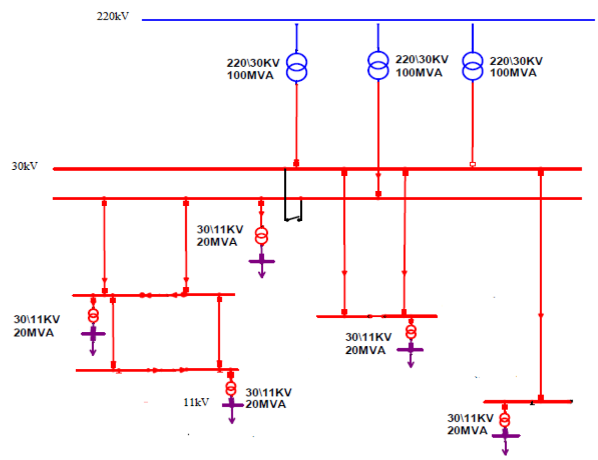

Fig. 2. Main Injection Point Feeding 30kV Network

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II. GROUNDING POLICY IN LIBYAN 30kV NETWORK AND IN TURKISH34.5kV NETWORK

In the Libyan 30kV network, limiting the single line to ground fault current is done through connecting 10 ohm neutral-grounding resistance. As a result, the possible danger of too high potential gradients is reduced. In a network consisting mainly of cables effective for grounding (e.g. lead sheath protected cables with jute covering), according to German specifications VDE 0141, for example, the proof of step and touch voltages may be renounced if the l-phase-fault current is limited to 2 kA. If these conditions are not fulfilled, then the necessary effort for the safe grounding of the equipment is considerably less than that for direct grounding. The most common implementation type in Turkey is to limit the phase to ground current to 995 A in the secondary side of the 154/34.5kV power transformer with YNyn0 vector group by connecting 20 ohm resistances to the secondary wye points. Table I shows characteristics of the neutral grounding resistance in the Libyan 30kV and the Turkish 34.5kV networks [3] [4].

TABLE I
CHARACTERISTIC OF NEUTRAL GROUNDING RESISTANCE FOR LIBYAN AND TURKISH NETWORKS

Characteristic of Neutral Grounding Resistance	Libyan 30kV Network	Turkish 34.5kV Network
Neutral resistance	10 ohm	20 ohm
Nominal phase voltage	17.32kV	20.78kV
Short-time current	2kA	1kA
Short-time rating	5-10 sec	5sec
Energy dissipated	(200-400)MJ	100MJ

III. SHORT CIRCUIT CURRENT (SCC) AND TEMPORARY OVER VOLTAGE IN LIBYAN 30kV NETWORK

The single source feeding the 30kV network can be either a 220/30kV transformer of 63 or 100MVA size connected to 30kV network. The double-source-fed network contains either two 220/30kV transformers (of a 63 or 100MVA size) or a 10.5-13.2 kV generator and a transformer. The triple-source-fed network is usually done by connecting two transformers and a generator, and sometimes by connecting three transformers. Figure 3 illustrates two transformers and one generator feeding the 30kV network. [3] [4]

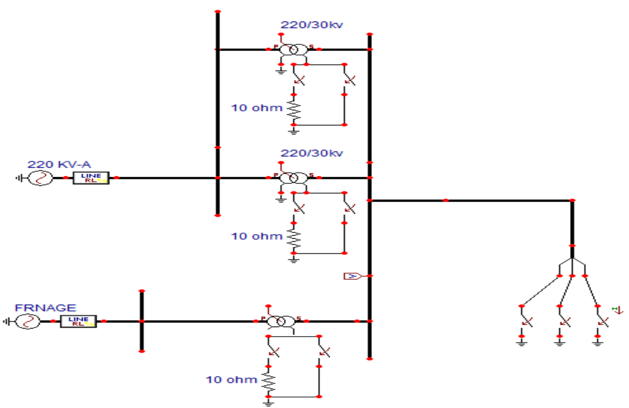

Fig. 3. Two Transformers and One Generator Feeding Network

The general results for the short circuit current and temporary over voltage level at different number of feeding sources are summarized in the following Table II.

