

# Load Flow and Fault Studies for Efficient Power Management of Steel Plant

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**Abstract:** This project presents the load flow and fault studies of the Steel Plant using ETAP (version 19.0.1) software to evaluate the systems steady state performance and reliability. The plant receives power from the Substation (220/33 kV). Two transformers are connected to this bus where 25 MVA, 220/33 kV unit feeding Zone-I and 60 MVA, 220/33 kV unit feeding Zone-II. The load flow simulation results indicate that all bus voltages remain within  $\pm 10\%$  of their nominal values, confirming a balanced load distribution and stable operation under normal conditions. In the fault studies, both single line-to-ground (L-G) and three-phase faults are simulated at various bus locations to analyze the systems response under abnormal conditions. The resulting fault currents, bus voltages are examined, particularly during the sub-transient period. These results help verify the adequacy of circuit breaker ratings and relay settings, ensuring safe and reliable fault clearance.

**Keywords:** ETAP, Load flow analysis, Short-circuit analysis, Power system protection, Industrial power systems.

## I. INTRODUCTION

Load flow analysis and fault studies is a crucial aspect of power system planning, operation and control. It provides the steady state solution for the power system network. The Newton Raphson method is widely regarded as the most dependable and successful load flow method due to its higher accuracy and faster convergence. ETAP 19.0.1 is widely used for Load flow analysis and fault studies due to its ease of use and speed. The program's operation closely resembles that of a real electrical system. By analysing load flow under various operating conditions using ETAP, power system engineers can evaluate the system response to different disturbances and plan for future system expansion. They involve numerical analysis of the flow of electric power in a power system under steady-state conditions, calculating voltage magnitude and phase angle at each bus, real and reactive power flows in transmission lines.

The primary objectives of load flow studies are to determine voltage levels, calculate power flows, identify potential issues such as overloads and under voltages and optimise system operation. Fault analysis determines how a system responds to abnormal conditions such as symmetrical and unsymmetrical fault.

## II. OBJECTIVES OF THE THESIS

1. To create an accurate model of the Steel plant using ETAP [Electrical Transient Analyzer Program] 19.1.0.
2. To investigate the steady state power flow using the Newton Raphson method. This thesis presents the details for assessing the voltage profile within its nominal range.
3. To conduct a short circuit study for the loads connected to the industry by collecting all relevant load data and analysing both symmetrical and unsymmetrical faults.

## III. STUDY ON LOAD FLOW

Load flow analysis is an important aspect in the study of electrical power networks. It contains critical information on the steady state operation of a power network. The analysis is crucial for system planning and operational research, allowing engineers to determine voltage levels at different buses.

- a. Assess power flow across transmission cables.
- b. Identify overloaded equipment.
- c. Optimize network operations for economic dispatch and stability.

Without reliable Load flow analysis power system operators cannot make educated judgments on network layout or the integration of new generation and load centres.

### 3.1 TYPES OF BUSES

In load flow studies, buses are grouped into three main classifications depending on known and unknown quantities:

- i. Slack Bus (Swing Bus): This bus maintains a balance between active and reactive power in the system. Voltage magnitude and angle are provided, but actual and reactive powers are unknown.
- ii. PV Bus (Generator Bus): The actual power generation (P) and voltage magnitude (V) are supplied. The voltage angle and reactive power (Q) need to be determined.
- iii. PQ Bus (Load Bus): The real and reactive power requirements (P and Q) are given. Voltage magnitude and angle are unknowns that must be calculated.

### 3.2 NUMERICAL TECHNIQUE

The following Figure 1.1 illustrates the flowchart of the full process of Newton Raphson method.

