# LOAD FLOW ANALYSIS, SHORT CIRCUIT ANALYSIS, AND RELAY PROTECTION USING ETAP

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**ABSTRACT:**

For the development of any country, energy is a fundamental resource. In this paper load flow analysis, short circuit analysis, and relay protection of substation in ETAP software. These three tests are essential for both the design and operating stage and monitoring the performance of the grid. The capacity of the power grid and the protections are verified by conducting these tests. The load flow analysis helps the power generation and load distribution. Measured short circuit analysis helps to prevent the heavy equipment from damage and values are compared with the values given by the power plant sources. The results have been accomplished through ETAP for power system analysis. Relays and circuit breakers are known as the main components of the power system. Proper coordination is essential to reduce the unnecessary outages of the grid.

**INTRODUCTION:**

The fact that the Unit of electric energy generated by Power Station does not match with the units distributed to the consumers. Some percentage of the units is lost during the transmission of power from generation to distribution network. This difference in the generated & distributed units is known as Transmission and Distribution loss. The technical losses are due to energy dissipated in the conductors, equipment used for transmission Line, Transformer, sub-transmission Line and Distribution Line, and magnetic losses in transformers. To compensate and reduce the losses in the Transmission line Load flow analysis was used. This helps to improve the power supplied to the customer(Loads).

In a power system, the components are highly sensitive and expensive. If any major and sudden fault occurs means the equipment may damage. To prevent the equipment from damage short circuit analysis can be conducted. To design the relay coordination system short circuit analysis is needed.

For relay protection, this project uses the overcurrent relay and the circuit breaker opens the circuit when the short circuit happens. Relay is an important component for the protection of the power system. It senses the overcurrent in the system and sends the trip command to the circuit breaker based on the trip timing.

**ETAP DESCRIPTION:**

Power System study and analyses are important parts of power system engineering. Electrical engineers have been focusing on power system studies for the past few years using software tools. Recent advances in engineering sciences have brought a revolution in the field of electrical engineering after the development of powerful computer-based software. This research work highlights the effective use of Electrical Transient analyzer Program (ETAP) software for analyses and monitoring of large electrical power systems which comprises of large power distribution network.

System studies are an integral part of power system engineering and design. A structured computer program that uses technically correct models, employs a user-friendly interface, uses a common database, and traps user error is a powerful tool that greatly enhances the engineer's efficiency and productivity. ETAP is an engineering design and analysis program which satisfies these criteria. Also, ETAP performs numerical calculations with tremendous speed, automatically applies industry-accepted standards to provide easy-to-follow output reports.

**ETAP PROGRAMS:**

- One-Line Diagram
- Load Flow
- Short Circuit
- Dynamic Stability
- Motor Acceleration
- Motor Starting
- Cable Derating
- Cable Pulling
- Ground Grid Design
- Induction Machine Parameter Estimation
- Induction Machine Torque/Slip Curve

**LOAD FLOW ANALYSIS:**

- Draw the single line in the editor window of the ETAP.
- Set the values for the components.
- Do the connections with the wire.
- Run load flow analysis
- Obtain the results using display options.

Rating of components is an important note for load flow analysis because based on these values only load flow results may be varied.

*Component and rating*

| Component | Type | Rating (KVA) | Primary voltage (KV) | Secondary Voltage (KV) |
|---|---|---|---|---|
| Transformer | Transformer 1 | 1500 | 11 | 0.4 |
| | Transformer 2 | 1000 | 11 | 0.4 |
| | Transformer 3 | 1200 | 11 | 0.4 |
| | Transformer 4 | 1500 | 11 | 0.4 |
| | Transformer 5 | 1200 | 11 | 0.4 |
| | Transformer 6 | 1500 | 11 | 0.4 |
| | Transformer 7 | 1000 | 11 | 0.4 |

| Bus | Type | Load (KVA) | Type of Load |
|---|---|---|---|
| | Bus 1 | 0 | None |
| | Bus 2 | 500 | Residential |
| | Bus 3 | 1000 | Residential |
| | Bus 7 | 450 | Residential |
| | Bus 9 | 1000 | Residential |
| | Bus 12 | 800 | Residential |

| TX line length | Type | Length/km |
|---|---|---|
| | Line 12 | 1km |
| | Line 23 | 2km |
| | Line 34 | 1.5km |
| | Line 45 | 2km |
| | Line 56 | 1.5km |

