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Power System Analysis of an Industrial Distribution Network Using ETAP: Load Flow, Short Circuit and Protective Device Coordination Studies

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ABSTRACT

This project focuses on analyzing an industrial electrical distribution network of a Cement Plant using ETAP software. A detailed Single Line Diagram (SLD) of the plant is modeled in ETAP. Load Flow studies are conducted to determine real and reactive power distribution, voltage profiles, system losses and equipment rating. Short Circuit analysis is used to evaluate fault currents for appropriate equipment rating and protection design. Protective Device Coordination ensures proper fault isolation while maintaining system stability and minimizing disruption. One of the key focuses of this project is to avoid Blackouts in the industry by enhancing system reliability and responsiveness during fault conditions. The objective is to ensure reliable, safe, and efficient power delivery through Load Flow Analysis, Short Circuit Studies, and Protective Device Coordination.

Keywords: Load Flow, Short Circuit, Protective Device Coordination, Power System Analysis, Industrial Power System, ETAP Simulation.

INTRODUCTION

The plant draws its primary power from a nearby 66 kV grid substation through a 2.8 km long, 630 sq.mm single-core underground cable.

Plant shall import the power via two no of power transformer 66/11.5kV, 12/15 MVA having %impedance of 8.22 and vector group Dyn11. star point of transformers are ground through Neutral Grounding Resistor (NGR) with current limit of 100A. The plant has one Waste Heat Recovery System (WHRS) of 12MW at 11kV voltage level. Star point of generation is grounded through Neutral Grounding Resistor (NGR) with current limit of 100 A. The short circuit level at the 66 kV substation is 10.92 kA, or 1248 MVA (three-phase). To address these challenges, detailed Load Flow, Short Circuit, and Protective Device Coordination studies were conducted using ETAP software. The goal of this project is to evaluate the system's current operating conditions, verify the adequacy of equipment ratings, and ensure proper protection coordination.

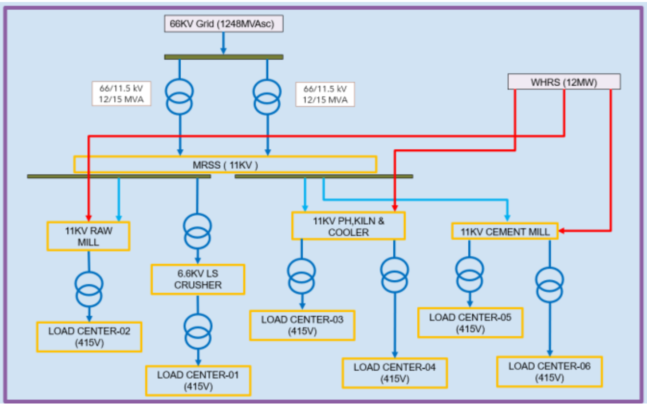

Figure 1 Power Distribution Layout

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Load Flow

Load flow analysis is a critical tool for assessing the steady-state operating conditions of an electrical power system. It provides essential information on active and reactive power flows, bus voltages, system losses, and transformer loading under normal operating conditions.

In this study, the industrial cement plant network was modeled in ETAP, considering two primary power sources: the utility grid and the Waste Heat Recovery System (WHRS). Load flow simulations were performed under varying operational scenarios to evaluate voltage profiles at key buses (66 kV, 11 kV, 6.6 kV, and 415 V), power factor behavior, and transformer tap settings.

The analysis ensures that the distribution network operates efficiently and reliably, maintains voltages and thermal limits within acceptable ranges, and delivers stable power under fluctuating load and generation conditions. It also identifies areas requiring reactive power compensation, voltage regulation, and equipment load balancing, supporting optimized and safe network performance.

Outcomes of Load Flow Analysis: The load flow study provides key insights into the performance and operational health of the industrial distribution network. The main outcomes are summarized below:

Outcome	Description / Analysis
Bus Voltage Profiles	Evaluates voltage magnitudes and angles at all buses to ensure they remain within permissible limits, preventing overvoltage or undervoltage conditions.
Real and Reactive Power Flow	Determines active (kW) and reactive (kVAr) power through lines, transformers, and cables, helping identify overloaded equipment and optimize power distribution.
Power Factor Evaluation	Identifies areas of low power factor, supporting the placement of capacitor banks or APFC units to improve efficiency and reduce reactive power demand.
Transformer Loading	Assesses transformer loading percentages to avoid overloading, optimize tap settings, and maintain thermal limits.
System Losses	Estimates I^2R losses across the network, providing a basis for improving efficiency and reducing operational costs.
Voltage Regulation	Detects undervoltage or overvoltage conditions across buses, aiding the development of effective voltage control strategies.
Reactive Power Compensation	Highlights locations where capacitor banks or APFC panels are required to maintain voltage stability and power quality.
Source Contribution Analysis	Analyzes power sharing between the grid and WHRS, ensuring balanced operation and improving network reliability.

Table 1 Outcomes of Load Flow Analysis

RECOMMENDATIONS IMPLEMENTED

Capacitor Bank Sizing:

To improve the low power factor at LOAD CENTER-02, a 600 kVAr capacitor bank (4 × 150 kVAr units) was installed. This intervention increased the power factor from 87.92% to 99.22%**,** significantly reducing reactive power demand from the grid and enhancing overall system efficiency.

A 600 kVAr (150x4) capacitor bank was installed at the LOAD CENTER-02 BUS with the low power factor. This adjustment resulted in a dramatic improvement in power factor from 87.92% to 99.22%.

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The capacitor bank not only improved the power factor to near unity but also reduced the overall reactive power demand from the grid.