TABLE II
SHORT CIRCUIT CURRENT AND TEMPORARY OVER VOLTAGE AT DIFFERENT NUMBER OF FEEDING SOURCES

Different feeding source		Three phase fault current KA r.m.s	Single line to ground fault current and Temporary Over Voltage			
			Neutral point solidly grounding		Neutral point grounded thought 10ohm resistance	
			kA r.m.s	kV r.m.s	kA r.m.s	kV r.m.s
Single feeding source		8.75	8.68	17.32	1.7	31.14
Double feeding source	One Transformer + One Generator	15.58	15.52	16.85	3.26	30.22
	Two Transformer	16.6	16.4	17.32	3.36	31.2
Triple feeding source	Two Transformer + One Generator	19.5	20.5	16.7	4.92	30.87
	Three Transformer	23.7	23.23	17.6	5.024	31.17

IV. EFFECT OF NEUTRAL GROUNDING RESISTANCE R_N ON SHORT CIRCUIT CURRENT AND TEMPORARY OVER VOLTAGE IN LIBYAN 30kV NETWORK

The single line to ground fault current changes depend on whether the system network is grounded or ungrounded neutral point; but it does not have an effect on the value of the three phase short circuit current. With the solidly grounded neutral point, the three phase short circuit current and single phase short circuit current levels are almost equal, considering single feeding source, double feeding source and triple feeding source. On the other hand, when the neutral point of the transformer is grounded through a 10 ohm resistance, the single line to ground fault current level is reduced to 20% of its original value, and does not exceed 2kA. For double feeding source, the single line to ground fault current does not exceed 4kA, and for the case of one transformer and one generator, the single line to ground fault current level is reduced to 21% of its original value. But for two transformers, the single line to ground fault current level is reduced to 20% of its original value. In triple feeding source, the single line to ground fault current level is reduced to 24% of its original value, considering two 220/30 kV transformers and one generator as feeding sources. But for three transformers considered as feeding sources, the value of the single line to ground fault current level is reduced to 23% of its original value, and not exceeding 5kA. This result is shown in figure 4, which means that the single line to ground fault current level proportionally increases with the number of feeding sources.

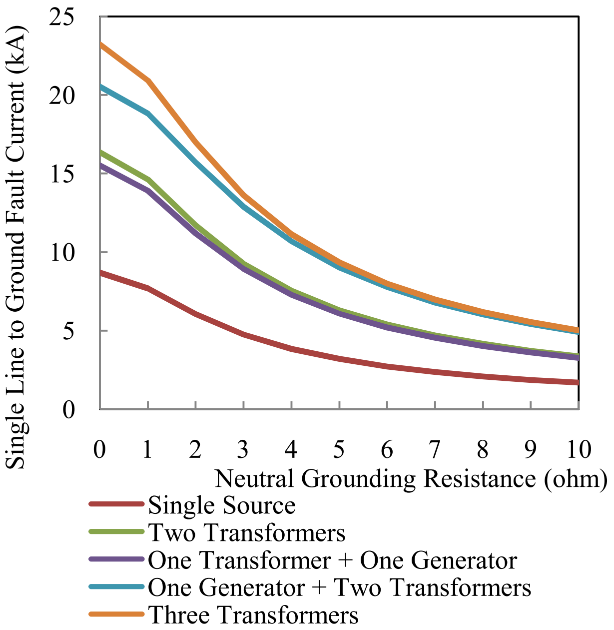

Fig. 4. Single Phase Short Circuit Current Variation with Number of Feeding Sources

To keep the single line to ground fault less than 2kA for safe step and touch voltages, the neutral grounding resistance should be 10ohm, 20ohm and 30ohm for single, double and triple feeding source, respectively. For n feeding sources, the value of neutral grounding resistance is determined to be equal to 10n for each source. For example, for six feeding sources, the value of neutral grounding resistance for each source is 10×6=60 ohm. Figure 5 shows the single line to ground fault Variation with Number of Feeding Sources n.