## BUS INPUT DATA:

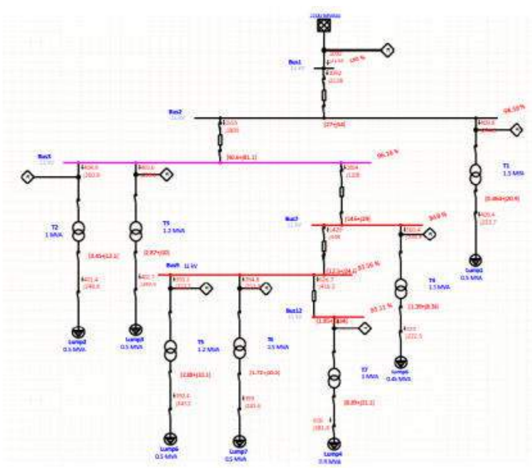
Bus Input Data

| Bus | | | | | Initial Voltage | |
|---|---|---|---|---|---|---|
| ID | Type | Nom. kV | Base kV | Sub-sys | %Mag. | Ang. |
| Bus1 | SWING | 11.000 | 11.000 | 1 | 100.00 | 0.00 |
| Bus2 | Load | 11.000 | 11.000 | 1 | 100.00 | 0.00 |
| Bus3 | Load | 11.000 | 11.000 | 1 | 100.00 | 0.00 |
| Bus5 | Load | 0.400 | 0.400 | 1 | 100.00 | -30.00 |
| Bus6 | Load | 0.400 | 0.400 | 1 | 100.00 | -30.00 |
| Bus7 | Load | 11.000 | 11.000 | 1 | 100.00 | 0.00 |
| Bus9 | Load | 11.000 | 11.000 | 1 | 100.00 | 0.00 |
| Bus10 | Load | 0.400 | 0.400 | 1 | 100.00 | -30.00 |
| Bus11 | Load | 0.400 | 0.400 | 1 | 100.00 | -30.00 |
| Bus12 | Load | 11.000 | 11.000 | 1 | 100.00 | 0.00 |
| Bus13 | Load | 0.400 | 0.400 | 1 | 100.00 | -30.00 |
| Bus17 | Load | 0.400 | 0.400 | 1 | 100.00 | -30.00 |
| Bus18 | Load | 0.400 | 0.400 | 1 | 100.00 | -30.00 |

13 Buses Total

All voltages reported by ETAP are in % of bus Nominal kV.
Base kV values of buses are calculated and used internally by ETAP.

## LOAD FLOW OUTPUT:



## LOAD FLOW RESULTS:

| CKT/ Branch ID | From- To Bus | | To From Bus | | Losses | | %Bus | | VD % |
|---|---|---|---|---|---|---|---|---|---|
| | MW | MVAR | MW | MVAR | KW | KVAR | FROM | TO | |
| Line12 | 3.33 | 2.093 | -3.273 | -2.075 | 60.3 | 17.7 | 100 | 98.5 | 1.54 |
| Line 23 | 2.851 | 1.805 | -2.759 | -1.778 | 91.5 | 26.8 | 98.5 | 95.8 | 2.67 |
| T1 | 0.422 | 0.270 | -0.42 | -0.261 | 1.3 | 9.4 | 98.5 | 97.3 | 1.2 |
| Line 34 | 1.925 | 1.238 | -1.891 | -1.228 | 33.3 | 9.8 | 95.8 | 94.4 | 1.39 |
| T2 | 0.417 | 0.272 | -0.415 | -0.257 | 2.6 | 15.3 | 95.8 | 93.8 | 2.01 |
| T3 | 0.417 | 0.268 | -0.416 | -0.258 | 1.4 | 10.2 | 95.8 | 94.5 | 1.28 |
| Line 45 | 1.518 | 0.989 | -1.489 | -0.981 | 28.7 | 8.4 | 94.4 | 92.9 | 1.49 |
| T4 | 0.374 | 0.239 | -0.373 | -0.231 | 1.2 | 8.4 | 94.4 | 93.2 | 1.16 |
| Line56 | 0.663 | 0.447 | -0.659 | -0.446 | 4.3 | 1.3 | 92.9 | 92.4 | 0.5 |
| T5 | 0.413 | 0.268 | -0.411 | -0.255 | 1.9 | 13.3 | 92.9 | 91.3 | 1.64 |
| T6 | 0.413 | 0.266 | -0.411 | -0.255 | 1.5 | 10.6 | 92.9 | 91.6 | 1.3 |
| T7 | 0.659 | 0.446 | -0.652 | -0.404 | 7.3 | 0.42 | 92.4 | 89.1 | 3.36 |
| Total | | | | | 235.3 | 173.1 | | | |

## SHORT CIRCUIT ANALYSIS:

- Draw the single line diagram in the ETAP editor window.
- Same as load flow set the ratings of the component.
- Run the short circuit analysis.
- For running the analysis make any one of the buses a fault bus.
- Obtain the results by display options.

