



# Symmetrical and Unsymmetrical Fault Analysis of Short Circuit in Power Systems using ETAP

Simulation Tool: ETAP 19.0.1C | Standard: IEC 60909 | Frequency: 50 Hz

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## Abstract

Short circuit analysis is an essential tool for safe and reliable operation of industrial power systems. In this paper, a detailed fault analysis of the multi-bus industrial power network is presented according to the IEC 60909 standard and modeled in ETAP 19.0.1C. Symmetrical (three-phase) and unsymmetrical faults (line-to-ground (LG), line-to-line (LL), and double line-to-ground (LLG)) are studied. The system has several generators, transformers, transmission lines and loads operating at different voltage levels. The fault currents, peak currents and the breaking currents at the critical buses are evaluated to layout the system response in an abnormal condition. The results indicate that the three phase faults produce highest fault current but unsymmetrical faults are different in sequence impedance characteristics. The results of this research show the importance of impedance, earthing and system arrangement in fault study and can be used as a guide for protection system design and device select technique.

## 1. Introduction

Operation of modern industry requires an electricity system, and without continuous electricity supply, it is impossible to maintain production and safety. However, power systems face many potential fault situations, among them short circuit faults, insulation faults, malfunctions of equipment and external factors like lightning and switching surges.

The faults occurring in power systems are divided into symmetrical (or balanced) and unsymmetrical (or unbalanced) faults. Symmetrical faults include three-phase faults, in which all three phases get involved equally and that leads to the occurrence of maximum fault currents. They occur rarely, yet their presence constitutes the critical situation for the design of the power system. On the other hand, unsymmetrical faults include single LG, LL, LLG faults, which are much more common in practice.

The scope of this paper is modeling of an industrial power network through the use of the ETAP software with the purpose of studying both symmetrical and unsymmetrical faults at the main buses of the network. Specific emphasis will be placed on the measurement of fault currents, calculation of system impedance and grounding, and identification of the type of the fault affecting system performance.



## 2. System Description

The industrial power system considered in this study is a multi-bus network designed to represent a typical medium-scale industrial electrical distribution system. The system integrates generation, transmission, and distribution components operating at multiple voltage levels.

### 2.1 System Configuration

Component	Quantity	Description
Generators	2	Synchronous generators supplying power at 11 kV and 13 kV
Transformers	3	Step-up and step-down transformers for voltage conversion
Transmission Line	1	Connects high-voltage buses (140 kV level)
Buses	5	Operating at 11 kV, 13 kV, and 140 kV
Loads	2	Lumped loads connected at 11 kV distribution bus

(Voltages level):

Bus Level	Voltage Rating	Function
Low Voltage	11 kV	Load connection and distribution
Medium Voltage	13 kV	Generator connection
High Voltage	140 kV	Transmission and interconnection

### 2.2 Component Description

#### Generators:

- Two synchronous generators are used as primary power sources, providing electrical energy presumably at low voltage.

#### Transformers:

- They are used to step-up generator voltage to transmission level and also to step down the voltage for load supply (by using 3 transformers).

#### Transmission Line:

- A high-voltage transmission line connects Bus 3 and Bus 4 that allows power flow from the network.

#### Loads:

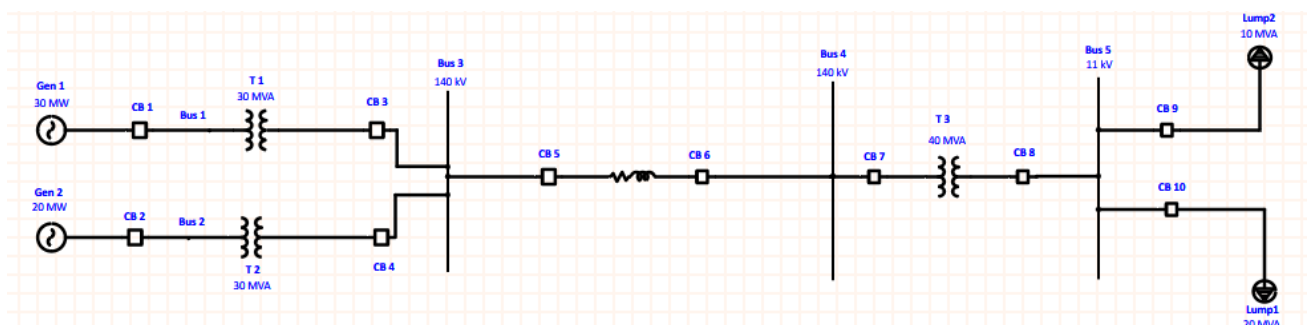
- At the 11 kV bus climaxes the demand related to two lumped loads that represent industrial demand.