Capacitor Size (in kVAr)

$Qc = P \times (\tan\phi1 - \tan\phi2)$

Qc = Required reactive power in kVAr (size of capacitor), P = Active power in kW, $\phi1$ = Angle of the initial (existing) power factor, $\phi2$ = Angle of the desired (corrected) power factor

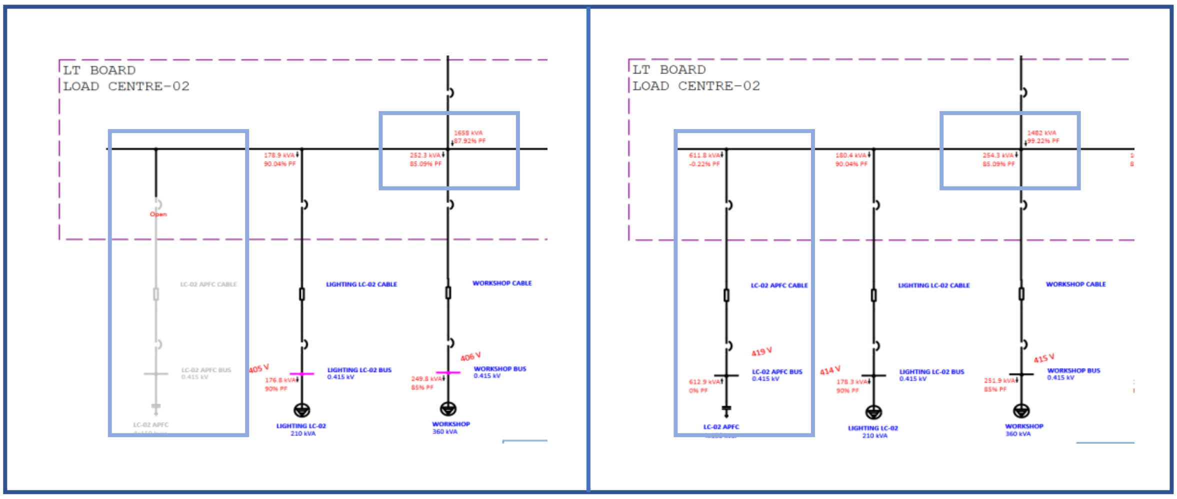

Figure 2 LOAD CENTRE-02 Without Capacitor Bank and With Capacitor Bank

Transformer Tap Setting:

The 6.6/0.433 kV transformer is provided with a ±5% tap range for voltage regulation. The existing tap position of –2.5% was observed to cause an overvoltage condition at the LV side of Load Centre-01, with the voltage reaching 447 V, exceeding the permissible limit. It is therefore recommended to adjust the tap setting to +5%, which is expected to reduce the LV voltage to approximately 414 V, thereby restoring it within acceptable limits and improving load-side voltage stability.

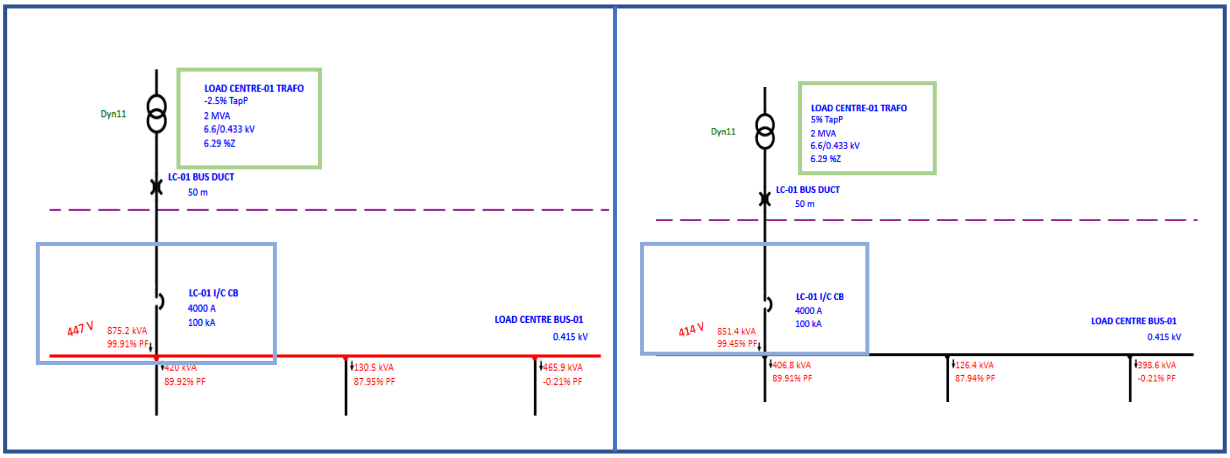

Figure 3 Load Centre Bus-01 Overvoltage and Voltage Within Limit

Cable Sizing Review:

The existing configuration of 4 runs of 3-core 400 sq.mm cables has been evaluated and is currently operating at 102.7% of its rated capacity under present plant loading conditions. This indicates an overloading condition, which may lead to excessive thermal stress, insulation degradation, voltage drop, and reduced system reliability.

To mitigate this issue and enhance the overall current-carrying capacity of the feeder, it is recommended to install one additional parallel run, increasing the total to 5 runs of 3-core 400 sq.mm cables. This modification

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will reduce the current loading per cable run, improve thermal performance, and ensure safe, stable, and reliable power distribution in accordance with applicable design standards.

Alternatively, the load connected to MCC-06 may be redistributed by transferring a portion of the demand to another MCC panel with available spare capacity. This load balancing approach would reduce the loading percentage on MCC-06, eliminate the overcapacity condition, and optimize the overall utilization of the plant's power distribution system without requiring additional cable installation.

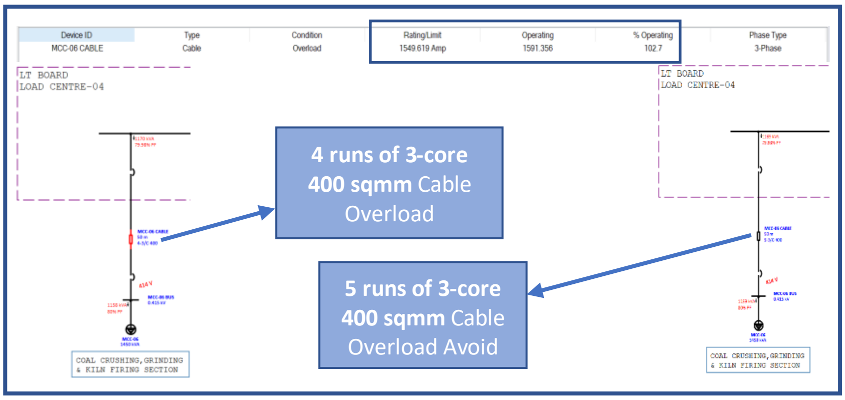

Figure 4 Cable Sizing Review

Cable Sizing Calculation Criteria

The minimum cross section of LV and HV voltage cables shall be calculated based on below methods:

1. Short circuit current capacity
2. Current carrying capacity
3. Voltage drop of cable

1.Short Circuit Current Capacity:

The minimum cross-sectional area of the cable is determined based on its ability to withstand short circuit conditions. The formula is:

$$A = \frac{Isc \times \sqrt{t}}{K}$$

Where:

- A = Cable cross-sectional area in mm²
- Isc = Short circuit current in kA
- t = Duration of short circuit in seconds
- K = Constant

2.Current carrying capacity

The cable current carrying capacity under derated condition must be greater than the full load current ($I < I_{Derated}$). If it is not greater, then increase the cross section of the cable or the number of runs.

