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Protective Relay Coordination in an Injection Substation Using an Over Current Relay (Case Study: Iriebe 33kV Injection Substation)

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Abstract:- Effective relay coordination is critical for ensuring reliable protection and minimizing power disruptions in electrical substations. This study investigates the coordination of overcurrent relays for both primary and backup protection in a medium-voltage substation. The primary objective is to achieve selective tripping, isolating only the faulted section of the network while maintaining the integrity of the unaffected sections. The research addresses common challenges in relay coordination, including improper tripping and relay restraint features. Data was collected from components associated with the Iriebe 33kV injection substation, including the grid, power transformers, cables, and buses, and a Single Line Diagram (SLD) was utilized for analysis. Overcurrent relay coordination was performed using the ETAP Protection Coordination Technique. After simulating fault conditions, miscoordination was observed, which was subsequently addressed through manual calculations of Time Multiplier Setting (TMS) and Plug Setting Multiplier (PSM). The results demonstrated that with optimized relay settings, system coordination was restored, leading to improved protection performance. The study also analyzed the sequence of operation, showing that proper relay coordination enhances substation reliability by reducing outage durations and preventing equipment damage during fault events. This research contributes to the optimization of overcurrent relay settings in medium and high-voltage substations, ensuring more efficient and reliable protection systems.

Keywords:- *Injection Substation, Overcurrent, Relay Coordination, ETAP, Time Current Curve Fitting, Time Dial setting, Pickup Current.*

I. INTRODUCTION

In modern electrical power systems, protection schemes are essential for maintaining the safety and reliability of both the power infrastructure and the end users. Protective relays, which detect faults in the electrical network and initiate disconnection of affected parts of the system, play a critical role in ensuring the continuity of service. A common protective device employed in substations is the overcurrent relay (OCR), which detects fault currents exceeding predefined thresholds. The effectiveness of these relays depends significantly on the coordination between upstream and downstream protection devices to ensure selective tripping, which isolates only the faulty section of the network without unnecessarily disrupting the entire system.[1]

In high-voltage systems, such as the 33kV injection substation in Iriebe, the challenge of implementing proper protective relay coordination becomes more complex due to factors such as network topology, fault current levels, and relay characteristics. Injection substations are pivotal in power transmission networks as they facilitate the integration of electricity from generation sources into the broader grid, making them critical points for both protection and operational continuity [2]. In such substations, overcurrent protection relays are typically configured to operate in a time-coordinated manner, with the goal of ensuring that fault currents are cleared as quickly as possible without affecting unaffected parts of the system.

Protective relay coordination involves determining the optimal settings for each relay to ensure proper selectivity and time grading. In the case of the Iriebe 33kV substation, coordination involves the careful calibration of relay characteristics such as time delays and current settings to ensure that upstream relays respond only when downstream relays fail to operate, thus minimizing system downtime and preventing unnecessary outages. Furthermore, the proper coordination of these devices reduces the risk of equipment damage due to prolonged fault conditions [3]. The design of a relay protection scheme must also consider the variation in fault currents during different operating conditions, as well as the fault-clearing time necessary to avoid cascading failures across the network [4].

This study aims to investigate the protective relay coordination at the 33kV Iriebe injection substation, focusing on the configuration and optimization of overcurrent relays. By conducting a case study of this specific substation, we seek to explore the challenges faced in achieving proper relay coordination and to propose solutions for enhancing the reliability and protection of the network, ensuring minimal disruption to service during fault conditions.

➢ *Injection Substations*

Plate 1.0: 33kV Iriebe Injection Substation
(Source: Field)

An injection substation is a critical infrastructure component in the electrical transmission and distribution system, designed to inject electrical power into an existing grid or network. These substations play an essential role in ensuring the reliability and stability of power supply by facilitating the transfer of electricity from generation sources to various distribution points. In this paper, we examine the operational characteristics, design considerations, and technological advancements associated with injection substations.

An injection substation serves as a point where electrical power, typically at high voltage, is "injected" into the transmission network to serve as a supplementary source of power. These substations are strategically located to manage the flow of power and ensure that electricity is distributed efficiently across long distances to meet local demand. The main components of an injection substation include transformers, circuit breakers, busbars, and protection systems, each playing a crucial role in the operation of the grid [5].

➢ *Components and Functionality*

- **Transformers**: These devices step up or step down the voltage levels to make the power compatible with the transmission network. Transformers are key in regulating the voltage levels to match the operational requirements of the electrical grid [6].
- **Circuit Breakers**: These are crucial for isolating faults and protecting the equipment within the substation. They can automatically disconnect faulty sections to prevent further damage or cascading failures [7].
- **Busbars**: A busbar serves as a central point for connecting different parts of the electrical system. It provides a common connection for transformers, generators, and other components of the substation [8].
- **Protection Systems**: Modern substations are equipped with digital protection systems that ensure quick identification and isolation of faults, minimizing potential damage. These systems employ algorithms that detect abnormalities such as short circuits, overcurrent, or under-voltage [9].

➢ *Role in Grid Stability and Reliability*

The primary function of an injection substation is to enhance grid reliability by providing a robust point of injection for electricity into the transmission network. These substations help to balance supply and demand across different regions by injecting surplus energy or redistributing power as necessary. The strategic placement of injection substations within the transmission network can prevent overloads, facilitate fault isolation, and enable the efficient management of grid stability [10].

Injection substations are also vital during periods of high demand, when they allow for the diversion of power from less stressed parts of the grid to areas with higher loads. This reduces the risk of voltage sags or brownouts and ensures a continuous supply of electricity to end users [11].