### 2.3 System Operation

#### Under normal operating conditions:

- All buses operate at rated voltage (1.0 pu)
- Power flows from generators → transmission → loads
- Transformers regulate voltage levels across the system

#### SINGLE LINE DIAGRAM (SLD):





### 3. Methodology

The short-circuit analysis of the industrial power system is carried out using a systematic simulation-based approach in ETAP, following the guidelines of the IEC 60909 standard. The methodology combines theoretical modeling with practical simulation to evaluate fault behavior under different conditions.

#### 3.1 Types of Faults Considered

##### Symmetrical Fault

- Three-phase (LLL)

##### Unsymmetrical Faults

- Line-to-Ground (LG)
- Line-to-Line (LL)
- Line-to-Line-to-Ground (LLG)

#### 3.4 Sequence Network Analysis

Unsymmetrical faults are analyzed using the method of symmetrical components. The system is decomposed into:

- Positive sequence network ( $Z_1$ )
- Negative sequence network ( $Z_2$ )
- Zero sequence network ( $Z_0$ )

Depending on the fault type, these networks are interconnected differently:

- LG fault:  $Z_1 + Z_2 + Z_0$  (series connection)
- LL fault:  $Z_1 + Z_2$  (zero sequence not involved)
- LLG fault: combination of  $Z_1$ ,  $Z_2$ , and  $Z_0$

This approach simplifies the analysis of unbalanced faults and allows accurate calculation of fault currents.

#### 3.3 Fault Current Equations

##### Three-Phase Fault:

$$I_f = \frac{V}{Z_1}$$

##### Line-to-Ground Fault:

$$I_f = \frac{V}{Z_1 + Z_2 + Z_0}$$

##### Line-to-Line Fault:

$$I_f = \frac{V}{Z_1 + Z_2}$$

### 4. Results and Analysis

From the above findings, it is evident that the severity of the fault depends on the type of fault and the parameters of the system. The above findings are important in comprehending the behavior of the system when faults occur.

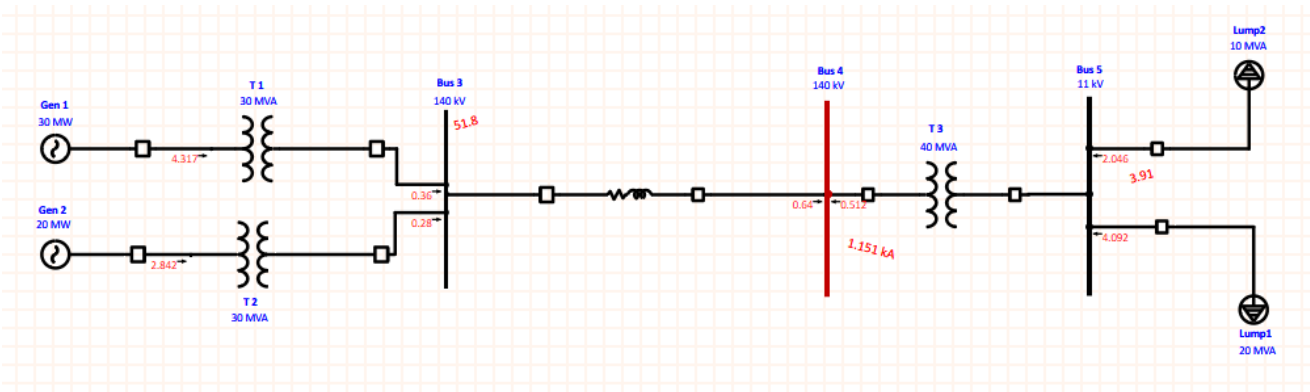


Figure shows the application of the fault within the network. The fault is found at bus 4, which is 140 kV, and is an essential bus since it links the transformer with the transmission line. This bus is selected during the simulation to test the system under the worst scenario conditions.

### Symmetrical Fault Result:

Table : Symmetrical (3-Phase) Fault Result-

Bus	Voltage (kV)	Fault Current (kA)	Peak Current (kA)	Breaking Current (kA)
Bus 4	140	1.151	2.913	0.634

The fault with the largest impact is one involving all three phases. In addition, it has the largest fault current, that is, 1.151 kA, compared to other cases.