3.Voltage drop of cable

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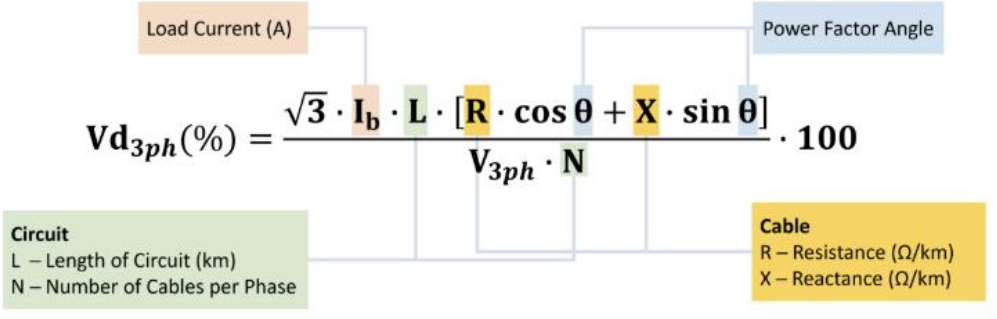
The cable has its resistance and reactance causing some voltage drop.

The voltage drop during running must be less than 3% ($V_{(Running)} < 3\%$).

The voltage drops during starting must be less than 10 to 15% ($V_{(Starting)} < 10\text{-}15\%$).

The balanced three-phase voltage drop equation is below. For single phase voltage drop replace the √3 with 2 and V3ph with V1ph.



Reactive Power Compensation for Induction Motor:

The load flow study was conducted for two distinct scenarios—first, without the capacitor bank, and second, with the implementation of an 885 kVAr capacitor bank at the 11kV bus. The comparative results, presented in the following figures, demonstrate significant enhancements in power factor, stabilization of the voltage profile, and effective reactive power compensation after the capacitor installation.

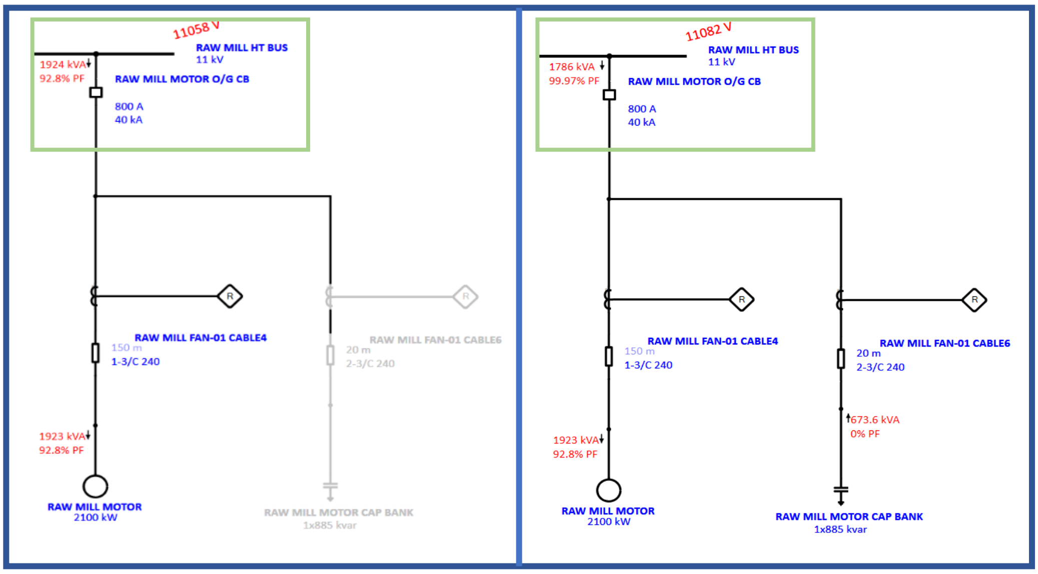


Figure 5 Motor Feeder without Capacitor Bank and with Capacitor Bank

Contingency Analysis

The plant is supplied by Two 66/11.5 kV power transformers and a 12 MW Waste Heat Recovery System (WHRS) operating at 11 kV. Under normal conditions, these three sources run in parallel, sharing the plant load of 20.59 MVA efficiently.

- **Single Transformer Outage:** If either of the two transformers is offline, the remaining transformer, together with the WHRS, is sufficient to meet the plant's load demand, ensuring uninterrupted operation.
- **WHRS Outage:** If the WHRS is unavailable, the two transformers can supply the entire plant load without compromising voltage or system stability.

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- **Dual Transformer Outage:** If both transformers fail simultaneously, the WHRS alone cannot supply the full plant load of 20.59 MVA. In this scenario, partial load shedding or alternate supply arrangements would be required to maintain safe operation.

This contingency analysis confirms that the system is robust to single-source outages but highlights the limitation if both main transformers are unavailable, underlining the importance of redundancy and protection coordination in the network.