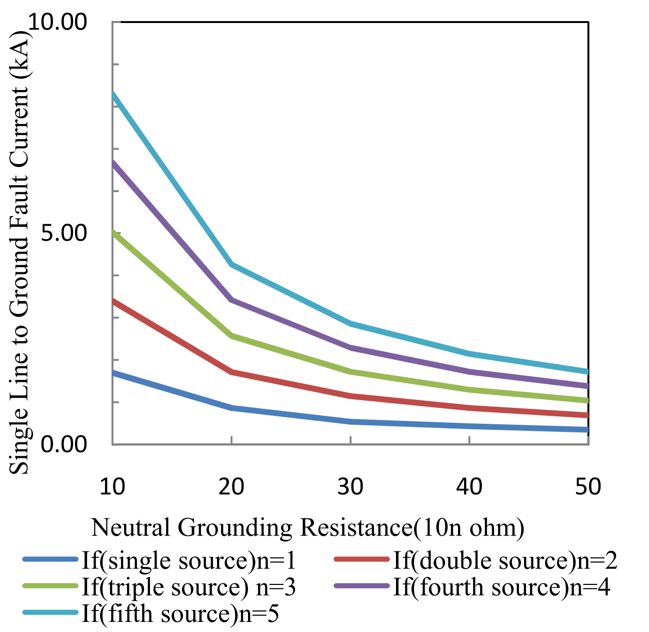

Fig. 5. Single Phase Short Circuit Current Variation with Number of Feeding Sources n

Also, the Temporary Over Voltage is calculated at the same time with varying the neutral grounding resistance, and with solidly neutral grounded point. Figure 6 shows that the Temporary Over Voltage is not affected by the number of feeding sources of the 30kV network for the solidly neutral grounded point or through the neutral grounding resistance.

The neutral grounding resistance effective on the single line to ground fault current and Temporary Over Voltage is shown in the figure 7. From this figure, one can easily discern that increasing the neutral grounding resistance decreases the single line to ground fault current, but increases the Temporary Over Voltage.

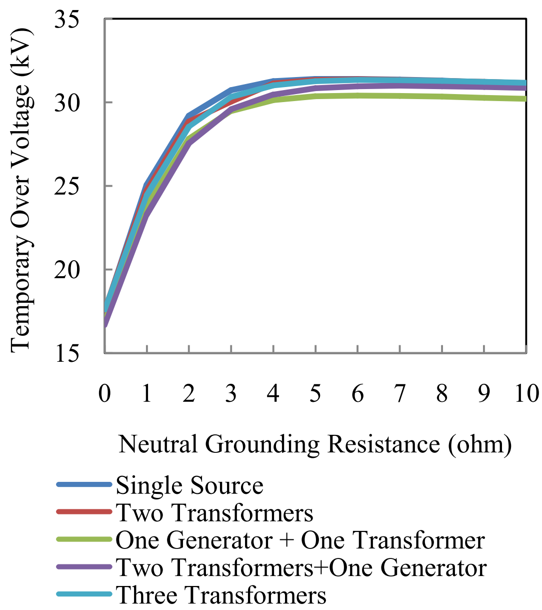

Fig. 6. Behaviour of Temporary Over Voltage with the number of feeding sources

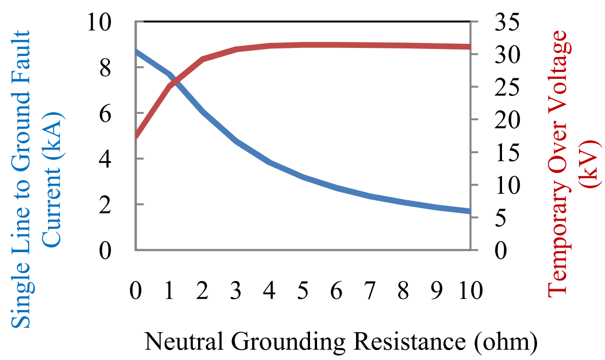

Fig. 7. Neutral Grounding Resistance Effective on Single Line to Ground Fault Current and Temporary Over Voltage