➢ *Distribution System Protection Coordination*

The electrical protection system is designed to safeguard all components of the power system, including generators, transformers, transmission and distribution networks, insulators, and other related equipment [12]. This protection mechanism is activated under abnormal conditions, which can include faults such as short circuits, voltage deviations (both high and low), overloads, and fluctuations in system frequency, among others.

➢ *Relay Coordination*

Relay coordination involves triggering the relays in a power system in a systematic or sequential order. The goal of relay coordination is to quickly isolate the faulty section of the system while minimizing unnecessary operations of relays and circuit breakers, ensuring that the rest of the system remains operational. Software tools commonly used for protection coordination include ETAP, DigSilent PowerFactory, PSCAD, PSS/E, and others.

➢ *Key Concepts in Relay Coordination*

- Pick-Up Current: This refers to the minimum current level at which a relay activates. The pick-up current typically ranges from 1.05 to 1.3 times the full-load rated current.
- Plug Setting Multiplier (PSM): PSM is the ratio of the fault current to the pick-up current. It is used in relays to set the tripping threshold, indicating the severity or danger level of the fault current. While this setting is commonly applied in electromagnetic relays, it is conceptually used in numerical relays, even though they do not require plugs.

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- Time Multiplier Setting (TMS): Also known as the time dial setting, the TMS adjusts the relay's tripping time. A higher TMS results in a longer operating time for the relay, whereas a lower TMS results in quicker operation.
- Time-Current Characteristic (TCC) Curve: The TCC curve is a graph that plots the relationship between time and current. It illustrates the tripping time of a protective device for a given current. Protection engineers use the TCC curve to visually represent relay coordination. The graph may include elements such as cable and transformer damage curves, transformer inrush currents, and IDMT relay curves. Adjustments to the pick-up current and TMS values of relays can be made using this graph [13]

➢ *Relay Communication Protocol IEC 61850*

The expansion of power network and advancement in the technology led to more reliable and easier communication between protection relays themselves and with the central substation controller which is much better and faster in system communication. ABB recently developed protection and control IED manager (PCM600) software which communication protocols is the IEC 61850 standard. With this protocol, data can be transferred directly among bays to provide system interlocks. The figure below shows the connection between relays and system controller through Ethernet-IEC61850 protocol

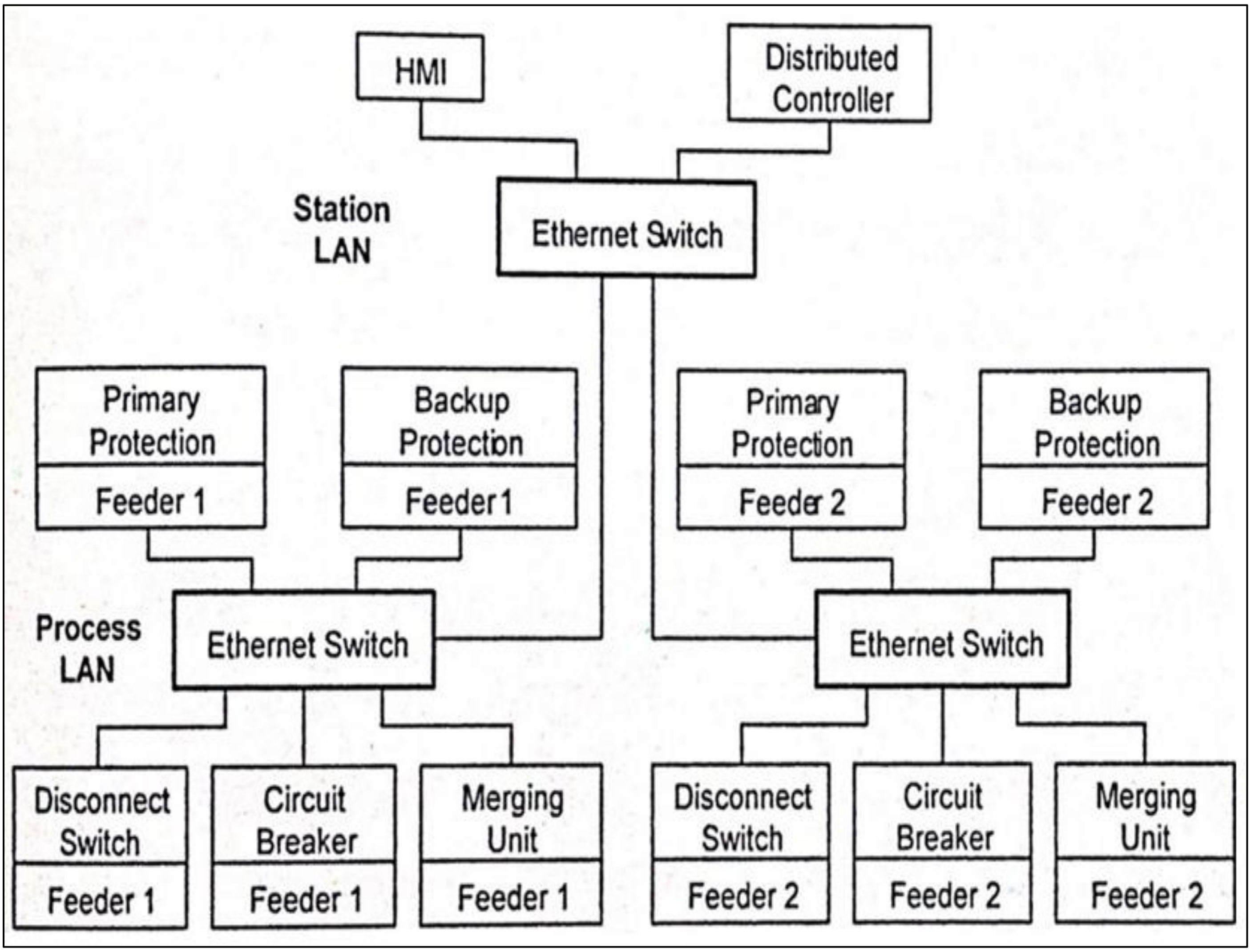

Fig 1 Ethernet-IEC61850 protocol for OCR Coordination [14]