	MW	Mvar	MVA
Source (Swing Buses):	9.898	1.029	9.952
Source (Non-Swing Buses):	10.000	3.630	10.638
Total Demand:	19.898	4.658	20.436

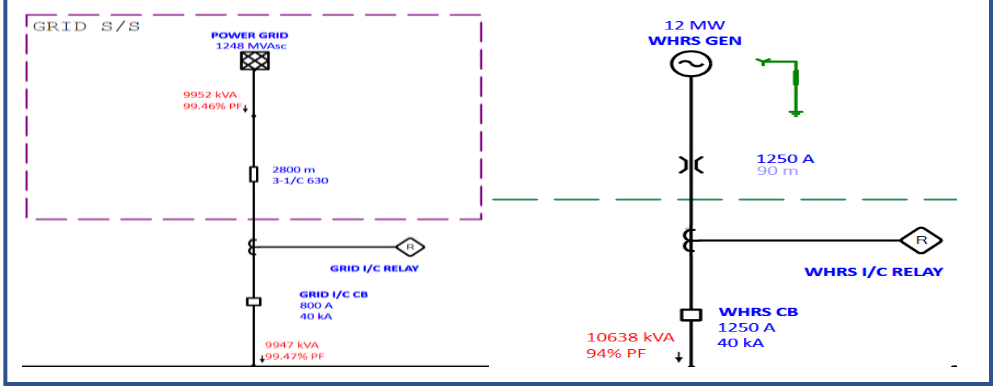

Figure 6 Normal Condition three sources run in parallel (Two Transformer + One WHRS)

Short Circuit Study

Short circuit analysis is a critical component of power system studies used to determine the magnitude of fault currents under various fault conditions such as three-phase, line-to-line, and line-to-ground faults. This analysis helps in verifying the adequacy of equipment ratings, ensuring safe system operation, and designing appropriate protection schemes. The results aid in selecting circuit breakers, relays, and other protective devices capable of interrupting fault currents without damaging the system components.

Short circuit study and analysis were performed to evaluate the maximum fault current levels, referred to as Device Duty, and the minimum fault currents, which are critical for Relay Coordination. This ensures that all protective devices are correctly rated and coordinated to operate reliably under both extreme and marginal fault Conditions.

Device Duty (DD) – Max Option

To calculate the maximum possible fault current for verifying the interrupting capacity of protective devices like circuit breakers.

Negative tolerance applied to:

- Generator and motor sub-transient reactance (Xd″)
- Transformer, reactor, and overload heater impedances
- Cable and line lengths
- Resistance is reduced by assuming minimum ambient temperature, simulating lower conductor resistance

Maximizes fault current, ensuring that devices are capable of withstanding and interrupting the worst-case fault.

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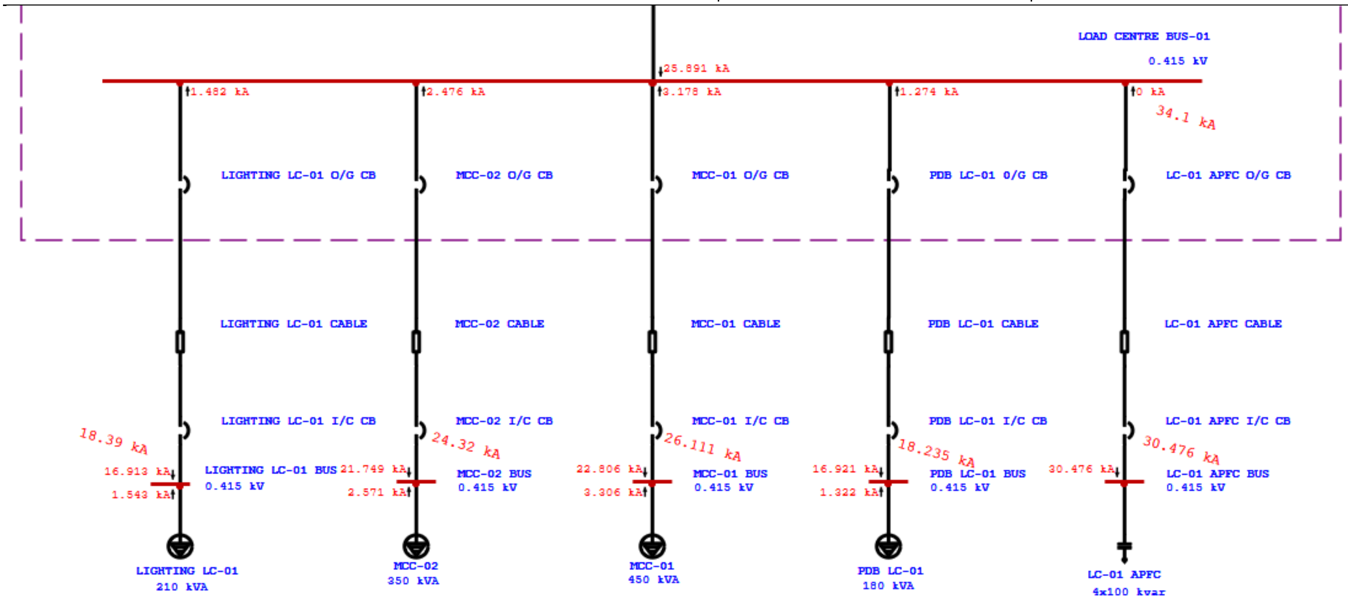

Figure 7 DD (Device Duty) Result (LC-01 Isc=34.1 kA)

Relay Coordination Duty – Min Option

To calculate the minimum fault current for ensuring that relays still operate correctly and selectively under weak fault conditions.

Positive tolerance applied to:

- Generator and motor sub-transient reactance (Xd″)
- Transformer, reactor, and overload heater impedances
- Cable and line lengths
- Resistance is increased by assuming maximum operating temperature, simulating higher conductor resistance.

Minimizes fault current, useful for relay coordination and sensitivity analysis.