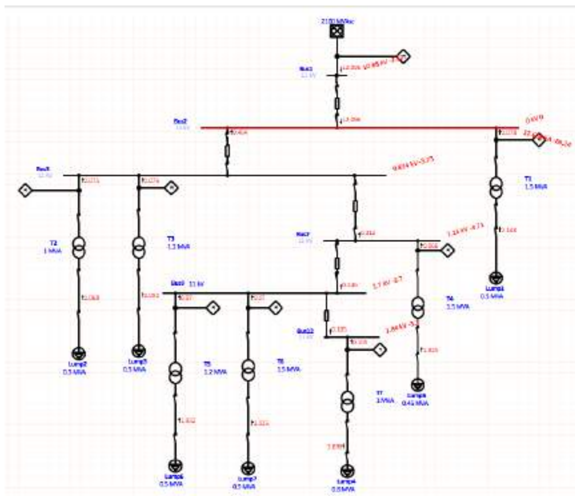
There are three types of fault currents.

**Sub-Transient:** The number of faults current at the time on which the fault occurs.

**Transient:** The fault current after some time but still changing.

**Steady-state transient:** After the transient has reached the steady-state value.

## SHORT CIRCUIT ANALYSIS OUTPUT:



## SHORT CIRCUIT ANALYSIS RESULTS:

**SHORT- CIRCUIT REPORT**

Fault at bus: Bus2
Nominal kV = 11.000
Voltage c Factor = 1.10 (User-Defined)

| Contribution | | 3-Phase Fault | | Line-To-Ground Fault | | | | | Positive & Zero Sequence Impedance Looking into "From Bus" | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From Bus ID | To Bus ID | % V From Bus | kA Symm. rms | % Voltage at From Bus Va | Vb | Vc | kA Symm. rms Ia | 3I0 | % Impedance on 100 MVA base R1 | X1 | R0 | X |
| Bus2 | Total | 0.00 | 12.698 | 0.00 | 130.44 | 129.97 | 8.282 | 8.282 | 1.84E+001 | 4.18E+001 | 3.51E+001 | 1.13 |
| Bus1 | Bus2 | 98.98 | 12.096 | 102.41 | 110.09 | 110.06 | 8.045 | 8.282 | 1.98E+001 | 4.37E+001 | 3.51E+001 | 1.13 |
| Bus3 | Bus2 | 7.58 | 0.464 | 3.31 | 137.41 | 131.38 | 0.325 | 0.000 | 4.80E+002 | 1.15E+003 | | |
| Bus4 | Bus2 | 11.51 | 0.078 | 77.31 | 82.53 | 110.00 | 0.054 | 0.000 | 2.60E+003 | 6.92E+003 | | |
| Power Grid | Bus1 | 110.00 | 12.096 | 110.00 | 110.00 | 110.00 | 8.045 | 8.282 | 1.73E-001 | 5.24E+000 | 1.73E-001 | 5.24 |
| Bus7 | Bus3 | 11.43 | 0.312 | 4.99 | 137.51 | 131.97 | 0.136 | 0.000 | 6.58E+002 | 1.59E+003 | | |
| Bus5 | Bus3 | 14.47 | 0.075 | 79.29 | 82.44 | 110.00 | 0.053 | 0.000 | 2.72E+003 | 6.61E+003 | | |
| Bus6 | Bus3 | 13.38 | 0.076 | 78.90 | 82.14 | 110.00 | 0.053 | 0.000 | 2.69E+003 | 6.53E+003 | | |
| Lump1 | Bus4 | 110.00 | 2.148 | 110.00 | 110.00 | 110.00 | 0.813 | 0.000 | 2.58E+003 | 6.15E+003 | | |

## SHORT CIRCUIT SUMMARY:

**Short-Circuit Summary Report**

3-Phase, LG, LL, LLG Fault Currents:

| Bus | | 3-Phase Fault | | | Line-to-Ground Fault | | | | Line-to-Line Fault | | | | *Line-to-Line-to-Ground | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | kV | I"k | ip | Ik | I"k | ip | Ib | Ik | I"k | ip | Ib | Ik | I"k | ip | Ib | Ik |
| Bus2 | 11.000 | 12.698 | 31.907 | 12.096 | 8.282 | 15.012 | 8.282 | 8.282 | 10.944 | 19.338 | 10.944 | 10.944 | 11.641 | 21.108 | 11.641 | 11.641 |