II. MATERIALS AND METHODS

➢ *Materials Gathered;*

- Single Line Diagram SLD obtained from Iriebe 33kv injection Substation.
- Data obtained from the field.
- Personal computer.
- Software; AutoCAD, ETAP19.01

➢ *Existing Single Line Diagram of Iriebe Substation Network*

The SLD shows the arrangement and interconnections between components in the Injection Substation. From the SLD, a 1200MVAsc/33kV Public Mains supplies power to 2 x 15MVA power transformer, which supplies power to both 11kV busbars, Bus-6 and Bus-7. Bus-6 and Bus-7 are interlocked using a 1250A bus coupler. Bus-6 and 7 feeds 12MVA loads each.

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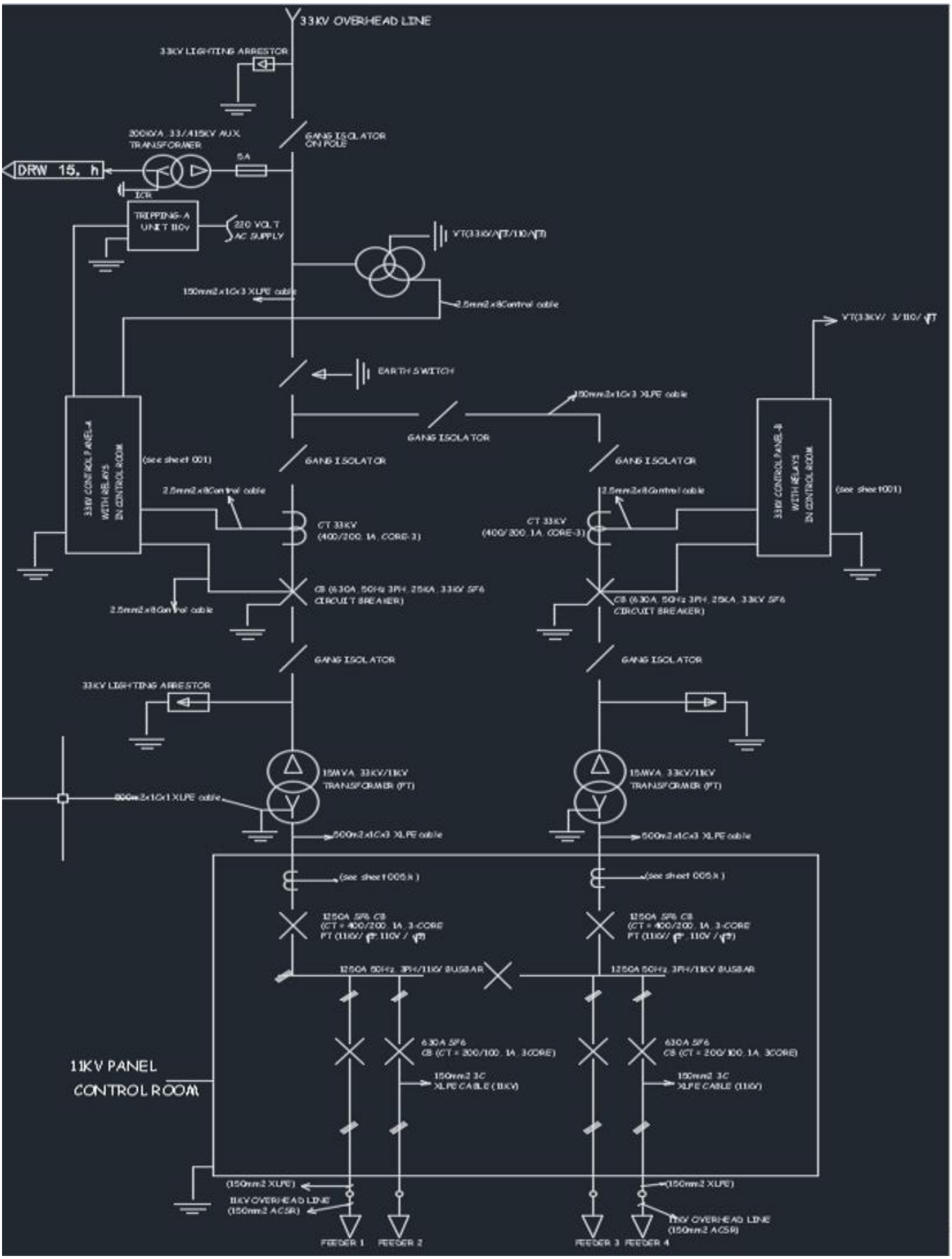

Fig 2 Simplified AutoCAD Presentation of the single line diagram of Iriebe injection substation

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Table 1 Equipment Specification and Values of Iriebe Substation Network

DESCRIPTION	RATING
Public mains	1200MVAsc/33kV
Fuse	2-300E/38kv/10kA
Bus 1	33kv
CB1	630Amp/36kv
Cable 1	1C X 95sqmm XLPE, 33kV
Power transformer	2 x 15MVA, 33/11kV
Bus 6	11kv
CB 4	1250A/12kV/31.5kA
LOAD	12MVA

➢ *Method Used*

Using ETAP software, Load flow analysis, short circuit analysis and protection coordination was conducted. Using the data from the load flow and short circuit analysis, manual calculation of the relay settings such as TMS and PSM was done.