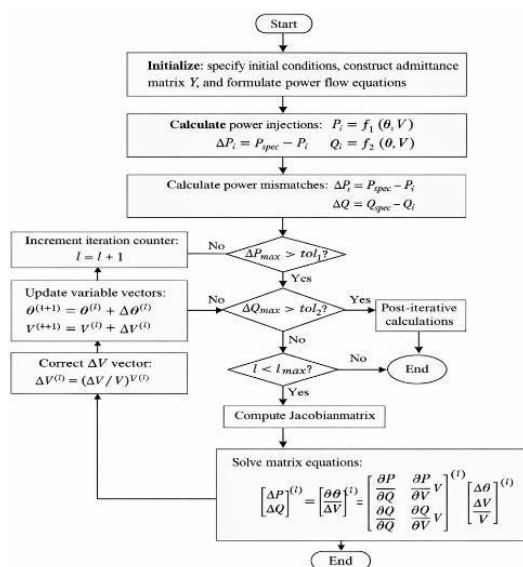


Figure 1.1 flowchart of the of Newton Raphson method.

## IV. ANALYSIS ON FAULT STUDIES

A short circuit or fault happens when the systems insulation fails or a conducting object contacts a live point. Fault analysis in power systems involves identifying, calculating and mitigating the effects of faults to ensure system reliability and safety. It occurs due to a low resistance connection between phase conductors or to ground. They are further divided into symmetrical and unsymmetrical faults based on the balance of fault currents [1].

### 4.1 ASSUMPTIONS AS PER STANDARD

- The following assumption is made for electrical network modelling in the ETAP.
- The maximum three phase fault current at the grid is assumed as per the standard 40kA and X/R as 14. The single-phase fault current and the three-phase fault current is assumed as the same.
- The Impedance parameter of all the cables is assumed as per the ETAP standard Library.

## V. TYPES OF FAULTS

Various types of faults can occur in the system. Figure 1.2 represents the different types of faults in power system studies.

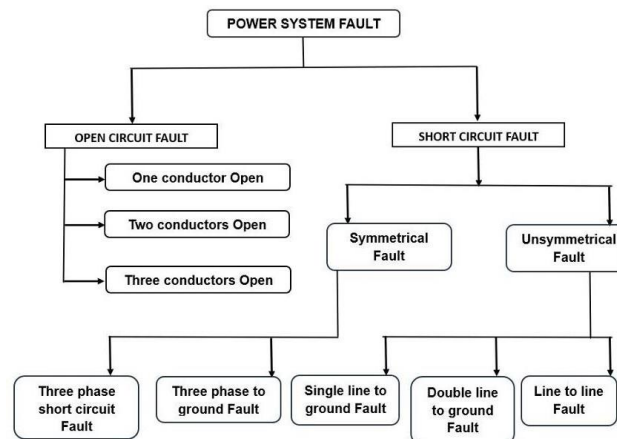


Figure 1.2 the different types of faults in power system studies.

### 5.1 OPEN CIRCUIT FAULT

An open circuit fault is an interruption in the current path of an electrical circuit that prevents current from reaching the intended load or component. This problem could be caused by disconnected wires, defective switches, broken components or blown fuses. As a result, the circuit becomes incomplete, with a high impedance that restricts current passage, frequently causing systems to malfunction.

### 5.2 SHORT CIRCUIT FAULT

A short circuit problem arises when there is an unintentional low resistance channel between two locations in an electrical circuit, allowing electricity to bypass the load. When conductors, like wires make contact directly with each other or conductive materials, they form a connection. As a result, excessive current flows through the circuit, often exceeding the systems safe limit. This can cause overheating, component damage, fires and system failure. Circuit protection devices such as fuses or circuit breakers detect short circuits or disconnect them to avoid further harm.

#### ▪ Symmetrical Faults in Power Systems

A symmetrical fault is a type of fault in a power system where all three phases are affected equally. This type of fault is rare in actual practice (accounts for only about 5% of all faults) but it is the most severe type of fault because it causes maximum fault current to flow through the system. It is very important for designing circuit breakers and protective relays since they must be able to handle the maximum fault level. A symmetrical fault occurs when all three phases (R, Y and B) of a power system are short circuited together, either with or without a connection to the ground.

- i. It maintains symmetry among the phases,
- ii. All phase currents are equal in magnitude.
- iii. All phase voltages are displaced by  $120^\circ$  from each other.

