Short Circuit Analysis Of 33/11 Kv Msedcl Using Etap Software

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ABSTRACT- This paper presents a detailed short circuit analysis of the 33/11 kV MSEDCL substation using ETAP (Electrical Transient Analyzer Program) software. The substation, located in a critical urban zone, is responsible for distributing power to several essential areas, including medical and residential facilities. Short circuit faults—such as three-phase, line-to-ground, line-to-line, and double line-to-ground—can severely impact power system reliability if not properly analyzed and mitigated. In this study, real-time data was collected from the MSEDCL substation, including transformer ratings, circuit breaker settings, current and potential transformer ratios, and system layout. The substation was modeled in ETAP, and fault simulations were conducted on the 11 kV bus to observe the system's behavior under various fault conditions. The results provided valuable insights into fault current magnitudes, equipment stress levels, and the adequacy of existing protection systems. Based on the analysis, recommendations were made to improve protection coordination and ensure safer operation. This study highlights the importance of short circuit analysis in designing and maintaining reliable power distribution systems and supports the development of optimized protection schemes for urban substations.

Keywords: Short Circuit Analysis, 33/11 kV Substation, ETAP Software, Fault Current, Electrical Faults, 4-Bus Network, Substation Simulation.

I. INTRODUCTION

Short circuit analysis is an important study in electrical power systems. It helps us understand what happens when a fault or error occurs in the system, such as wires touching each other accidentally or equipment failing. These faults can cause very high current to flow, which may damage machines or stop the power supply. This analysis helps engineers know how much current will flow during these faults and how to protect the system. In this paper, we studied the 33/11 kV MSEDCL, which is designed as a 4-bus system. We used short circuit analysis to check how the substation works during different types of faults like single line-to-ground, line-to-line, double line-to-ground, and three-phase faults. This helped us find out where the highest current can occur and whether the substation is safe during these conditions. To do this analysis, we used ETAP software, which is a special computer program made for designing and analyzing power systems. With ETAP, we created a model of the substation and tested it under different fault conditions. It gave us clear results about how the system behaves and how much current flows during faults.

The main goal of this analysis is to make sure the substation equipment, like transformers, circuit breakers, and busbars, are strong enough to handle these fault conditions. If the equipment is not chosen properly, it can fail during a fault and cause serious problems. That's why it's important to check the fault current levels before setting up or upgrading a substation. This study also helps in making decisions about safety and maintenance. If we know the weak points in the system, we can improve the protection system and prevent power failures. In the end, this analysis helps in keeping the power supply smooth, safe, and reliable for the people and services depending on it.Short circuit analysis also plays a big role in choosing and setting up protection devices like circuit breakers, relays, and fuses. If a fault occurs, these devices must trip quickly to isolate the faulty section and protect the rest of the network. Without proper settings and capacity, these devices may fail, leading to larger system failures.

Here, our aim is to show how simulation and fault analysis can improve the safety and reliability of substations. It also helps electrical engineers and utility planners make better decisions during the design, operation, and maintenance of substations. In conclusion, short circuit studies are not only a technical necessity but a key part of ensuring uninterrupted and safe power supply, especially in sensitive areas like the Medical Square.

II.   LITERATURE REVIEW

Short circuit analysis is a critical aspect of power system studies, particularly for urban substations like 33/11 kV configurations, which serve high-demand areas. Numerous studies over the past decade have focused on analyzing fault behaviors, protective coordination, and system stability using simulation tools such as ETAP, MATLAB, etc.