➢ *Load Flow Analysis*

The 33kV Injection Substation components and their specification was inputted into ETAP software and load flow analysis was **performed using the Adaptive Newton Raphson Method.**

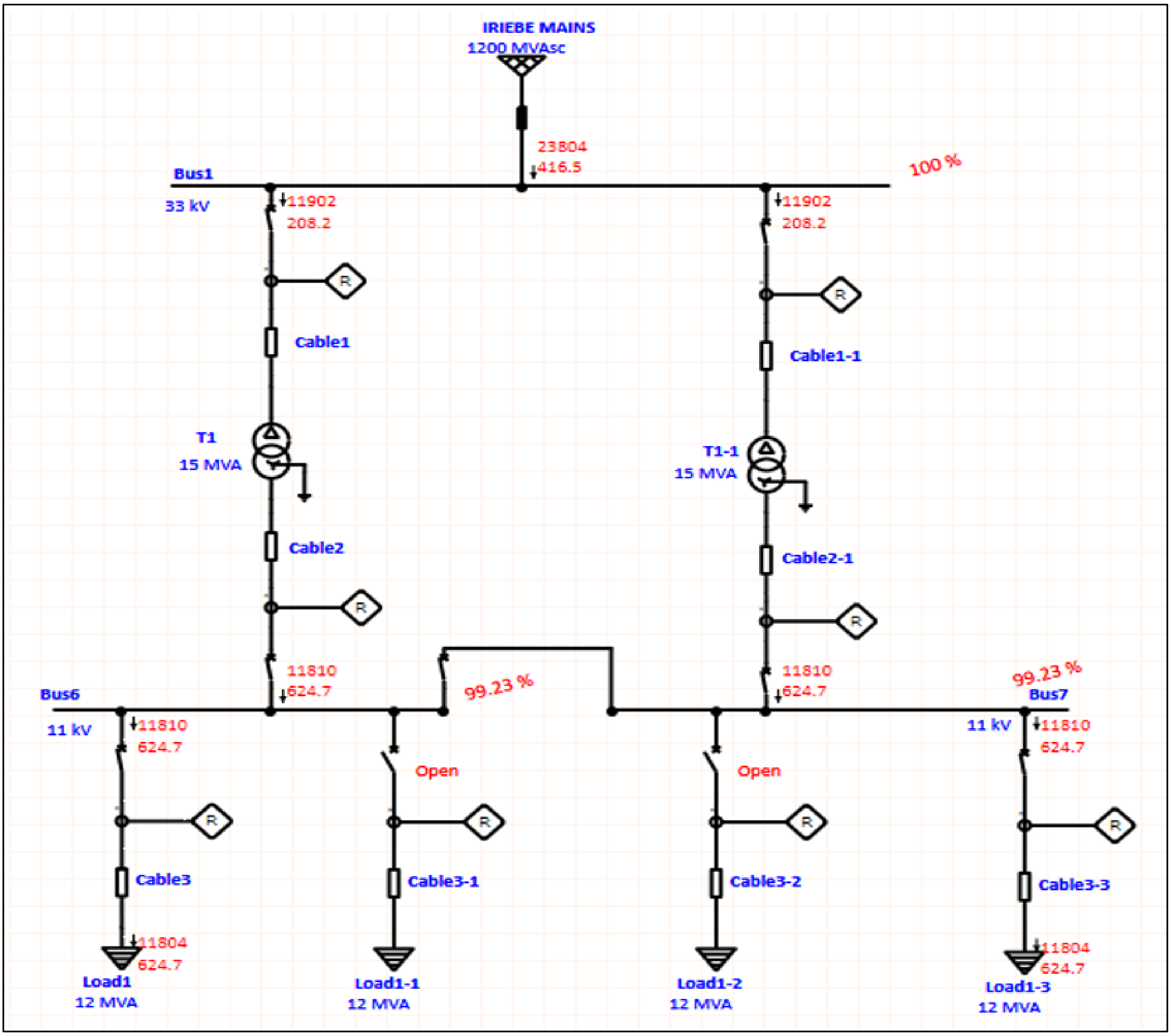

Fig 3 Load Flow Analysis of Iriebe 33kV Injection Substation

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The Loading of the network as shown in figure 3 is optimal only when the network has a loading factor of 50% unlike in figure 4 shown below when the network experiences a loading factor of 100% causing overload alert on specific equipment and undervoltage alerts on the buses.