There are two main types of symmetrical faults,

- (a) Three-Phase Fault (L-L-L Fault)
- (b) Three-Phase to Ground Fault (L-L-L-G Fault)

#### ▪ Unsymmetrical Faults in Power Systems

An unsymmetrical fault is a type of fault in a power system where the three phases of the system are not affected equally. The fault causes an unbalance in voltages and currents in the system. Unlike symmetrical faults, unsymmetrical faults are more common, 9 accounting for nearly 95% of all power system faults, but they generally cause less severe currents compared to symmetrical faults. An unsymmetrical fault occurs when one or two conductors of a three-phase system are short circuited either to ground or to each other, but not all three phases are involved

equally. This results in,

- i. Unbalanced phase voltages.
- ii. Unequal phase currents.
- iii. Flow of zero, positive and negative sequence components.

There are three main types of unsymmetrical faults,

- (a) Single Line-to-Ground (L-G) Fault
- (b) Line-to-Line (L-L) Fault
- (c) Double Line-to-Ground (L-L-G) Fault

**VI. BLOCK DIAGRAM OF THE STEEL PLANT**

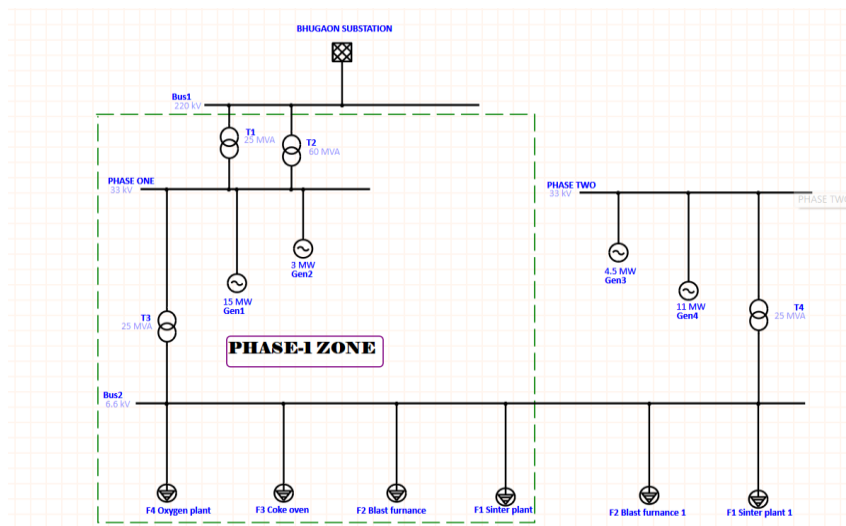


Figure 1.3 the block diagram of the steel plant

Figure 1.3 illustrates the block diagram of the steel plant which receives power from the Substation, which feeds a 220/33 kV switchyard. From this switchyard, two outgoing transformers operate: one transformer rated at 25 MVA, 220/33 kV is connected to Zone-I and another transformer rated at 60 MVA, 220/33 kV is connected to Zone-II. Four generators are running in parallel with the grid, one of which is proposed. Two generators, rated at 15 MW and 3 MW, are connected to Zone-II. The third generator, rated at 4.5 MW, is connected to Zone-II Blast Furnace 2, while the proposed generator, rated at 11 MW, is connected to Zone- II.