It conducted a comprehensive short circuit study on a 33/11/0.4 kV distribution system using ETAP. Their research emphasized the importance of simulating different fault types—line-to-line, line-to-ground, and three-phase faults—to determine critical fault currents and ensure proper relay coordination. Their findings suggested that optimized protective relay settings reduce unnecessary outages and enhance system reliability. [1]

It analysed fault levels on a 33/11 kV substation and highlighted the importance of accurate fault current estimation to protect system components. They identified that neglecting impedance values and relay coordination could lead to transformer and feeder damage during a fault scenario.[2]

It focused on relay coordination in a 33/11 kV injection substation, outlining the effectiveness of relay grading and coordination to isolate faulted sections while maintaining supply to healthy feeders. This approach is essential in substations like Medical Square where service continuity is crucial, especially for medical facilities.[3]

It presented a case study using ETAP for load flow and short circuit analysis in a 33/11 kV substation. The study revealed how real-time modeling and fault simulation contribute to safer designs and better fault-clearing strategies. Similarly, simulation-based studies such as those by Das and Sharma (2024) provided insight into analyzing fault levels in complex substations using a multivoltage level approach.[4]

If emphasized the performance analysis of substations and feeders, focusing on undervoltage issues and voltage drops under fault conditions. Their work reinforced the need for regular fault analysis to ensure compliance with safety and operational standards. [5]

III. METHODLOGY

Data Source

The data used for this short circuit analysis was collected from the actual 33/11 kV MSEDCL, including details like transformer ratings, feeder lengths, line impedance, circuit breaker specifications, CT/PT ratios, and load information. Equipment parameters such as bus voltages, protection settings, and fault current ratings were gathered from substation records and site visits. This real-time data was organized and used as input in the ETAP software to create a one-line diagram and simulate the substation's electrical behaviour accurately during fault conditions.

3.1 Data Collection

The data required for short circuit analysis was collected through on-site visits and in consultation with the substation engineers. Essential parameters such as transformer ratings, single line diagram (SLD), circuit breaker details, CT ratios, and feeder configurations were gathered. The substation under study is a 33/11 kV MSEDCL with two 10 MVA transformers connected in parallel. These transformers are of star-delta configuration, with CTs installed on both primary and secondary sides. The SLD was especially useful in mapping the overall structure, which includes 33 kV incoming lines and multiple 11 kV outgoing feeders, such as RAMBAGH, AUNI RAILWAY, FULE NAGAR,and others. Information regarding relay types, breaker capacity, and existing protection settings was also documented to ensure a comprehensive analysis.

3.2 System Modelling

Using the gathered data, the substation network was modelled in ETAP (Electrical Transient Analyzer Program). The software enabled accurate representation of the power system including:

- Busbars, transformers, transmission/distribution lines
- Circuit breakers, isolators, and protection relays

3.3 Fault Simulations

Short circuit simulations were carried out to analyse different types of faults at critical locations in the system, including:

- Three-phase faults (symmetrical)
- Single line-to-ground (LG)
- Line-to-line (LL)
- Double line-to-ground (LLG)

Each fault was simulated on the 3rd bus 11 kV sides of the substation.

3.2.1 Three-Phase Fault at the 11 kV Bus

This is the most severe type of fault, where all three phases (R, Y, and B) are short-circuited together. It results in the highest fault current and tests the system's ability to handle extreme fault conditions.

3.2.2 Line-to-Ground Fault at the 11 kV Bus

This occurs when one phase comes into direct contact with the ground. It is the most common fault type in power systems and generally results in moderate fault current.

3.2.3 Line-to-Line Fault on an 11 kV Bus

This happens when two phases are short-circuited, bypassing the ground. It generates a high fault current but is usually less severe than a three-phase fault.

3.2.4 Double Line-to-Ground Fault Bus

This fault occurs when two phases simultaneously come into contact with the ground. It typically results in a fault current that is lower than a three-phase fault but higher than a single line-to-ground fault.

3.4 Analysis of Fault Currents

For each simulated fault, the following parameters were evaluated:

- Maximum fault current magnitude
- Fault duration
- Equipment stress levels

These results were compared against the existing protection settings to assess adequacy.

3.5 Validation and Interpretation

The final step involved validating the simulation results by comparing them with practical field data. The analysis confirmed whether the system was operating within safety margins and if the protective devices were suitable for the fault currents observed. Any discrepancies between theoretical and actual values were noted, and recommendations were made for improving protection coordination. This could include changes to CT ratios or the addition of backup protection. The interpretation helped bridge the gap between digital modeling and real-world substation performance, ensuring a reliable and robust protection scheme.