The Temporary Over Voltage values of healthy phases during single line to ground fault reach to 31.2 kV (1.04p.u) of the line voltage. According to the General Electric Company of Libya (GECOL) standard, the equipment of 30kV network must withstand the Temporary Over Voltage levels of 36 kV. Table III shows Temporary Over Voltage for 66 kV, 30 kV and 11 kV.

TABLE III
GECOL STANDARD OF TEMPORARY OVER VOLTAGE FOR DIFFERENT VOLTAGE LEVELS

Nominal voltage of system	Temporary Over Voltage
11kV	12kV
30kV	36kV
66kV	72.5kV

V. CASES STUDIES

Two actual cases of tripping in the 30kV network of the western area are chosen to be studied and simulated. The first case study of tripping is for Ainzara 220/30/11kV substation, and the second case study of tripping is for Tripoli South 220/30/11kV substation.

A. Case1 (Ainzara 220/30/11 kV Substation)

The trip event of single line to ground fault current on the 220/30 kV transformer at Ainzara substation occurred on 21/11/2007, which caused damage to the 10 ohm neutral grounding resistance of the transformer. The 10 ohm resistor connected through the neutral grounding has the characteristics shown in following table:

TABLE IV
CHARACTERSITICS OF NEUTRAL GROUNDING RESISTANCE OF AINZARA SUBSTATION

Neutral resistance	10 ohm
Nominal phase voltage	17.32 kV
Short-time current	2kA
Short-time rating	2sec
Energy dissipated	80MJ

1) Recorded Readings

From the readings provided by the trip (event sequence) recorder of the back-up protection device of 7SG65 type, which is installed on Ainzara 220/30kV transformer number 1, and from the readings given by the recorder of the distance protection device of 7Sa631 type, which is installed on al-Fornaj substation's 30kV cables (2) and (3) inside of Ainzara substation, it is noted that the total duration time of the fault is 1.453 seconds, and is split into 0.88 seconds for the single line to ground fault current of 7.9 kA and 0.573 seconds, during which the current slid back (decayed) to 3.88 kA. This is to say that the short circuit current is divided over two different periods of time.

Period (I)

- The value of the fault's current on Al-Fornaj cables (1), (2), and (3) is 2.6 kA for the phase (B) of each cable.
- Al-Fornaj cables (2) and (3) tripped at the third stage, with a time of 0.8 seconds. The tripping is considered selectively for the reason that the protection device installed on the fault cable failed to work.
- The fault persisted due to the failure of the protection device installed on Al-Fornaj cable (1).

Period (II)

- The value of the single line to ground fault current declined to 3.88 kA during 0.573 seconds; it is the same value of the current passing through the neutral point of the 30kV secondary side of the transformer, which is attributed to the change in the neutral grounding resistance.
- The tripping of Ainzara transformer due to earth fault occurred after the lapse of 1.453 seconds. This trip is considered selectively for the reason that the protection device installed on al-Fornaj cable failed to work.

Figure 8 shows the behavior of the short circuit current in neutral conductors during measurements.

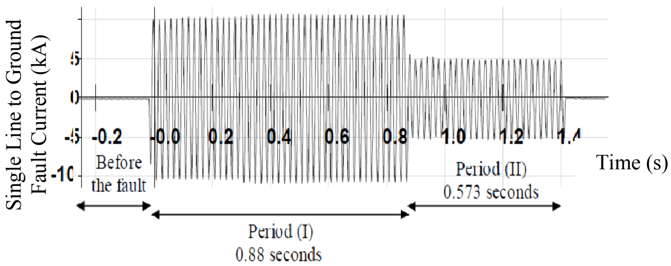

Fig. 8. Measurement of Short Circuit Current in the Neutral conductor

2) Tripping Event Simulation by ATP Program

The actual operating network scheme shown in figure 9 is considered and simulated, using ATP program. The following are founded:

- The resistance value of the neutral point in period (I) by no means exceeds 1.6ohm to obtain a single line to ground fault current of 7.9 kA.
- The value of the fault resistance changed to 4.9ohm, driving the single line to ground fault current to fall to 3.88 kA.