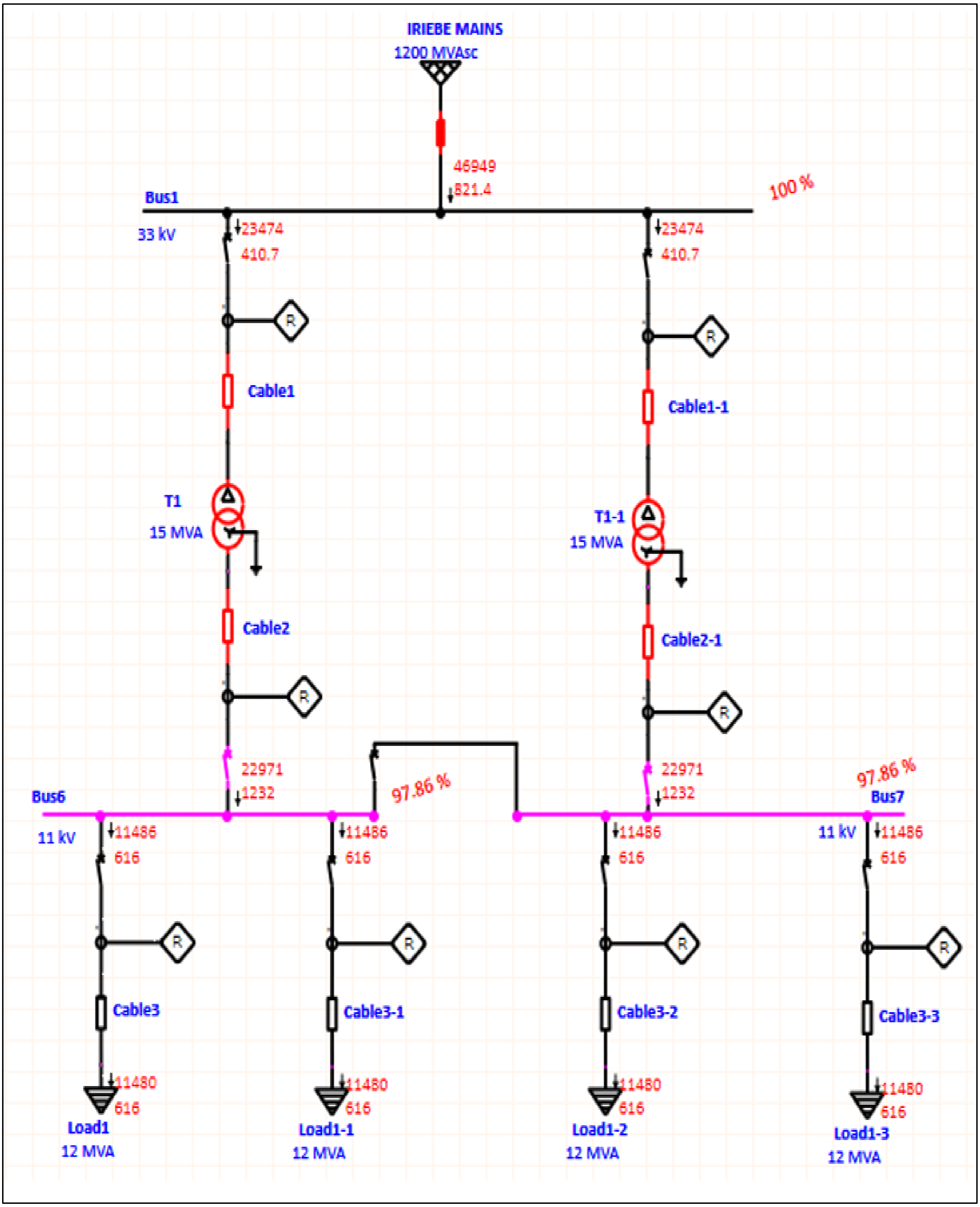

Fig 4 Load Flow Analysis of Iriebe 33kV Injection Substation when the System is over Loaded

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➢ *Short Circuit Analysis*

Short circuit analysis was performed on ETAP to obtain the maximum 3-phase short circuit fault on the buses using IEC 60909 Standard.