IV. 33/11 KV SUBSTATION LAYOUT DIAGRAM

The critical node in the power distribution system is substation. The single line diagram of the 33/11 KV MSEDCL substation is shown in figure 1. This outlines the configuration and flow of electrical energy from the high voltage 33 kV incoming feeders to the 11 kV outgoing feeders through step-down transformers. The substation receives power from three different sources: Jatta Rodi (underground), Sutgirni, and Pardi Medical (overhead), each equipped with protection components such as lightning arresters (LA), isolators (ISO), vacuum circuit breakers (VCB), and current transformers (CT). The incoming feeders connect to a 33 kV bus that supplies two 10 MVA power transformers (TF-1 and TF-2), which reduce the voltage from 33 kV to 11 kV. The low-voltage side then feeds multiple 11 kV outgoing feeders, supplying various load centers like Fule Nagar, Rambagh, and Auni Railway, with dedicated VCBs and CTs for individual protection and monitoring. The layout also includes potential transformers (PT) for voltage measurement at both 33 kV and 11 kV levels, ensuring operational accuracy and system safety.
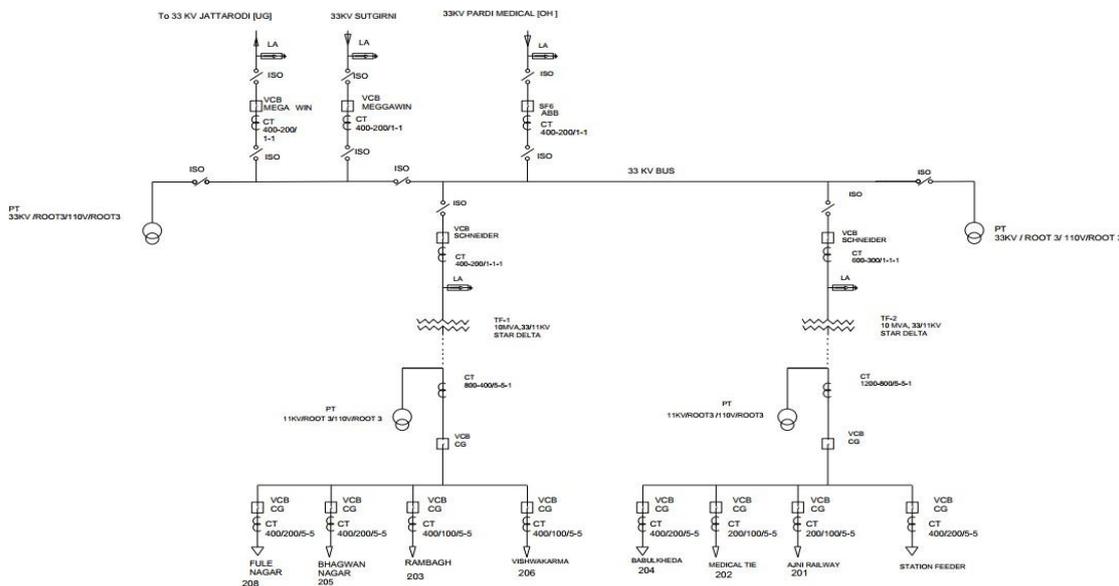

Fig 1: Single Line Diagram of 33/11 kV MSEDCL

V.   SYSTEM CONFIGURATION

The power grid system under study comprises 4 buses, 2 power transformers, 4 potential transformers, 15 current transformers, 15 circuit breakers, and 8 feeders. All of this data is based on real-time values collected from the 33/11 kV MSEDCL, operated by MSEDCL. The detailed rating of each equipment is given in Table No. 1. Table 1 contains ratings & Power transformer, current transformers, Potential transformers, Circuit breakers, and Feeders .

