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

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Abstract-
Direct Grounding of the transformer neutral point leadms 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.

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.

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 characteristic of the neutral grounding resistance installed in 220/30 kV transformer will be determined and discussed.

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.

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, Temporary Overvoltage (TOV), Short-time Rating, Alternative Transient Program (ATP).

I. INTRODUCTION

The 66 kV 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, 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]

1-2 Geographic Regions of Medium Voltage Network:

The Libyan electric network is divided into six areas for the operation and maintenance of stations and the 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 feeding a 66kV or 30kV network; it is called the main Injection point. Figure (1) and Figure (1) show the geographical division of the six operation and maintenance regions and the main injection point, respectively. [1]

Figure (**Error! No text of specified style in document.**) - Division of Geographical Regions of the Six Electric Operating Areas

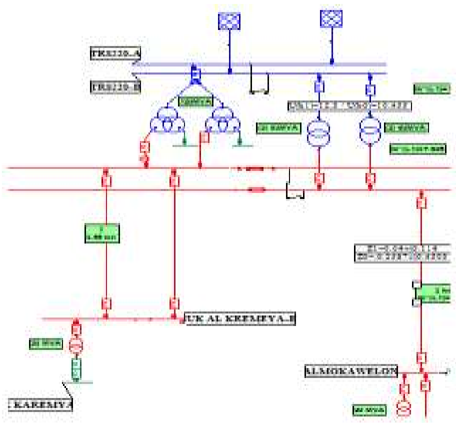

Figure (1) - Main Injection Point Feeding 30kV Network

2- Grounding Policy in 30kV Libyan Network and in 34.5kv Turkish network

In 30 kv Libyan network limiting the currents through low-ohmic neutral-grounding, the possible dangers of too high potential gradients are reduced. In a network consisting mainly of cables effective for grounding (eog. lead sheath protected cables with jute covering), according to German specifications VDE 01~41, 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 full-filled, than the necessary effort for the safe grounding~ of the equipment is considerably less than 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 by connecting 20 ohm resistances to the secondary wye points of the 154/34.5 kV power transformer with YNyn0 vector group. the table (1) shows characteristic of neutral grounding resistance (NGR) in 30 kv Libyan network and 34.5 kv Turkish network.

Table (1) NGR characteristic

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

3- Short Circuit current (SCC) and TOV in 30kV Libyan Network

Determine the short circuit SCC level in 30kV western Libyan network, considering the single fig. (3) and the same way when we have multiple fed sources.

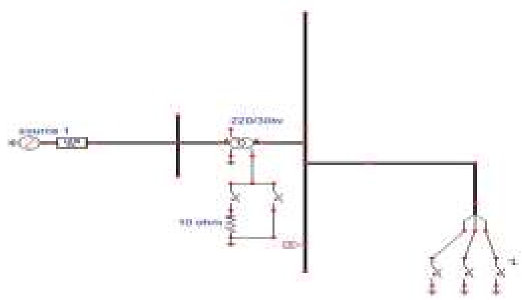

Figure (3) single fed source

The general results for the short circuit level and TOV at different number of feeding sources are summarized in the following table (2).

Table 2 SC level and TOV for different feeding

Short Circuit Level and TOV at Different Number of Feeding Sources						
Different feeding source		Three phase fault current	Single line to ground fault current and TOV			
			Neutral point solidly grounding		Neutral point grounded thought 10ohm resistance	
		KAr.m.s	KA r.m.s	KVr.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	(I)	15.58	15.52	16.85	3.26	30.22
	(II)	16.6	16.4	17.32	3.36	31.2
Triple feeding source	(I)	19.5	20.5	16.7	4.92	30.87
	(II)	23.7	23.23	17.6	5.024	31.17

4- Effect of Neutral Grounding Resistance R_N on SCC and TOV in 30kV Libyan Network

The single phase short circuit current changes, depending on whether the system network is grounded or ungrounded 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. While 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 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. When the generation expansion planning in 220kV the network is considered, the short circuit level increases (three phase and single phase short circuit currents) in the high voltage network, whereas the 10 ohm-neutral grounding resistance is still keeping the single line to ground fault less than 2kA, 4 kA and 5kA in the 30kV network for single fed, double fed and triple fed source, respectively

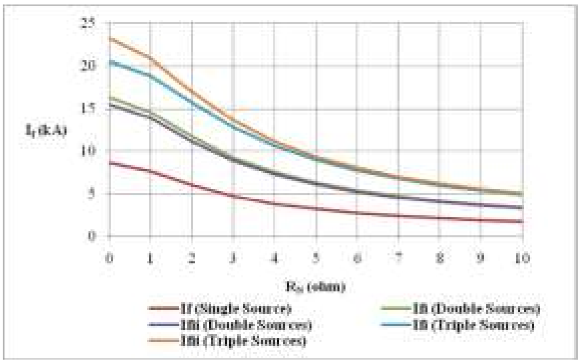

Fig.(4) SC current level at different feeding sources

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 10x6=60ohm. Figure (5) shows the single line to ground fault Variation with Number of Feeding Sources n.