**VII. MODELLING OF THE STEEL PLANT**

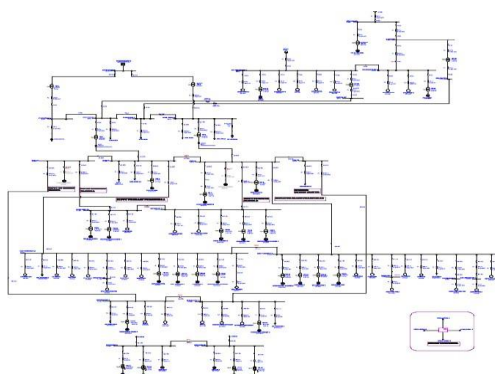


Figure 1.4 Modelling of zone-I

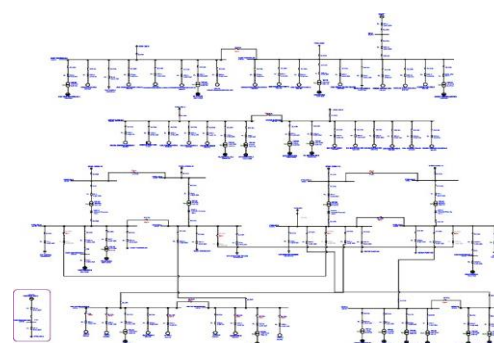


Figure 1.5 Modelling of zone-II

The Figure 1.4 and 1.5 is the detailed modelling of Steel Plant Zone-I and Zone-II, which are modelled using ETAP 19.1.0 software. It includes a many inner plants with various voltage ranges, like mentioned at the block diagram.

### VIII. SIMULATION TOOL

ETAP is a robust software application for power system engineers to model and simulate electrical networks. It contributes to the creation of an "electrical digital twin" for analysing system dynamics and protection. ETAP, which was originally built for the MS DOS operating system, was intended to help with the analysis and operation of both commercial and nuclear power systems. ETAP allows electrical engineers and operators to conduct a variety of studies both offline and online. This software can simulate tasks like short circuit investigation and motor starting studies

### IX. SIMULATION RESULTS FOR LOAD FLOW ANALYSIS

As per the standard of load flow analysis, the system maintains its nominal tolerance of  $\pm 10\%$  of its range. The load flow analysis results are provided in the Figure 1.6 and 1.7 which specify the voltage of all buses in zones I and II, respectively.

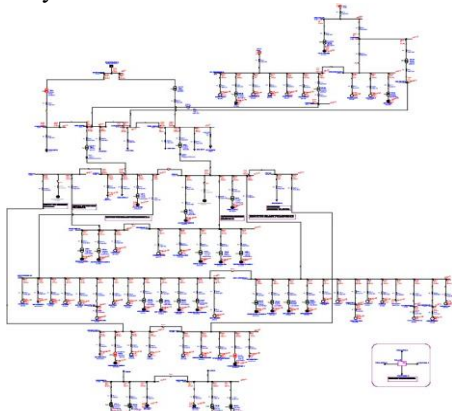


Figure 1.6 load flow analysis results of zone-I

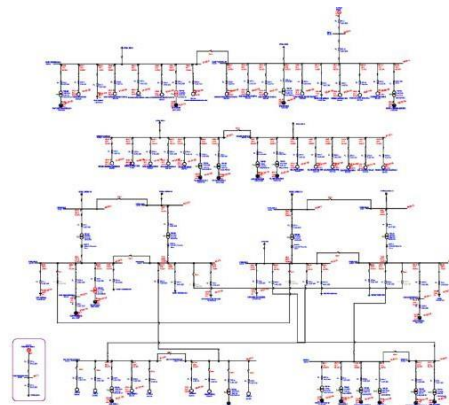


Figure 1.7 load flow analysis results of zone-II

### X. SIMULATION RESULTS FOR FAULT STUDIES

From the voltage profile obtained through the load flow analysis, fault studies are subsequently performed using the data from the plant. Based on the results of the earlier simulation, the short-circuit current at the grid and the impedance values of the generators are incorporated into the system model. Using this information, various fault conditions are simulated to analyze the system response. The fault analysis includes both three-phase (symmetrical) and single line-to ground (L-G) (unsymmetrical) faults. The results for the symmetrical fault for the zones I and II, respectively are illustrated in Figure 1.8 and 1.9. And the results for the unsymmetrical fault are illustrated in Figure 1.10 and 1.11.