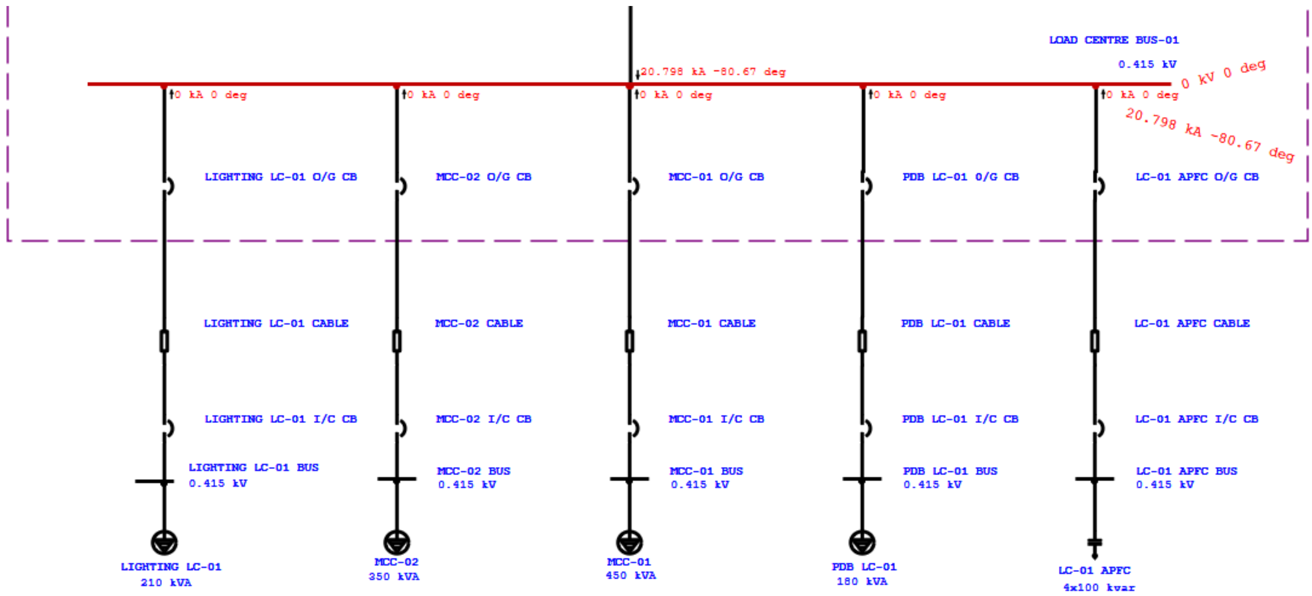

Figure 8 Relay Coordination Duty Result (LC-01 Isc=20.7 kA)

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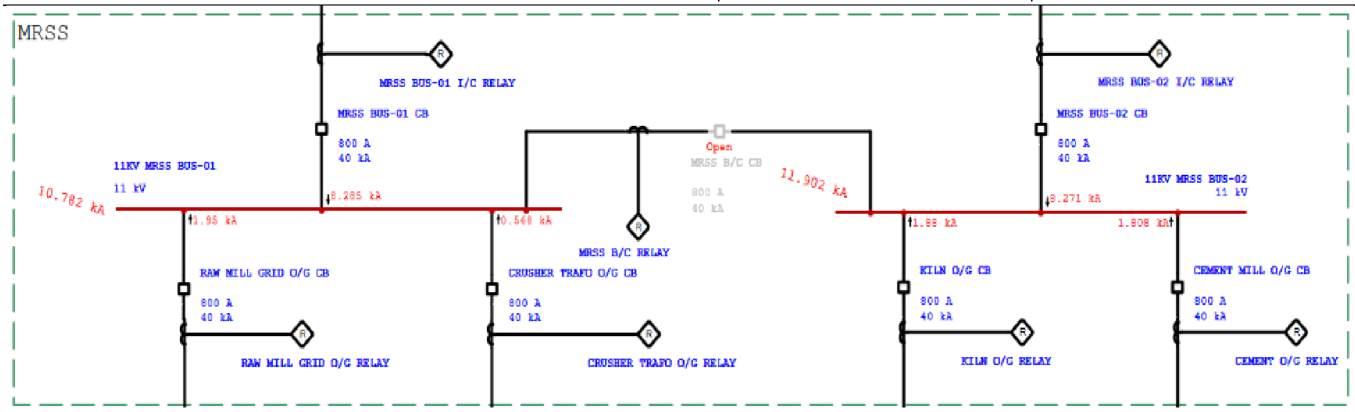

Figure 9 Bus Coupler Open (Device Duty)

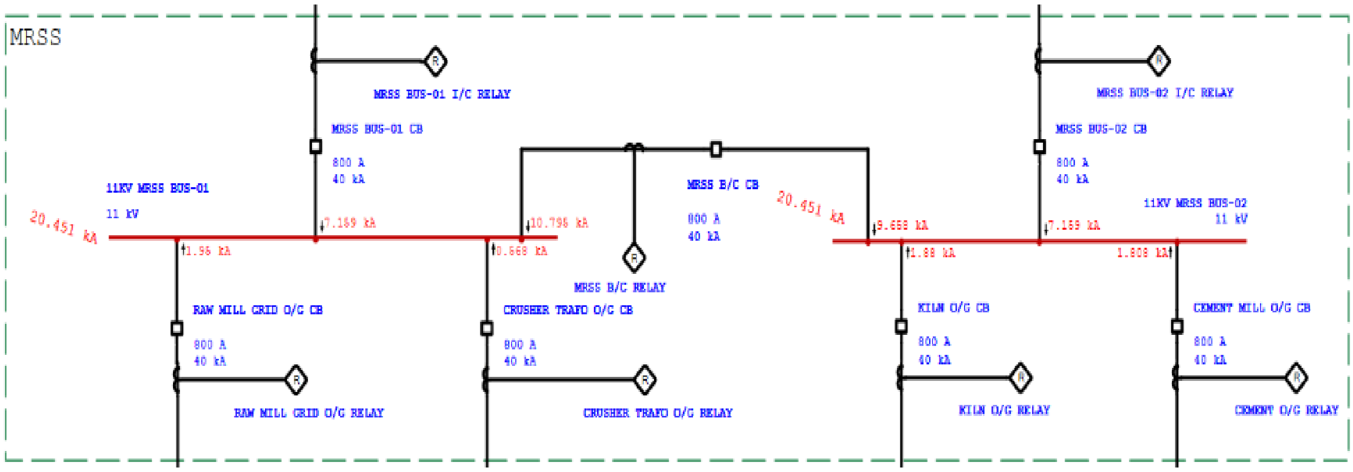

Figure 10 Bus Coupler Close (Device Duty)

When the 11 kV MRSS bus coupler is open, the fault currents at Bus-01 and Bus-02 are 10.782 kA and 11.902 kA respectively. However, closing the bus coupler results in a combined fault current of 20.415 kA. Therefore, operating the bus coupler in the open condition effectively isolates the two buses, reducing the fault current contribution from the interconnected network and serving as a practical fault current limiting strategy.

Selection of Circuit Breaker base on Device Duty

The existing circuit breaker is rated for 50 kA for 1 second, while the calculated device duty short circuit current is 59.154 kA. This means the current breaker is undersized and inadequate for safely interrupting or making the expected fault current.

To ensure safe and reliable operation under fault conditions, a new breaker rated at 70 kA is recommended. This provides adequate margin above the required 59.154 kA duty and ensures compliance with protection and safety standards.