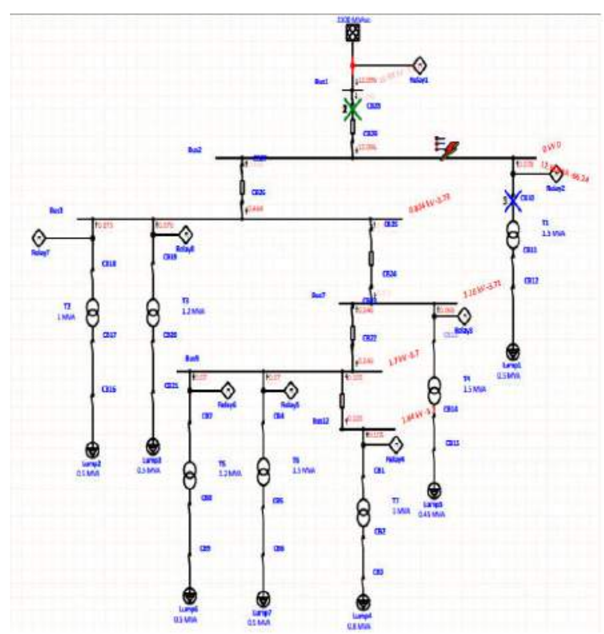
All fault currents are in rms kA. Current ip is calculated using Method C.

* LLG fault current is the larger of the two faulted line currents.

## RELAY PROTECTION:

- Draw the single-line diagram using the ETAP editor window.
- Fix the over-current relay to operate the circuit breaker.
- Set the time delay for the relay.
- Place a fault in the bus.
- Simulate star protection coordination.
- Obtain the results using the display option.

## RELAY PROTECTION OUTPUT:



## RELAY PROTECTION RESULTS:

Sequence-of-Operation Event Summary Report

Symmetrical 3-Phase Fault at Bus2.

| Time (ms) | ID | If (kA) | T1 (ms) | T2 (ms) | Condition |
|---|---|---|---|---|---|
| 10.0 | Relay1 | 12.096 | 10.0 | | Phase - OC1 - 50 |
| 15.7 | Relay1 | 12.096 | 15.7 | | Overload Phase - Thermal |
| 15.7 | Relay2 | 0.078 | 15.7 | | Overload Phase - Thermal |
| 15.7 | Relay7 | 0.075 | 15.7 | | Overload Phase - Thermal |
| 15.7 | Relay8 | 0.076 | 15.7 | | Overload Phase - Thermal |
| 19.2 | Relay1 | 12.096 | 19.2 | | Phase - OC1 - 51 |
| 30.0 | CB28 | | 20.0 | | Tripped by Relay1 Phase - OC1 - 50 |
| 39.2 | CB28 | | 20.0 | | Tripped by Relay1 Phase - OC1 - 51 |
| 7051 | Relay2 | 0.078 | 7051 | | Phase - OC1 - 51 |
| 7071 | CB10 | | 20.0 | | Tripped by Relay2 Phase - OC1 - 51 |
| 8600 | Relay8 | 0.076 | 8600 | | Phase - OC1 - 51 |
| 8620 | CB19 | | 20.0 | | Tripped by Relay8 Phase - OC1 - 51 |
| 9453 | Relay7 | 0.075 | 9453 | | Phase - OC1 - 51 |
| 9473 | CB18 | | 20.0 | | Tripped by Relay7 Phase - OC1 - 51 |
| 13441 | Relay3 | 0.066 | >13441 | | Phase - OC1 - 51 |
| 13441 | Relay5 | 0.070 | >13441 | | Phase - OC1 - 51 |
| 13441 | Relay6 | 0.070 | >13441 | | Phase - OC1 - 51 |
| 13461 | CB4 | | 20.0 | | Tripped by Relay5 Phase - OC1 - 51 |
| 13461 | CB7 | | 20.0 | | Tripped by Relay6 Phase - OC1 - 51 |
| 13461 | CB13 | | 20.0 | | Tripped by Relay3 Phase - OC1 - 51 |

## CONCLUSION:

In this project Load Flow, short circuit study, and relay protection using ETAP software is carried out with an approach to overcome the problem of an under-voltage, and the maximum short circuit current is simulated by ETAP and to protect the system from fault.

Load flow studies determine if system voltages remain within specified limits under various contingency conditions and whether equipment such as transformers and conductors are overloaded.

A number of operating procedures can be analyzed such as the loss of a generator, a transmission line, a transformer, or a load. Also, they are useful in determining the system voltages under conditions of suddenly applied or disconnected loads. The current of the short circuit is 12kA the existing CB panel bus of the system is 80 kA, which means the safety margin is still far above that installed.

From these short circuit analyses, we designed the relay coordination by the over-current relay. Finally, it opens the CB when the fault occurs.

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