The simulation suggested that the neutral point's resistance experienced a collapse during period (I), where the fault resistance was about 1.6 ohms, making the single line to ground fault current to rise to 7.9 kA. On the other hand, the single line to ground fault current in period (II) dropped to 3.88 kA, as a consequent result of the change in the fault's resistance.

Figure 10 explains the behavior of the single line to ground fault current throughout the simulation process.

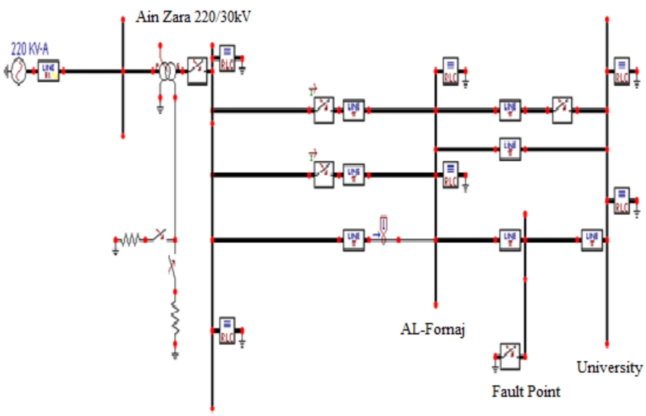

Fig. 9. Simulation of Case1 by ATP Program

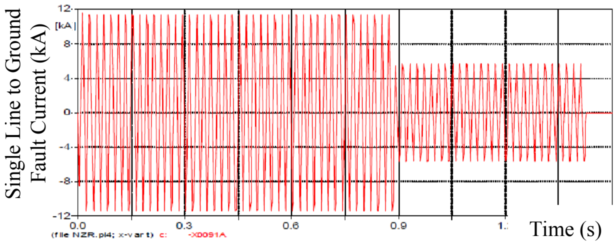

Fig. 10. Behavior of Short Circuit Current throughout Simulation Process

3) Results and Discussion

- The rise in the value of the single line to ground fault current to around 8 kA, at the moment when the earth fault occurred, shows that the neutral point resistance had been damaged before the earth fault took place.
- The specifications of the neutral point resistance installed in the 220/30kV transformers of Ainzara substation do not match those recommended specifications.

A. Case2 (Tripoli South 220/30/11 kV Substation)

The trip event in Tripoli South 220/30/11 kV substation on 27/11/2010, where a high single line to ground fault current due to explosion occurs on the front cable of Al-Mukaweloon substation yields to trip the protection system of 25-3-2 Recorded Readings. The 10 ohm resistor connected through neutral grounding has the characteristics shown in Table V:

TABLE V
CHARACTERSITICS OF NEUTRAL GROUNDING RESISTANCE OF AINZARA SUBSTATION

Neutral resistance	10 ohm
Nominal phase voltage	17.32 kv
Short-time current	2kA
Short-time rating	10 sec
Energy dissipated	400MJ

1) Recorded Readings

The settings of the distance protection devices installed at Tripoli South substation for Al-Muqawiloon-Tripoli South were inspected and compared with the settings provided by the Protection Department, and were found compatible.

From the readings of the event recorder of the distance protection device, of 7SJ611 type, installed at Tripoli South for the 30kV line (1), it can be seen that the fault duration is 0.38 seconds, with single line to ground fault current of around 11.5 kA. As shown in figure 11.