Alternatively, installation of a current-limiting reactor may be considered to reduce the fault level. However, this solution would introduce additional system impedance, potentially affecting the voltage profile and overall system performance. Therefore, this option is not recommended.

Alternative Option – ABB IS Limiter: The ABB IS Limiter instantly limits short-circuit current within msec, protecting switchgear and transformers and avoiding costly equipment upgrades. Under normal operation, current flows through the main conductor; on fault detection, the main conductor opens, diverting current through a parallel fuse to limit the fault current.

The device acts within milliseconds (msec), specifically detecting faults in ~15 microseconds and limiting the current before the first peak.

Mitigation Techniques to Limit Short Circuit Current

- Current Limiting Reactors (CLR)

  Purpose: To limit the fault current by adding impedance to the circuit.

  Operation: These reactors are connected in series with the circuit and reduce the fault current by introducing additional impedance.

  Benefit: Effective in limiting the fault current without the need for expensive upgrades to switchgear.

- Network Splitting

  Purpose: Divide the network into smaller sections to reduce the fault current.

  Operation: By isolating parts of the network (e.g., opening bus couplers), the fault current contributions from multiple sources are limited.

  Benefit: Cost-efficient and simple to implement without extensive equipment changes.

- Increasing Cable Length

  Purpose: Increase the impedance in the system, which in turn reduces fault current.

  Operation: Longer cables have higher resistance and reactance, which limits the flow of fault currents.

  Benefit: Simple and low-cost solution, though only effective for certain systems.

- Lighting Transformers

  Purpose: Use 1:1 isolation transformer to limit fault current.

  Operation: The transformer separates circuits while also limiting the fault current to safe levels.

  Benefit: A straightforward approach for current fault reduction without significant impact on system operation.

- Unit Ratio Transformer (1:1 Transformer)

  Purpose: Provides electrical isolation and reduces fault current without changing voltage.

  Benefit: Limits short-circuit current, protects equipment, and improves system safety.

  Operation: Power flows normally under load; during faults, transformer impedance helps reduce.

- IS Limiter (ABB)
  Purpose: To instantly limit short-circuit current before it reaches dangerous levels-within msec-and protect the system.
  Benefit:
  - World's fastest switching for fault control
  - Protects switchgear and transformers
  - Avoids equipment upgrade costs
  - Enables safe parallel operation of systems

Operation:

- Under normal load, current flows through the main conductor

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- On fault detection, the main conductor opens and current is diverted to a parallel fuse, which instantly limits the current.

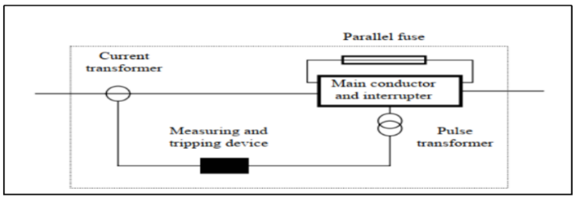

Figure 11 IS Limiter

protective Device Coordination

Protective Device coordination is a critical aspect of power system protection that ensures selective, reliable, and timely isolation of faults. The goal is to coordinate multiple protective device in such a way that only the Protective Device closest to the fault operates first, while backup Protective Device are set with appropriate time delays to operate if the primary protection fails.

Protective Device coordination involves analyzing the time-current characteristics (TCC) of relays, ensuring there is a discrimination margin between primary and backup relays. This is especially important in industrial plants, substations, and transmission networks, where continuity of supply is critical.

Key Objectives of Protective Device Coordination:

- Selectivity: Only the faulty section is isolated.
- Speed: Minimize fault clearing time to avoid damage.
- Sensitivity: Detect even low-level faults.
- Backup: Ensure operation if the primary relay fails.

In low-voltage power distribution systems, Air Circuit Breakers (ACBs) play a vital role in protecting equipment against overcurrent and fault conditions. A key component within an ACB is the release, also known as the trip unit or protection relay. The release is responsible for continuously monitoring the electrical parameters and initiating circuit interruption when predefined thresholds are exceeded.

Key Protection Functions

Protection Type	Symbol	Purpose
Long-time delay	L	Overload protection
Short-time delay	S	Short-circuit with delay (coordination)
Instantaneous protection	I	Immediate trip on high fault current
Ground fault protection	G	Earth fault protection

Table 2 Key Protection Function

Release Setting

1. L – Long-time (Overload Protection)

Purpose: Protects against prolonged overloads.

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Setting:

- Long-time pickup (Ir):

  (Load Current × Safety Margin)/CT Ratio
  Typically set at 1.0 – 1.2 times full load current.

- Long-time delay (tr): Usually 1.5 to 30 seconds

2. S – Short-time (Short-Circuit with Delay)

Purpose: Allows selective tripping for short circuits.

Setting:

- Short-time pickup (Isd): Typically, 2 – 10 × Ir

- Short-time delay (tsd): Typically, 0.1 – 0.5 s (to coordinate with downstream)

3. Instantaneous (Short-Circuit Without Delay)

Purpose: Fast tripping for close-in faults.

Setting:

- Instantaneous pickup (Ii): Typically, 8–15×Ir
  No intentional time delay.

Note: To achieve proper time grading and eliminate unwanted tripping during through faults or inrush conditions, it is recommended to switch off the 'INS' setting of Release.

4. G-Ground Fault Protection

Purpose: Detects earth faults.

Setting:

- Ground pickup (Ig): Typically, 0.1 – 0.5 × CT primary

- Ground delay (tg): 0-1s depending on coordination.

A relay is an electrical protection device designed to detect abnormal conditions such as overcurrent, phase faults, or earth faults in a system.

It continuously monitors electrical parameters and compares them to preset thresholds. When a fault or abnormal condition is detected, the relay sends a trip signal to operate a circuit breaker, isolating the faulted section.

This helps to prevent damage to equipment and maintain the stability of the system. Relay coordination ensures that only the nearest relay to the fault operates, minimizing disruption to the rest of the system. Different types of relays, like overcurrent and earth fault relays, are used based on the fault type. Proper settings and coordination of these relays are crucial for system protection.

Time Grading in relay coordination refers to the technique of setting relays in such a way that they operate sequentially, with each relay having a time delay that ensures the relay closest to the fault operates first, followed by others only if needed. This helps to prevent unnecessary trips of upstream relays and ensures that only the faulted section is isolated.