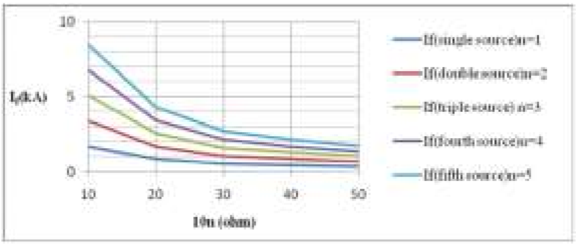

Fig. (5) SLG fault variation with different feeding sources

Also, the Temporary Over Voltage (TOV) is calculated at the same time with varying the neutral grounding resistance, and with solidly neutral grounded point. Figure (6) shows that the TOV 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.

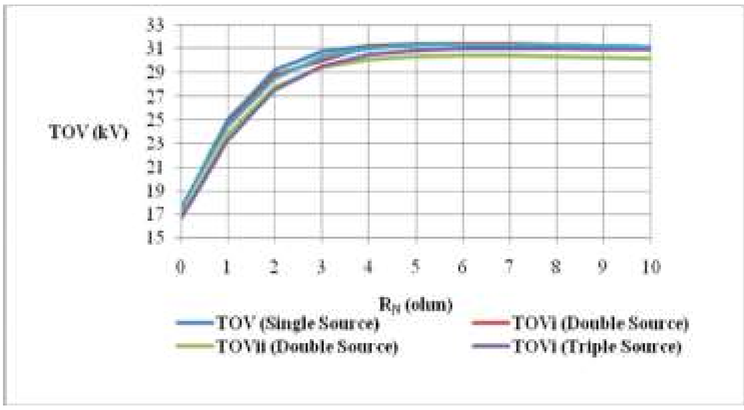

Fig. (6) TOV at different feeding sources

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

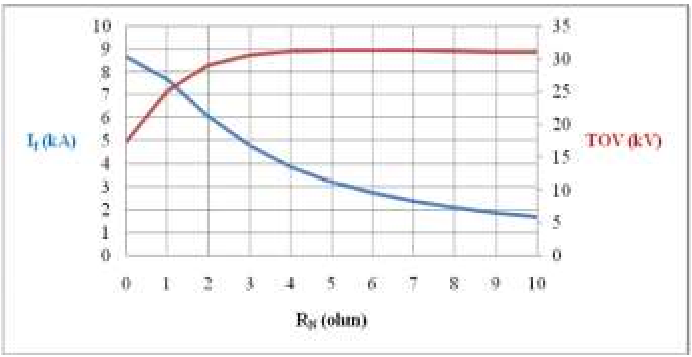

Fig. (7) Effect of increase of NGR on SLSC and TOV

The TOV values of healthy phases reach to 31.2 kV (1.04p.u) of the line voltage. According to the GECOL standard, the equipment of 30 kV network must withstand TOV of 36 kV. Table (3) explains TOV for 66 kV, 30 kV and 11 kV.

Table (3) TOV at different nominal voltages

Nominal voltage of system	TOV
11kV	12kV
30kV	36kV
66kV	72.5kV

5- Cases Study

Two actual cases of tripping in the 30kV network of 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.

5-1 Case1 (Ainzara 220/30/11 kV Substation)

The trip event of single line to ground fault current on the 220/30 kV transformer in Ainzara substation occurred on the 21/11/2007, which caused damage to the 10 ohm neutral grounding resistance of the transformer, its characteristic shown in table (4).

Table (4) - Characteristics of Ain Zara Neutral grounding resistance Box

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

5-2-2 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 Ain Zara 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 Ain Zara 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 fault current of 7.9KA and 0.573 seconds, during which the current slid back (decayed) to 3.88KA. 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 second stage, with a time of 0.8 seconds. The tripping is considered selectively for the reason that the protection device installed on the tripped 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 fault's current declined to 3.88KA 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 point resistance as shown in Fig.(8).
- The tripping of Ain Zara transformer due to earth fault 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.