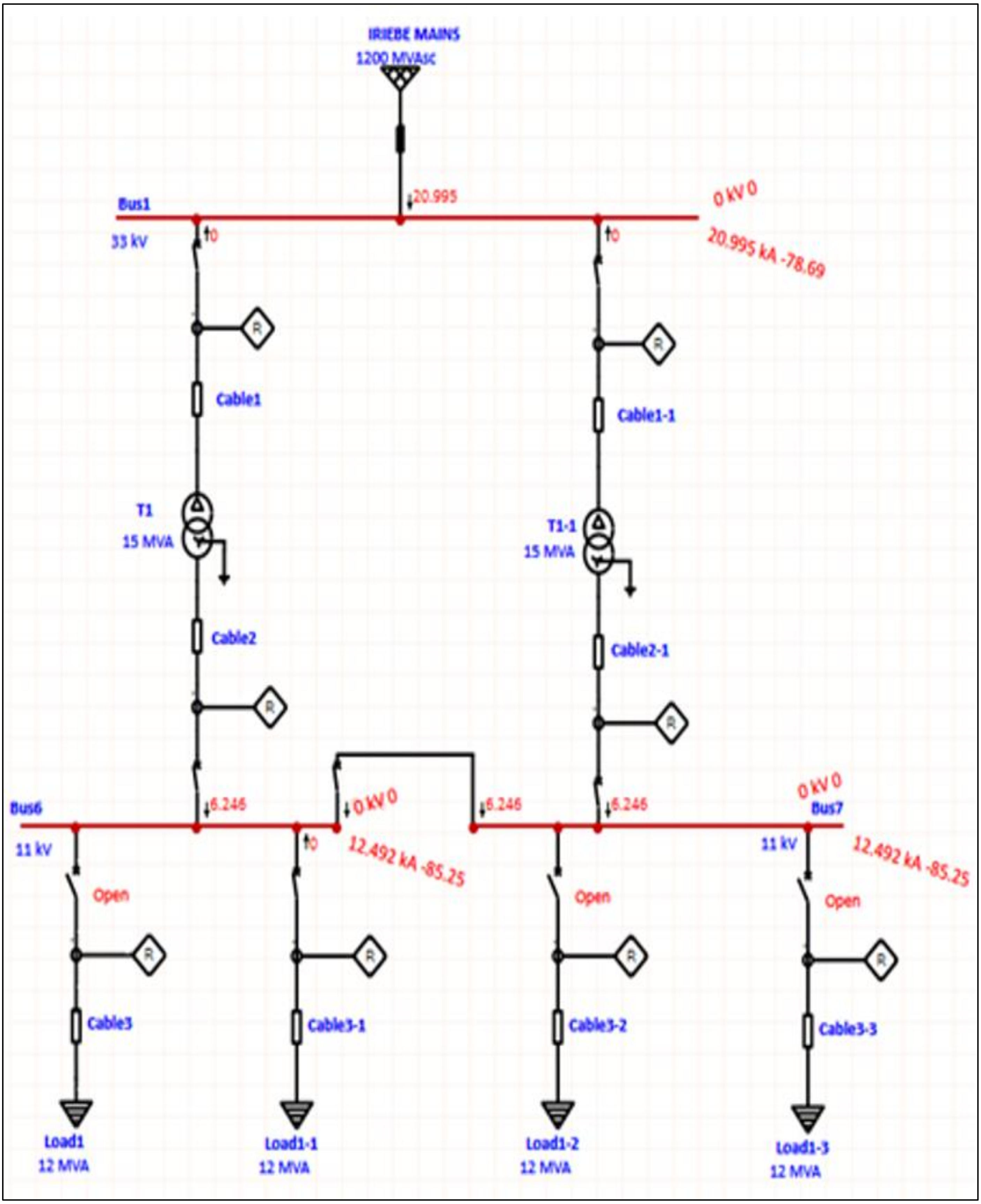

Fig 5 Short Circuit analysis of Iriebe Injection Substation

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV915

➢ *CT Size Selection*

The rating of CTs are selected on the basis of the full load current of the protected devices (motors, transformer, etc) that the CT is connected to. The CT ratio should be higher than the full load current.

Table 2 CT ratio Selection

Protected Device	Full Load Current (A)	Selected CT Ratio (A)
Tranformers, T1 HT side	262.4	400/1
Tranformers, T1-1 HT side	262.4	400/1
Tranformers, T1 LT side	787.3	1200/1
Tranformers, T1-1 LT side	787.3	1200/1
4 x 12MVA loads	629.8	1200/1

➢ *Coordination of 33kV Injection Substation Network*

In order to coordinate a relay properly it is important to choose the appropriate PSM and TSM values so that the relay can operate at a predetermined time, t.

$$t = \frac{\alpha \times TMS}{(PSM)^{\beta} - 1} \quad (1)$$

$$PSM = \frac{I_F}{I_P} \quad (2)$$

Where;

α= Constant

β= Constant

I_F= Fault Current in relay

I_P= Relay Pick up current

t= Relay operating time

From the equation above two constant values α and β are seen. These constant values depend on the relay curve type. Different relay curve types are available on ETAP relay properties. The values for α and β are shown for different curve types on table 3.

Table 3 IEC Constants Values for Relay Curve Types

Curve Type	α	β
Standard Inverse	0.14	0.02
Very Inverse	13.5	1.0
Extremely Inverse	80.0	2.0
Long-time Inverse	120.0	1.0

➢ *Plug Setting Multiplier (PSM) Calculation*

For calculation of PSM values fault current values are required. The fault current used are gotten from short circuit analysis result on ETAP.

Recall,

$$PSM = \frac{I_F}{I_P} \quad (3)$$

Table 4 PSM Values for Relays

Relays	Fault current I_F (A)	Pick-up Current, I_P (A)	PSM
Relay1 & Relay1-1	2033	278.1	7.31
Relay2 & Relay2-1	6098	834.53	7.307
Relay3	12196	667.59	18.268
Relay3-1	12196	667.59	18.268
Relay3-2	12196	667.59	18.268
Relay3-3	12196	667.59	18.268

➢ *TMS Calculation*

Recall,

$$t = \frac{\alpha \times TMS}{(PSM)^{\beta} - 1} \quad (4)$$

Making TMS the subject of formula,

$$TMS = \frac{t \times [(PSM)^{\beta} - 1]}{\alpha} \quad (5)$$

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV915

Table 5 TMS Calculated Values

Relays	t(secs)	PSM	β	α	TSM
Relay1 & Relay1-1	0.551	7.31	0.02	0.14	0.16
Relay2 & Relay2-1	0.483	7.307	0.02	0.14	0.14
Relay3	0.28	18.268	0.02	0.14	0.12
Relay3-1	0.28	18.268	0.02	0.14	0.12
Relay3-2	0.28	18.268	0.02	0.14	0.12
Relay3-3	0.28	18.268	0.02	0.14	0.12

The pickup and TMS (Time Dial) values for the respective relays are inputted into the relay property dialogue box on ETAP. After the insertion of bolted fault various buses on ETAP the following relay sequence of operation were observed as shown in figures 6-11.