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Component	Electro-mechanical Relay	Static Relay
Circuit Breaker Opening Time	0.08 s	0.08 s
Relay Overtravel	0.10 s	0.00 s
Relay Tolerance & Setting Errors	0.12 s	0.12 s
Total CTI Required	0.30 s	0.20 s

Table 3 Time Grading

Relay Setting Calculation

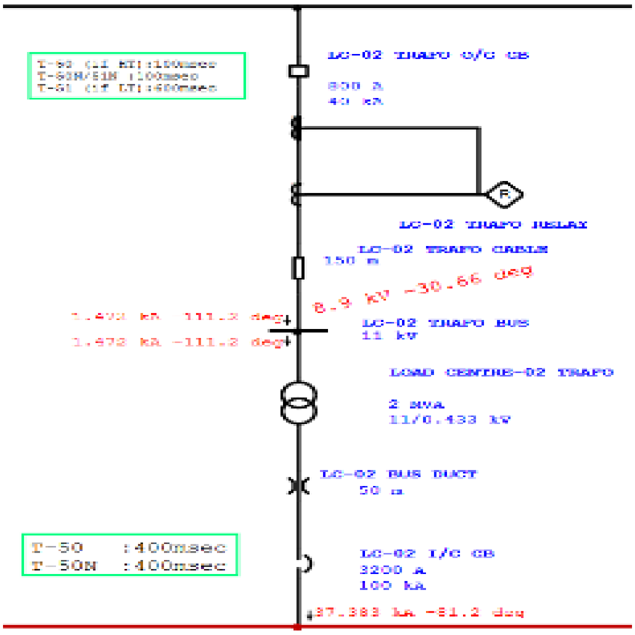

Figure 12 Time Grading and Fault Current

Transformer Details:

Rating: 2 MVA

Voltage ratio: 11/0.433 kV

FLA: 105 A

CTR: 150/1 A

Transformer Feeder 1st stage overcurrent setting (IDMT)

Pick-up(I>) $:\frac{1.2 \times FLA}{CTR}$

$:\frac{1.2 \times 105}{150}$

:0.84~0.85

Operating Characteristic Curve: IEC NI

Through Fault Current (Ithr) = $\frac{Vsec}{Vpri} \times LT\ fault\ current$

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= 1.472 kA

Plug setting multiplier (PSM) = $\frac{Fault\ current\ in\ relay\ coil}{Pick-up\ current}$

PSM = 9.8133/0.85

=11.54

Time of Operation =$TMS\left(\frac{k}{\left(\frac{I}{Is}\right)^{\propto}-1}\right)$

IEC NI so, k = 0.14 and α = 0.02

t(I) = 2.79 sec (TMS=1)

Time grading is 600 msec.

TMS = (required op. time) / (op. time at TMS=1)

= 0.600/2.79

= 0.214~ 0.215

Transformer Feeder 2nd stage setting (DMT)

Pick-up(I>>)

For through-fault stability, the high-set current (I>>) is set at

1.3 times the reflected current or 8 times the Full Load Amps (FLA) for inrush withstand—whichever is higher.

Pick-up= $\frac{1.3\times Ithr}{CTR}$ or $\frac{8\times FLA}{CTR}$

= $\frac{1.3\times 1472}{150}$

= 12.75 ~ 13

Figure 13 ETAP IDMT and DMT Stage Data Entry

Phase Fault Result:

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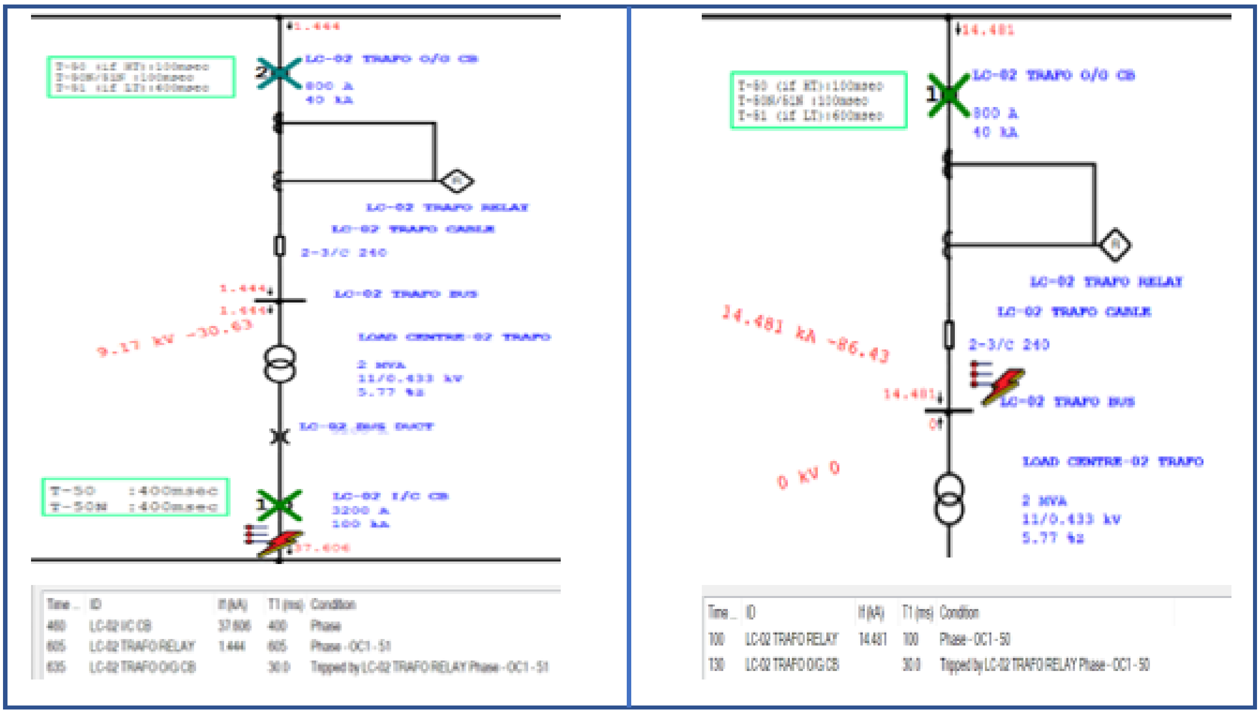

Figure 14 LC-02 Transformer Phase Fault DMT and IDMT Relay Operation Time

Earth Fault Relay Setting:

For NGR Earthed Systems:

- Set at 10–20% of CBCT current, or
- 10-30% of NGR current rating (whichever is appropriate)

For Solidly Earthed Systems:

- Set at 20–50% of rated current

Relay Earth fault Setting:

In an NGR-earthed system designed to limit earth fault current to 100 A, a CBCT (Core Balance Current Transformer) with a ratio of 100/1 A is used. The earth fault relay setting is typically set at 20% of the CBCT secondary current, i.e., 20 A. The time delay for the relay operation is set based on time grading to ensure coordination with upstream and downstream protection devices.