Table 1: Ratings & Components in 33/11 KV MSEDCL Substation

Components	Types	Ratings	Primary	Secondary
1) Power Transformer	T1 (2-Winding)	10 MVA	33 KV	11 KV
	T2 (2-Winding)	10 MVA	33 KV	11 KV
2) Current Transformer	CT 1 T O CT4	400	1 AMP	
	C T5	800	5 AMP	
	C T6	600	1 AMP	
	C T7	1200	5 AMP	
	CT8 T O CT12	400	5AMP	
	CT13 T O CT15	200	5 AMP	

3) Potential Transformer	P T		33 KV	110 V
4) Circuit Breakers			KV	AMP
	CB1 T O CB4		33	400
	C B5		33	800
	C B6		33	600
	C B7		33	1200
	CB8 T O CB12		11	400
	CB13 T O CB15		11	200
4) Feeders	(Inco mer 1)		(Inc omer 2)	
	Area	Rating	Area	Rating
	Fule Nagar	800 A	Babul Kheda	800 A
	Bhagwan Nagar	800 A	Medical	800 A
	Ram bag	800 A	Ajni Railway	800 A
	Vishwakarma	800 A	Station	800 A

VI. SIMULATION OF 33/11 KV SUBSTATION IN ETAP

The one-line diagram illustrates the structure and operational short circuit of a 33/11 kV MSEDCL, as modeled using ETAP software as shown in fig 2. It visually represents how electrical power is received from three separate 33 kV power grids and routed through a series of circuit breakers and transformers. These transformers step the voltage down to 11 kV, which is then distributed to various connected loads within the system. The configuration and short circuit of this substation are effectively depicted , serving as a vital reference for evaluating power flow, system stability, and short-circuit scenarios.
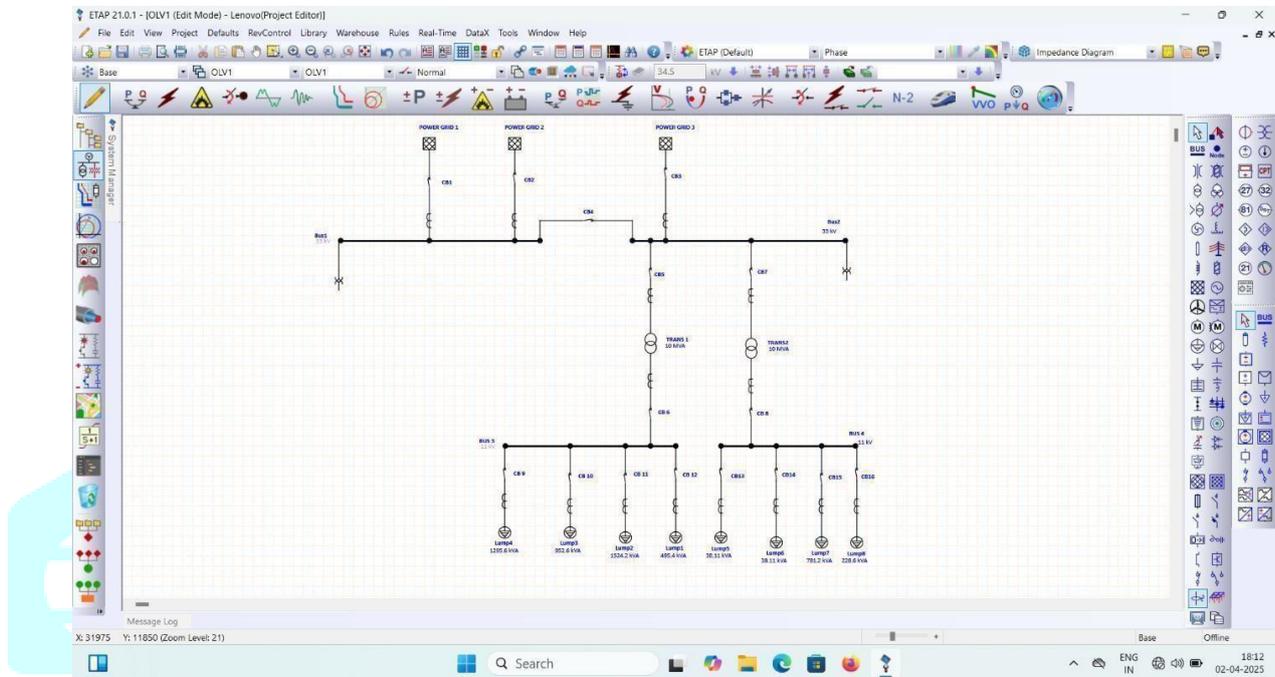