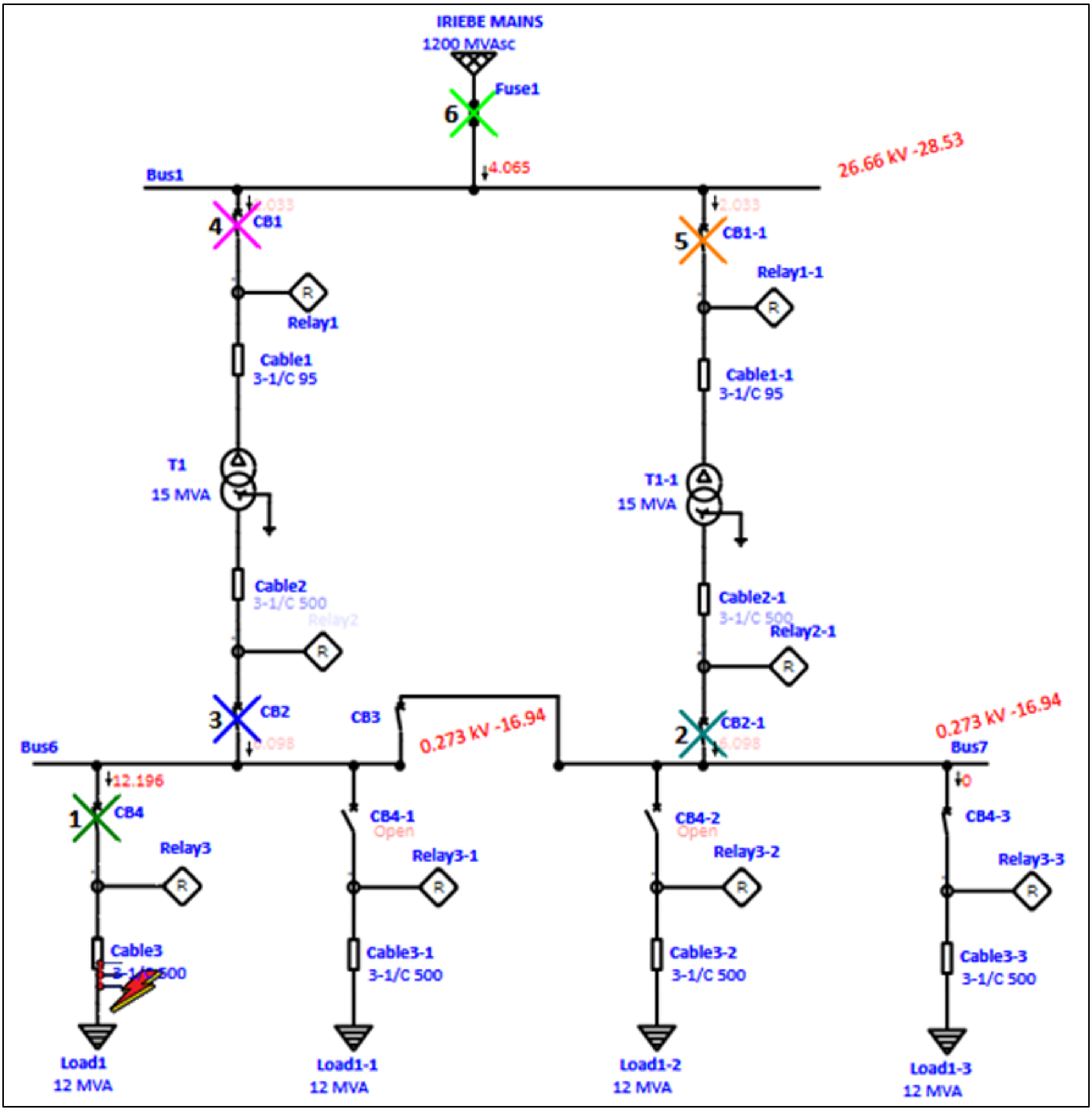

Fig 6 Relay Sequence of Operation with fault insertion on Load 1 (12MVA) after inputting Calculated Pickup and TMS values

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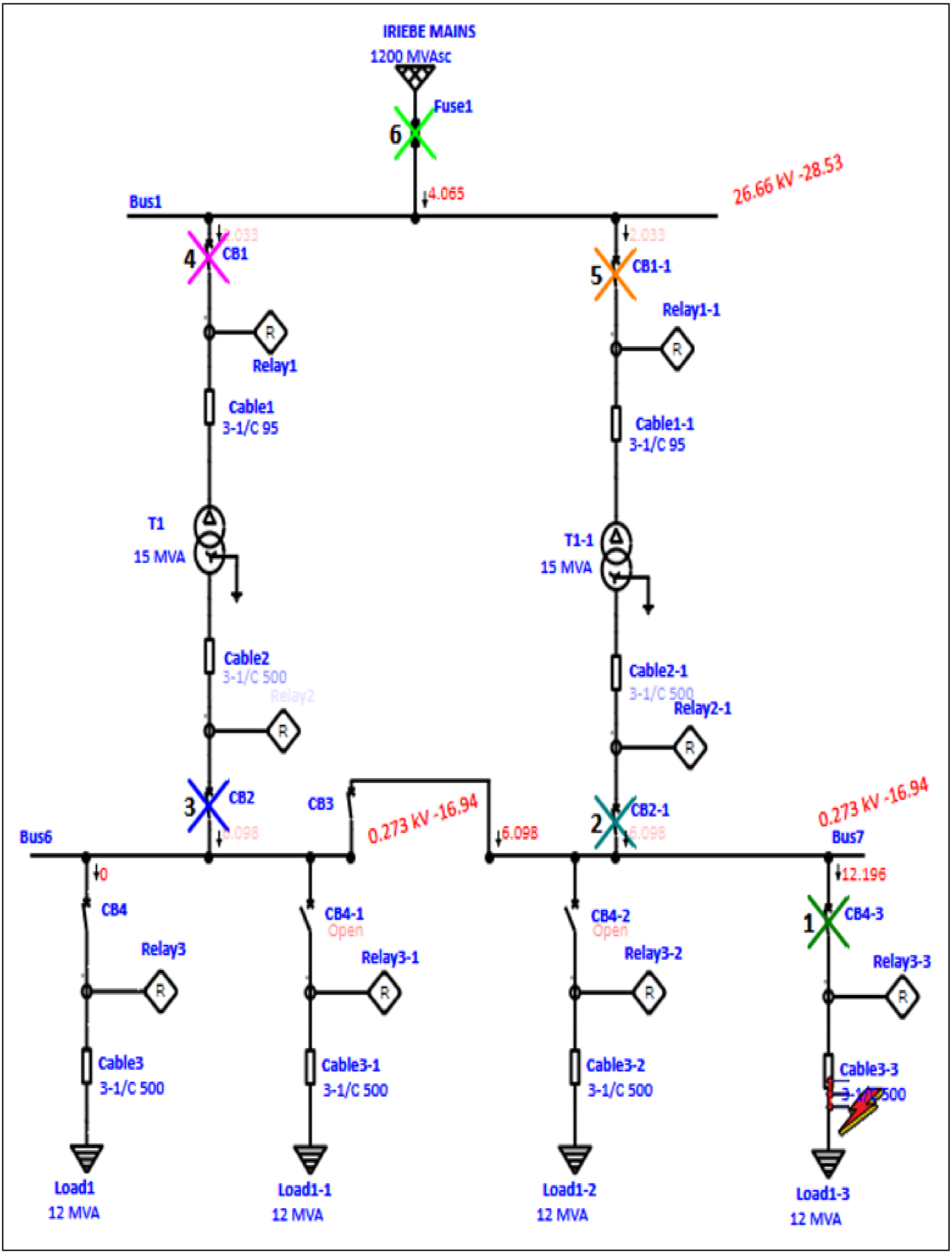