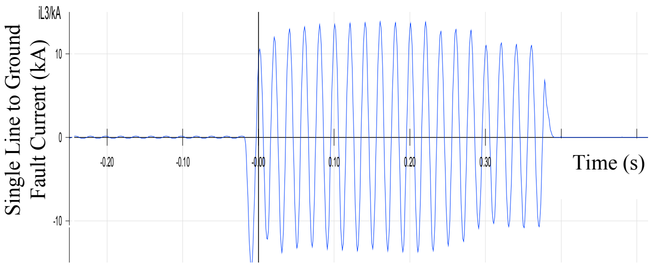

Fig. 11. Measurement of single line to ground fault current

Figures 12 and 13 explain the measurement contribution of single line to ground fault current from cables Tripoli South/ Al-Muqawiloon (1) and (2).

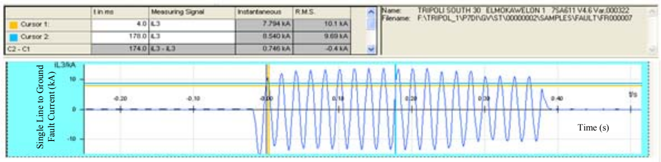

Fig. 12. Measurement the contribution of the single line to ground fault current by Cable (1) Tripoli South /Al-Muqawiloon

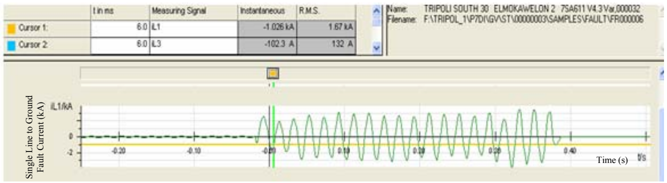

Fig. 13. Measurement the contribution of the earth fault short circuit current by Cable (2) Tripoli South /Al-Muqawiloon

2) Tripping Event Simulation by ATP Program

The simulation process of the tripping, illustrated in Figure 14, concluded that the single line to ground fault short circuit currents are as follows:

- The total single line to ground fault current at the end of the cable connecting Tripoli South and Al-Muqawiloon substations is 10.5 kA, as shown in Figure 15.
- The contribution of the single line to ground fault current by Al-Muqawiloon Cable (1) is 9 kA, as explained in Figures 16.
- The contribution of the single line to ground fault current by Al-Muqawiloon Cable (2) is 1.75 kA, as explained in Figures 17.

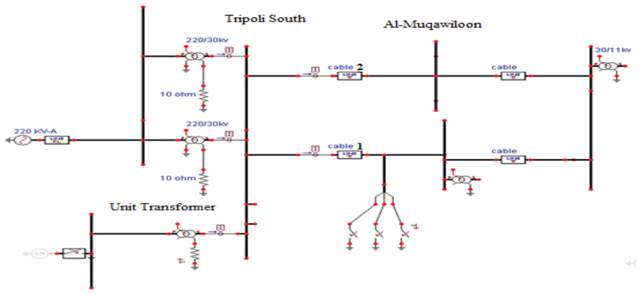

Fig. 14. Simulation of Case2 by ATP Program

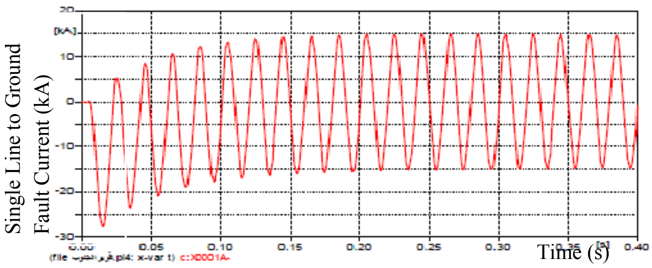

Fig. 15. Total Single-phase Short Circuit Current at the End of the Cable Connecting Tripoli South and Al-Muqawiloon Substations