Fig 2: Single Line Diagram of 4-bus model using ETAP

VII. RESULTS

The input data for the four electrical buses used in the ETAP short-circuit analysis. Each bus is categorized by type— swing, generator, or load—with corresponding nominal and base voltage levels (33 kV or 11 kV) As shown in Table No. 2. Bus Input Data for ETAP Simulation categorizes each bus by type—swing, generator, or load—with corresponding nominal and base voltage levels (33 kV or 11 kV). The initial voltage magnitudes are close to 100%, with some phase angles at -30 degrees for load buses. This information sets the foundational electrical conditions for system modeling and fault analysis.

Table.2 Bus Input Data

	Bus				Initial Voltage	
ID	Type	Nom. kV	Base kV	Sub-sys	%Mag.	Ang.
Bus1	SWNG	33.000	33.000	1	100.00	0.00
Bus2	Gen.	33.000	33.000	1	100.00	0.00
BUS 3	Load	11.000	11.000	1	98.16	-30.00
BUS 4	Load	11.000	11.000	1	99.54	-30.00

4 Buses Total

technical specifications of two 2-winding transformers (TRANS1 and TRANS2) used in the power system As shown in Table. 3. Transformer Input and Grounding Data outlines the transformers' identical ratings of 10 MVA, Both transformers have identical ratings of 10 MVA, with primary and secondary voltages of 33 kV and 11 kV, respectively. The impedance (%Z) is 7.85% with an X/R ratio of 156.98, and both have a Dyn

connection with a 30° phase shift. Additionally, grounding data indicates that both transformers have solid grounding on both primary and secondary sides, ensuring system stability and safety during faults.

Table. 3 Transformer Input and Grounding Data

2-Winding Transformer Input Data

Transformer		Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID		MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
TRANS 1		10.000	33.000	11.000	7.85	156.98	0	0	0	0	0	7.85	Dyn	30.00
TRANS2		10.000	33.000	11.000	7.85	156.98	0	0	0	0	0	7.85	Dyn	30.00

2-Winding Transformer Grounding Input Data

Transformer		Rating			Conn.	Grounding								
							Primary				Secondary			
ID		MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	ohm	Type	kV	Amp	ohm	
TRANS 1		10.000	33.000	11.000	D/Y					Solid				
TRANS2		10.000	33.000	11.000	D/Y					Solid				

The electrical branch connections between buses in the power system, including two transformers (TRANS1 and TRANS2) and a tie breaker (CB4) As shown in Table No. 4. Branch Connections and Impedance Data outlines each component's connection path, such as TRANS1 linking Bus2 to Bus3. Each component's connection path is specified, showing which buses they link (e.g., TRANS1 connects Bus2 to BUS 3). The table also presents the percentage impedance values (R, X, Z, and Y) on a 100 MVA base, crucial for short-circuit and load flow analysis. The identical impedance characteristics for both transformers indicate system symmetry and consistency in design.

Table.4 . Branch Connections and Impedance Data

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R	X	Z	Y
TRANS 1	2W XFMR	Bus2	BUS 3	0.50	78.34	78.34	
TRANS2	2W XFMR	Bus2	BUS 4	0.50	78.34	78.34	
CB4	Tie Breakr	Bus2	Bus1				

The input parameters for three power grid sources connected to the system, detailing their electrical characteristics. Each power grid (POWER GRID 1, 2, and 3) is connected to Bus1 or Bus2 and has an MVA short-circuit capacity of 1275.484 As shown in Table.5. Power Grid Input Data provides the specifications for POWER GRID 1, 2, and 3, each connected to Bus1 or Bus2 with an MVA short-circuit capacity of 1275.484. The impedance values, based on a 100 MVA base, are consistently low, indicating strong grid sources with minimal resistance and reactance. The grounding type for all grids is Wye-Solid, which ensures stable system grounding and fault current management. The total connected power grid capacity is calculated at 3826.452 MVA.