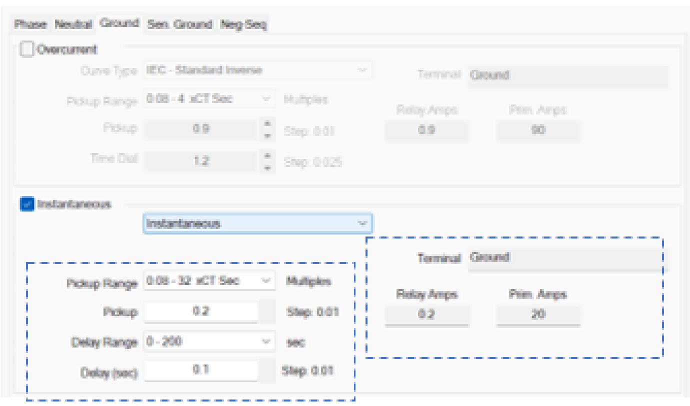

Figure 15 Earth Fault Setting Entry in ETAP

Earth Fault result:

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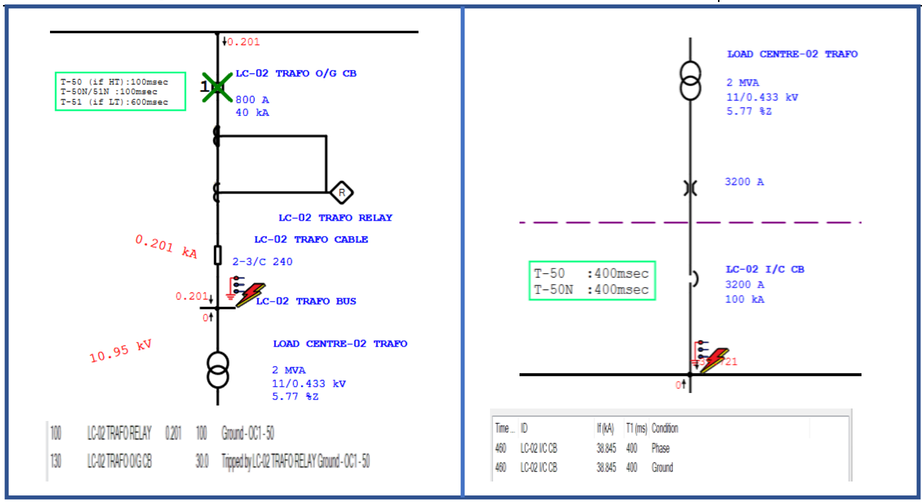

Figure 16 LC-02 Transformer Earth Fault DMT and IDMT Relay Operation Time

CONCLUSION

In this paper, a comprehensive analysis of the industrial power distribution system was carried out using ETAP software, focusing on Load Flow Analysis, Short Circuit Study, and Relay Coordination. The Load Flow Study enabled us to evaluate the adequacy of equipment ratings under various operating scenarios. It also helped in verifying the suitability of cable sizes and the effectiveness of Automatic Power Factor Correction (APFC) units for different load conditions. Additionally, new tap settings for transformers were suggested to achieve a proper voltage profile across the network, ensuring stable and efficient operation. The Short Circuit Analysis was instrumental in assessing the capability of existing switchgear and protective devices to withstand and interrupt fault currents. Based on the results, we proposed the addition of current limiting reactors and lighting transformers at specific buses to reduce excessive fault levels and enhance system protection. Through the Relay Coordination Study, we analyzed the performance of protection relays and optimized their settings. New IDMT (Inverse Definite Minimum Time) and DMT (Definite Minimum Time) stages were suggested to improve selectivity and system reliability. In the release settings, we specifically recommended turning off the instantaneous (INS) setting where necessary to achieve proper time grading between upstream and downstream relays. Overall, the study provided critical insights into the operational robustness of the distribution system and suggested key improvements to enhance safety, reliability, and performance.

REFERENCES

1. IEEE Recommended Practice for Conducting Load-Flow Studies and Analysis of Industrial and Commercial Power Systems, IEEE Std. 3002.2-2018.
2. IEC 60909, Short-Circuit Currents in Three-Phase AC Systems.
3. IEC 60909-0:2016, Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents.
4. IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, IEEE Std. 242-2001.
5. P. Paradva, A. M. Patel, and K. Chavada, "Power system analysis and relay coordination for an industrial distribution system," International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, vol. 10, no. 4, Apr. 2022.
6. B. A. Oza, N. C. Nair, R. P. Mehta, and V. H. Makwana, Power System Protection and Switchgear. New Delhi, India: McGraw Hill Education.
7. Power Projects India, "Cable sizing calculation low voltage." [Online]. Available: https://powerprojectsindia.com/cable-sizing-calculation-low-voltage/
8. Instrumentation Tools, "Types of relays used in an air circuit breaker (ACB)." [Online]. Available: https://instrumentationtools.com/types-of-relays-used-in-an-air-circuit-breaker-acb/
9. Power Projects India, "Methods of reducing short circuit current." [Online]. Available: https://powerprojectsindia.com/methods-of-reducing-short-circuit-current/

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

10. Schneider Electric, “EasyPact MVS Circuit Breaker, MVS12N3NW6A.” [Online]. Available: https://www.se.com/in/en/product/MVS12N3NW6A/.
11. Power Projects India, “Transformer protection overcurrent and earth fault.” [Online]. Available: https://powerprojectsindia.com/transformer-protection-over-current-and-earth-fault/
12. ELEK Software, “Voltage drop calculator AS3008.” [Online]. Available: https://elek.com/resources/free-electrical-calculators/voltage-drop-as3008/