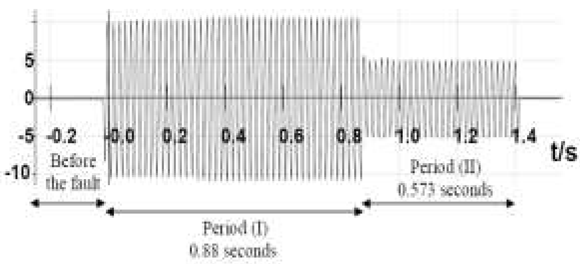

Fig. (8) SCC periods

5.2.3 Tripping Event Simulation by ATP Program

The simulation of the fault of the approved operation scheme, which is shown in Figure (9), and was carried out to arrive at the same the readings of the transformer's event recorder, gave the following findings:

- The resistance value of the neutral point in Period (I) by no means exceeds 1.6ohm to obtain a short circuit current of 7.9KA.
- The energy resulted in from the neutral point resistance in Period (I) is around 88 mega joules.
- The value of the fault resistance changed to 4.9ohm, driving the short circuit current to fall to 3.88KA.

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 short circuit current to rise to 7.9KA, resulting in a value of energy of 88 mega joules, which did not surpass the nominal limit set forth by its design. On the other hand, the short circuit current in Period (II) dropped to 3.88KA, as a consequent result of the change in the fault's resistance.

Figure (9) explains the behavior of the short circuit current throughout the simulation process, whereas Figure (10) depicts the power dissipated by the resistance during the fault.

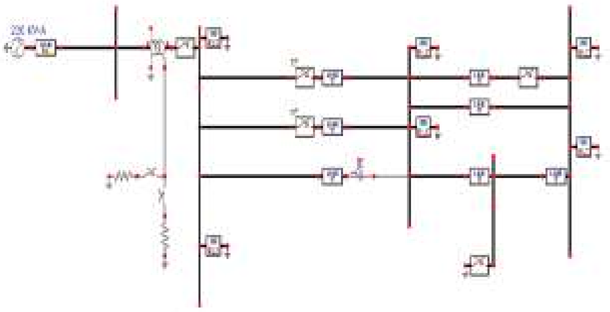

Figure (9) - Behavior of Short Circuit Current throughout Simulation Process

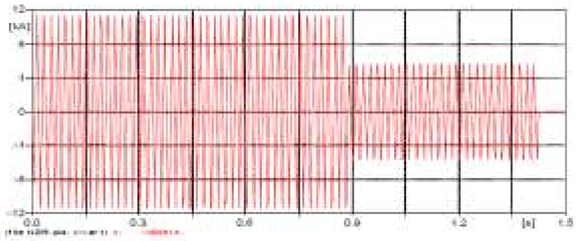

Figure (10) - Simulation of Case1 by ATP Program

5-2 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 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 380 seconds, with fault current of around 11.5 KA.

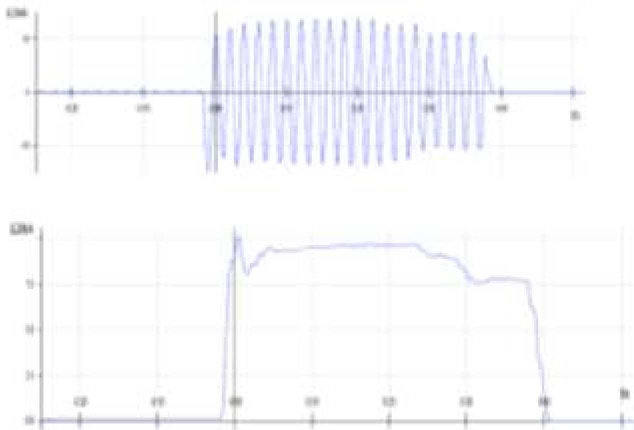

Figure (11) Measurement of Short Circuit Current

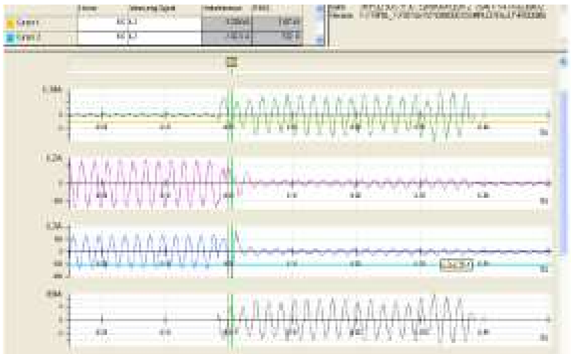

Figure (12) - Measurement of Short Circuit Current

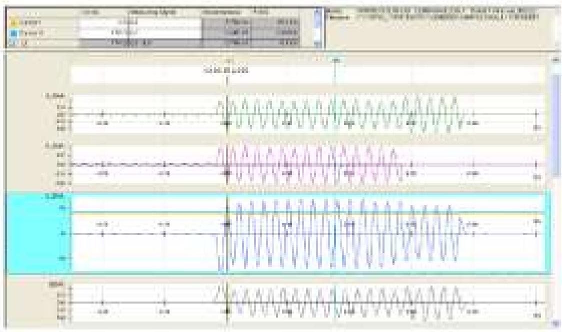

Figure (13) - Measurement of Short Circuit Current

5-3-3 Tripping Event Simulation by ATP Program

The simulation process of the tripping, illustrated in Figure (9), concluded that the single line to ground fault short circuit currents are as follows:

- The total single phase short circuit current at the end of the cable connecting Tripoli South and Al-Muqawiloon substations is 10.5 KA, as shown in Figure (12) and (13).
- The contribution of the earth fault short circuit current by Al-Muqawiloon Cable (1) is 9KA, as explained in Figures (11) and (13).
- The contribution of the earth fault short circuit current by Al-Muqawiloon Cable (2) is 1.75KA, as explained in Figures (10).

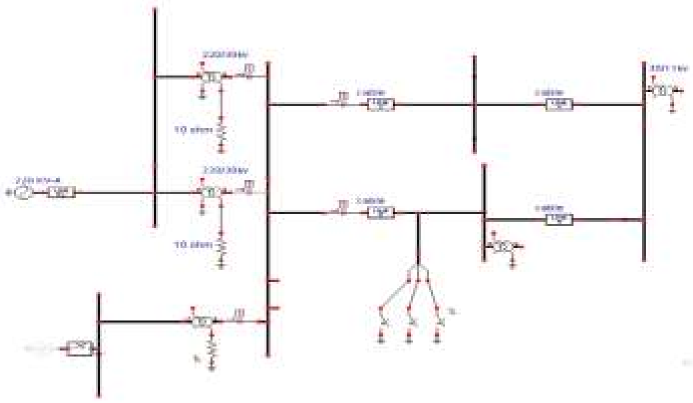

Fig.(14) - Simulation of Case2 by ATP Program

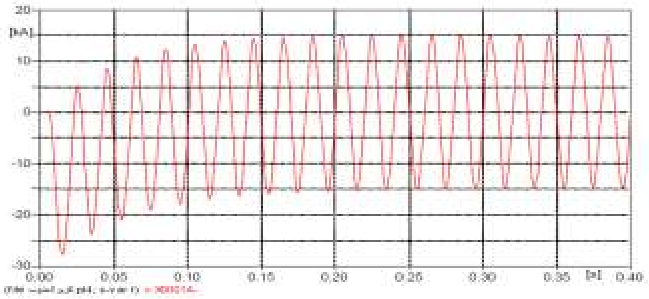

Figure (15) - Total Single-phase Short Circuit Current at the End of the Cable Connecting Tripoli South and Al-Muqawiloon Substations

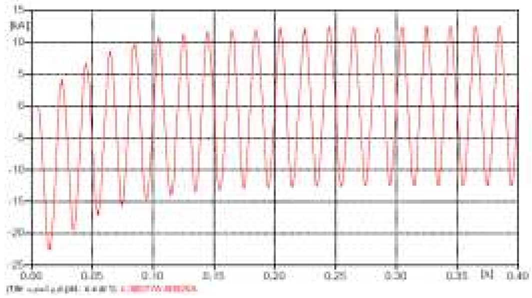

Figure (16) - Contribution of the Earth Fault Short Circuit Current by the Unit Transformer 20/30 kV transformer.

6- 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 10 ohm-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 sources, respectively, and increases the TOV 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.

7- Recommendations

- 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 persons working on them during single-phase short circuit current.
- In the case of n feeding source(s), 10n ohm resistance for the neutral point should be installed in all transformers that feeding 30kV network, to keep the single-phase short circuit current less than 2kA
- The neutral point resistance should be changed so that it matches the recommended specifications (10n ohm, 2KA, and 10sec).
- For the existing situation, it is recommended not to operate more than two sources to feed the 30kV network.
- The transformers of the generating units must be disconnected when a generating unit breaks off from the 30kV side.
- The neutral point resistance should be inspected on a regular basis.
- GECOL standards recommended that the equipment of 30kV network should withstand a TOV value of 36kV.

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Reference

[1] Hassan Z. El Amari, "Operation of electrical Libyan sub transmission grid" COMELAC Workshop, Tripoli, Libya, July 2009

[2] IEEE, "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems", Approved 7 June 2007.

[3] SIEMENS AKTIENGESELLSCHAFT, "Neutral Grounding in Tripoli 30kV Network", Erlangen, 02-10-1978.

[4] Neplan program V5.2

[5] EMTP - ATP programs 2004 (ATP draw version4.0p2).