Table.5 Power Grid Input Data

Power Grid Input Data

Power Grid ID	Connected Bus ID	Rating		% Impedance 100 MVA Base			Grounding Type
		MVASC	kV	R	X"	R/X"	
POWER GRID 1	Bus1	1275.484	33.000	0.05000	7.84000	0.01	Wye - Solid
POWER GRID 2	Bus1	1275.484	33.000	0.05000	7.84000	0.01	Wye - Solid
POWER GRID 3	Bus2	1275.484	33.000	0.05000	7.84000	0.01	Wye - Solid

Total Connected Power Grids (= 3): 3826.452 MVA

The input data for various lumped loads within the system, detailing their electrical ratings and load characteristics as shown in Table No.6. Lumped Load Input Data lists eight loads (Lump1 to Lump8), Eight loads (Lump1 to Lump8) are listed with values for kVA, voltage (kV), current (Amp), power factor, and percentage load. Motor-related parameters such as resistance (R), reactance (X"), and R/X ratio are included, along with grounding type and connection configuration (Delta). The total connected lumped load capacity sums up to 5353.8 kVA, essential for accurate load flow and fault analysis.

Table.6. Lumped Load Input Data

Lumped Load Input Data

| | Lumped Load | | | | | | Motor Loads | | | | | | | | |
| Lumped Load ID | Rating | | | | % Load | | Loading | | % Impedance (Machine Base) | | | Grounding | | | mFact. |
	kVA	kV	Amp	% PF	MTR	STAT	kW	kvar	R	X"	R/X"	Conn.	Type	Amp	MW/PP
Lump1	495.4	11.000	26.00	85.00	80	20	336.85	208.76	2.28	15.21	0.15	Delta			0.34
Lump2	1524.2	11.000	80.00	85.00	80	20	1036.46	642.34	1.53	15.31	0.10	Delta			1.04
Lump3	952.6	11.000	50.00	85.00	80	20	647.79	401.46	2.28	15.21	0.15	Delta			0.65
Lump4	1295.6	11.000	68.00	85.00	80	20	880.99	545.99	2.28	15.21	0.15	Delta			0.88
Lump5	38.1	11.000	2.00	85.00	80	20	25.91	16.06	2.28	15.21	0.15	Delta			0.03
Lump6	38.1	11.000	2.00	85.00	80	20	25.91	16.06	2.28	15.21	0.15	Delta			0.03
Lump7	781.2	11.000	41.00	85.00	80	20	531.19	329.20	2.28	15.21	0.15	Delta			0.53
Lump8	228.6	11.000	12.00	85.00	80	20	155.47	96.35	2.28	15.21	0.15	Delta			0.16

Total Connected Lumped Loads (= 8): 5353.8 kVA

This short-circuits report provides detailed analysis for Bus 3 at a nominal voltage of 11 kV with a voltage factor of 1.10, assessing the impact of different fault types as shown in Table No.7. it includes symmetrical and asymmetrical fault current contributions from various sources, such as buses, lumped loads, and power grids. Key metrics featured in the report include 3-phase fault currents, line-to-ground fault voltages, and sequence impedance values (R1, X1, R0, X0), all based on a 100 MVA base. It includes symmetrical and asymmetrical fault current contributions from various sources such as buses, lumped loads, and power grids. Key metrics include 3-phase fault currents, line-to-ground fault voltages, and sequence impedance values (R1, X1, R0, X0) based on a 100 MVA base. The report aids in understanding fault behavior and verifying system protection coordination.