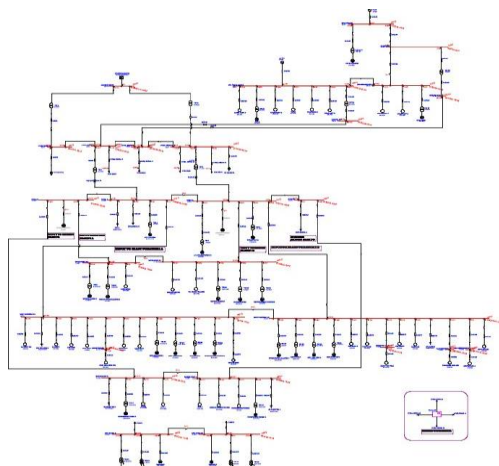


Figure 1.8 Symmetrical fault for the zones I

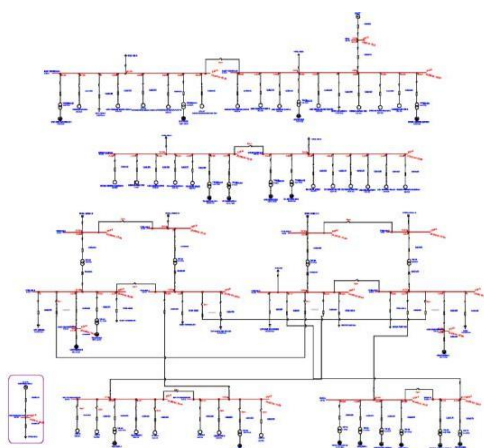


Figure 1.9 Symmetrical fault for the zones II

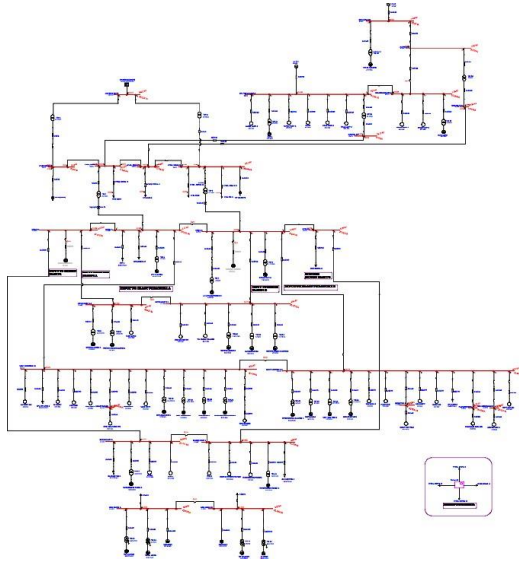


Figure 1.10 Unsymmetrical fault for the zone-I

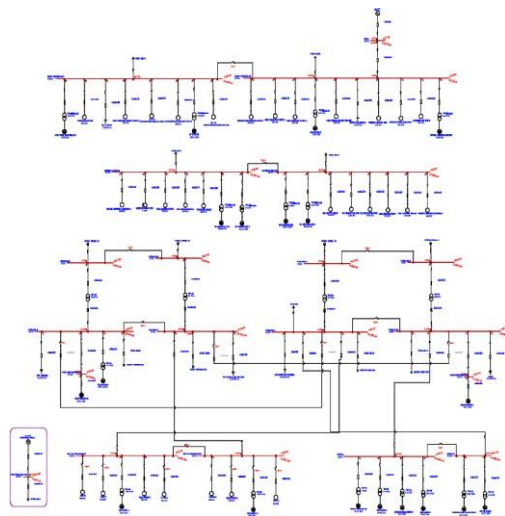


Figure 1.11 Unsymmetrical fault for the zone-II

## XI. CONCLUSION

The Plant has a total power capacity of 33 MW and receives its main power supply from the nearby Substation. In addition, the plant operates four in-house generating stations and the generated and supplied power is distributed to various units within the facility, including the Blast Furnace Plant, Sinter Plant, Coke Oven Plant, Oxygen Plant and Boiler Plant. The entire electrical network of the steel plant has been modelled and simulated using ETAP (19.1.0) software. The results indicated that the voltage profiles of all buses are within permissible limits, confirming the systems stable operating condition during the load flow analysis. Furthermore, Fault studies are then performed utilizing plant data and the voltage profile acquired from the load flow study. Using this information, various failure conditions are simulated to analyze the system's response. The fault analysis covers both three phase (symmetrical) and single line-to-ground (L-G) (unsymmetrical) faults. As a result, the following values are obtained sub transient short circuit current, peak short circuit current, steady-state short circuit current and breaking short circuit current.

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