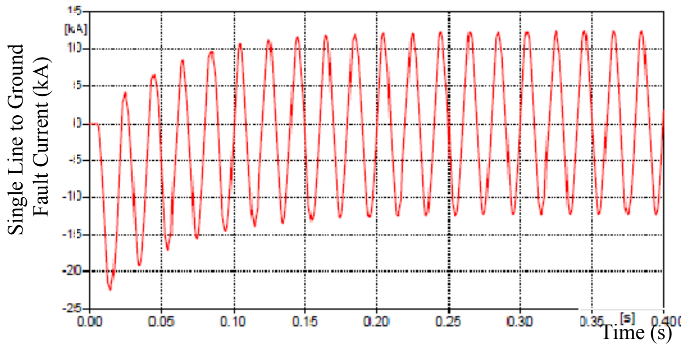

Fig. 16. Contribution of the single line to ground fault Current by Al-Muqawiloon Cable (1)

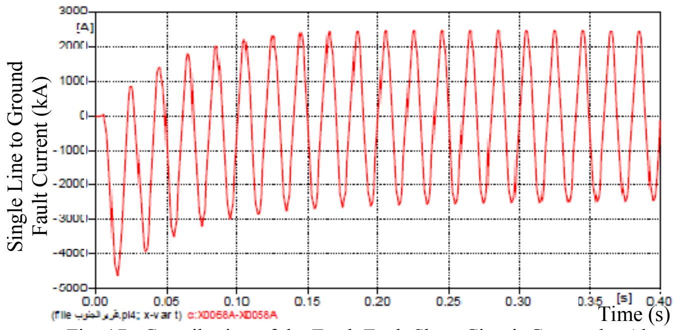

Fig. 17. Contribution of the Earth Fault Short Circuit Current by Al-Muqawiloon Cable (2)

3) *Results and Discussion*

- The upsurge in the single line to ground fault current is caused by the lack of the neutral point's 10ohms-resistance in the unit transformer.
- Three feeding sources for the 30kV network make the short circuit current to soar even if the unit transformer resistance is installed.
- When the operating generating unit is disconnected from the 30kV side, the unit 30/11kV transformer must be disconnected too.

VI. CONCLUSION

The neutral grounding point of transformer can be connected directly, through resistance or through reactance. Also, the neutral point can be ungrounded. Each type has a different application.

The main objective of the neutral grounding resistance is to reduce the single line to ground fault current to a value that makes the step and touch voltage safe to human.

The 10ohm-neutral grounding resistance installed in 30kV network decreases the single line to ground fault current to less than 2kA, 4 kA and 5kA in the 30kV network for single, double and triple feeding source, respectively, and increases the Temporary Over Voltage to approximately 30kV on the healthy phase for single, double and triple feeding source.

Increasing the number of feeding sources n increases the value of neutral grounding resistance installed to the neutral point to 10n, to keep the single line to ground fault current less than 2kA.

The specification of the neutral grounding resistance does not only depend on the value of the resistance, but also on the time needed for this resistance to consume energy.

The event recorder installed in the protection equipment is very important to record the voltage behavior and current behavior when the disturbance happens in the network.

ATP and Neplan programs are used to simulate the voltage behavior and current behavior in transient and in steady state conditions accordingly, and show matching results to the real measurement, as seen in the event cases.

VII. RECOMMENDATIONS

1) The neutral point of the 220/30kV transformer should be grounded from 30kV side through an appropriate resistance, to keep safe and secure the electric and communication apparatus and equipment, as well as working personnel on them during single-phase short circuit current.
2) In the case of n feeding source(s), 10n ohm resistance for the neutral point should be installed in all n transformers that feeding 30kV network, to keep the single line to ground fault current less than 2kA
3) The neutral grounding resistance should be changed so that it matches the recommended specifications (10n ohm, 2KA, and 10sec).
4) For the existing situation, it is preferred in Libya not to operate more than two sources to feed the 30kV network.
5) For the existing situation, the transformers of the generating units must be disconnected when a generating unit breaks off from the 30kV side.
6) The neutral grounding resistance should be inspected on a regular basis.
7) GECOL standards recommended that the equipment of 30kV network should withstand a Temporary Over Voltage value of 36kV.

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Nuran Yörükeren* and Musa Uçan
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