Table.7. short circuit report of bus-3

Fault at bus: **BUS 3**
Nominal kV   =   11.000
Voltage c Factor =   1.10 (Maximum If)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus	To Bus	% V	kA	% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
ID	ID	From Bus	Symm. rms	Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
BUS 3	Total	0.00	8.382	0.00	113.10	111.87	8.015	8.015	1.75E+000	6.89E+001	4.99E-001	7.83E+001
Bus2	BUS 3	106.11	7.109	108.15	110.00	108.14	7.204	8.015 *	5.18E-001	8.12E+001	4.99E-001	7.83E+001
Lump1	BUS 3	110.00	0.149	110.00	110.00	110.00	0.095	0.000	5.76E+002	3.84E+003		
Lump2	BUS 3	110.00	0.458	110.00	110.00	110.00	0.292	0.000	1.26E+002	1.26E+003		
Lump3	BUS 3	110.00	0.286	110.00	110.00	110.00	0.182	0.000	2.99E+002	2.00E+003		
Lump4	BUS 3	110.00	0.389	110.00	110.00	110.00	0.248	0.000	2.20E+002	1.47E+003		
BUS 4	Bus2	106.28	0.004	107.63	109.42	109.40	0.002	0.000 *	2.52E+004	8.82E+003		
POWER GRID 3	Bus2	110.00	0.789	110.00	110.00	110.00	0.435	0.000	5.50E-002	8.62E+000	5.50E-002	8.62E+000
POWER GRID 1	Bus1	110.00	0.789	110.00	110.00	110.00	0.435	0.000	5.50E-002	8.62E+000	5.50E-002	8.62E+000
POWER GRID 2	Bus1	110.00	0.789	110.00	110.00	110.00	0.435	0.000	5.50E-002	8.62E+000	5.50E-002	8.62E+000

The summary report outlines the calculated short-circuit currents at Bus 3 for various fault types, including 3-phase, line-to-ground (LG), line-to-line (LL), and double line-to-ground (LLG) faults at a voltage level of 11 KV as shown in Table No.8: Fault Currents at Bus 3 presents key parameters such as initial symmetrical current (Ik), peak current (ip), and steady-state fault current (Ib) in kiloamperes. The data helps in assessing the severity and impact of different fault conditions, critical for designing protective relays and ensuring system safety. The report uses Method C for peak current estimation.

Table. 8 Fault Currents at Bus-3

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
BUS 3	11.000	8.382	22.901	7.109	8.015	21.900	8.015	8.015	7.259	19.833	7.259	7.259	8.256	22.559	8.256	8.256

It provides the sequence impedance values at Bus 3 for a system operating at 11 kV as shown in Table.9: Sequence Impedance Summary Report – Bus 3 includes the positive, negative, and zero sequence impedance components, each broken down into resistance and reactance. These parameters are essential for fault analysis, relay coordination, and system stability studies. These parameters are essential for fault analysis, relay coordination, and system stability studies. The zero fault impedance (ZF) is reported as zero, indicating a bolted fault condition used in the analysis. This data is crucial for accurately simulating and protecting against different fault scenarios.

Table.9 Sequence Impedance – Bus-3

Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
BUS 3	11.000	0.02118	0.83322	0.83349	0.02118	0.83322	0.83349	0.00604	0.94793	0.94795	0.00000	0.00000	0.00000

VIII.   CONCLUSION

The short circuit analysis of the 33/11 kV MSEDCL has been successfully performed using ETAP software. The simulation results provide valuable insight into the system's performance under fault conditions. Various types of faults such as three-phase, line-to-ground (LG), line-to-line (L-L), and double line-to-ground (L-L-G) were analysed across different buses in the network. The analysis reveals that the substation is capable of handling different faultscenarios within acceptable limits. The calculated short-circuit currents at different buses help in selecting appropriate ratings for circuit breakers, current transformers, and other protection equipment. It also aids in understanding the fault level at each node, which is essential for designing reliable and safe protection coordination schemes. This study ensures the preparedness of the power system against potential fault conditions and highlights the importance of regular analysis for system stability and safety. The results also provide a real-time reflection of system behaviour, supporting future upgrades or expansions of the substation.

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