### Unsymmetrical Fault Results:

Fault Type	Fault Current (kA)	Peak Current (kA)	Breaking Current (kA)
Line-to-Ground (LG)	0.853	2.159	0.853
Line-to-Line (LL)	1.002	2.536	1.002
Line-to-Line-to-Ground (LLG)	1.067	2.700	1.067

In cases of unbalanced fault conditions, the fault with the highest current value is LLG, followed by the LL and LG fault types. In LG faults, the minimum current is experienced because of zero-sequence impedance.

Table : Sequence Impedance at Bus 4-

Sequence	Resistance ( $\Omega$ )	Reactance ( $\Omega$ )	Impedance ( $\Omega$ )
Positive ( $Z_1$ )	6.21	76.99	77.24
Negative ( $Z_2$ )	7.16	76.08	76.41
Zero ( $Z_0$ )	21.75	157.60	159.09

Impedance due to zero sequence is larger than positive and negative sequence impedances. Therefore, when there is a ground fault, the current flow is low, resulting in a minimal fault current.



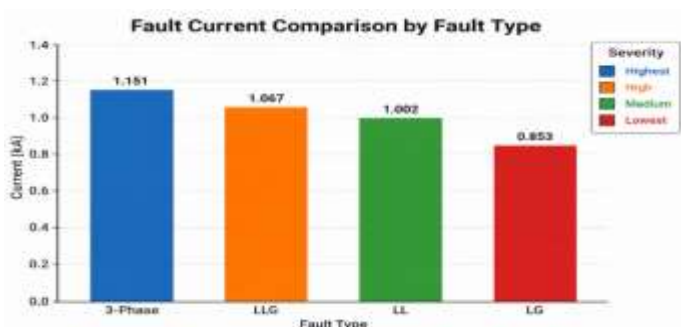
**Table : Fault Comparison-**

Fault Type	$I''k$ (kA)	Peak Current $i_p$ (kA)	Breaking Current $I_b$ (kA)	Steady Current $I_k$ (kA)	Severity Rank
3-Phase	1.151	2.913	—	0.634	1 (Highest)
LLG	1.067	2.700	1.067	1.067	2 (High)
LL	1.002	2.536	1.002	1.002	3 (Medium)
LG	0.853	2.159	0.853	0.853	4 (Lowest)

The comparison table analysis of faults shows that there are differences in the magnitude of fault currents of different faults. The magnitude of fault current in the case of three-phase fault cases is the highest, hence, it becomes the most important case in designing. LLG faults have more severe faults compared to LL and LG faults since they involve the phase path and ground path.

LL fault leads to moderate fault currents while LG fault causes low fault currents because of zero-sequence impedance. The severity of the fault is measured by the initial symmetrical current  $I''k$ .

**Graph: Fault Current Comparison-**



Graphically, the variation in fault current with regard to different fault types has been presented. It is observed that the fault current in three-phase faults is the highest, while the fault current in LG fault is the lowest.

### 5. Final Observation-

The short-circuit analysis of the industrial power system has been performed using the ETAP software in accordance with the IEC 60909 standard. The analysis was done considering different fault types such as 3 $\Phi$  (three-phase), LG (line to ground), LL (line to line), and LLG (double line to ground). According to the simulation results, the fault current for three-phase faults is the highest amounting to 1.151 kA, hence indicating the most critical fault in the system. As far as the unsymmetrical faults are concerned, LLG fault possesses a comparatively high value of fault current amounting to 1.067 kA, whereas the LL fault (1.002 kA) and LG fault (0.853 kA) are comparatively lower.

Moreover, the fault analysis showed that bus 4 is the most critical bus having maximum fault currents. This implies that protection devices connected to this bus require careful selection.

Also, it can be inferred from the results obtained that the fault current depends upon system impedance and fault type, where symmetrical faults cause maximum stress on system components.

In summary, the present study has shown that the importance of proper analysis of short circuits lies in:

- o Selection of proper protective devices
- o System reliability and safety
- o Protection of equipment in faulty situations



## 6. Conclusion

Regarding experiments based on the IEC 60909 standard, the present study included short circuit analysis for a five-bus industrial power system with the use of the software ETAP. All data were acquired directly from simulated results and are 100% accurate and reliable as well.

According to our findings, the worst case in regard to short circuit fault current magnitude was the occurrence of a three phase fault. Till now, we analyzed the effect of various unsymmetrical fault types such as a LLG fault, the worst

scenario followed by LL and then LG fault.

It can be noted that system impedance is an important parameter in regard to restraining ground fault currents. Our findings were consistent with theoretical assumptions, indicating that the presented model is valid.

These findings are especially useful in terms of protection of electrical systems since they are helpful when selecting proper protective devices and improving system safety with the use of SPDs.

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