Fig 7 Relay Sequence of Operation with fault insertion on Load1-3 (12MVA) after inputting calculated Pickup and TMS values

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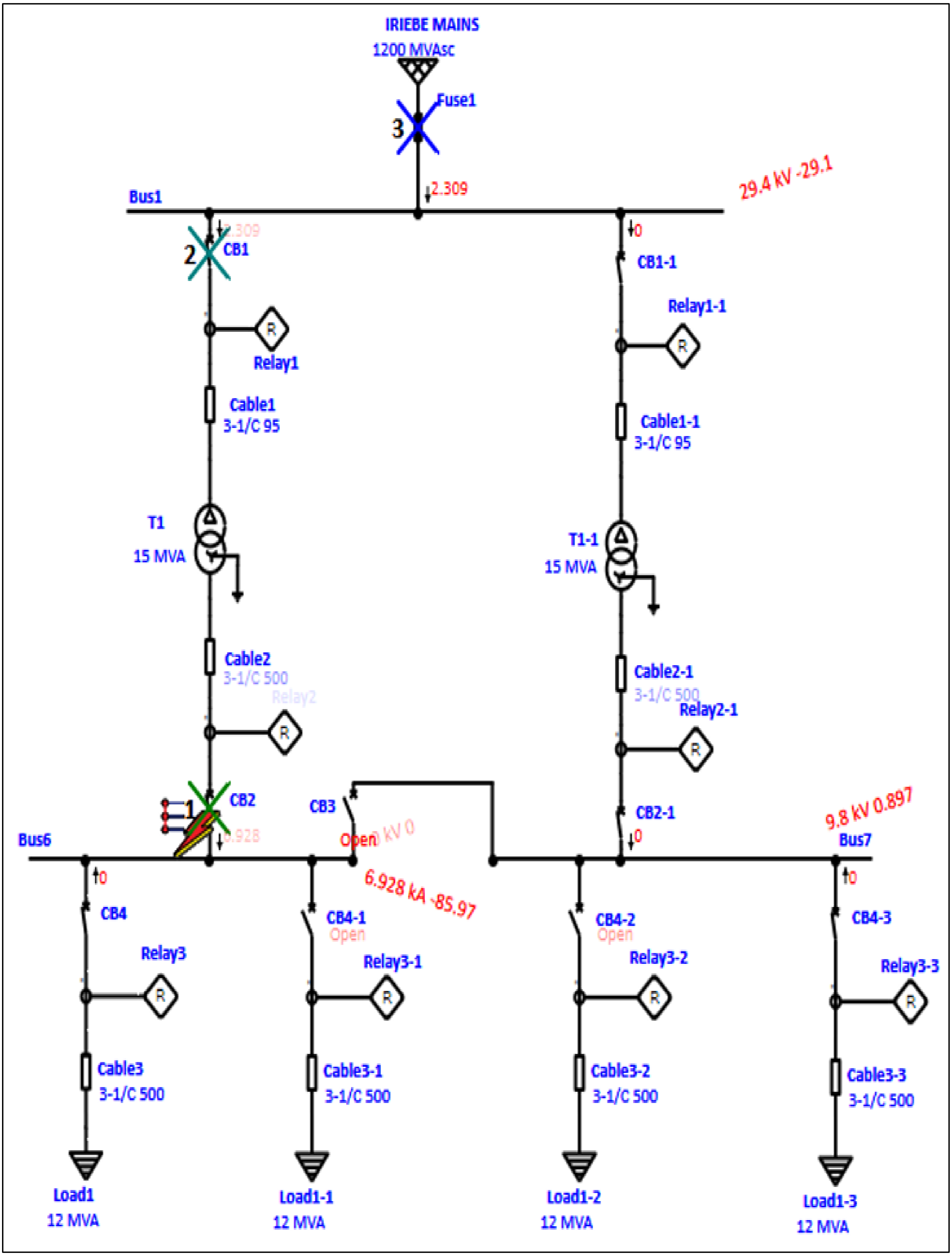

Fig 8 Relay Sequence of Operation with fault insertion on Bus6 after inputting Calculated Pickup and TMS values

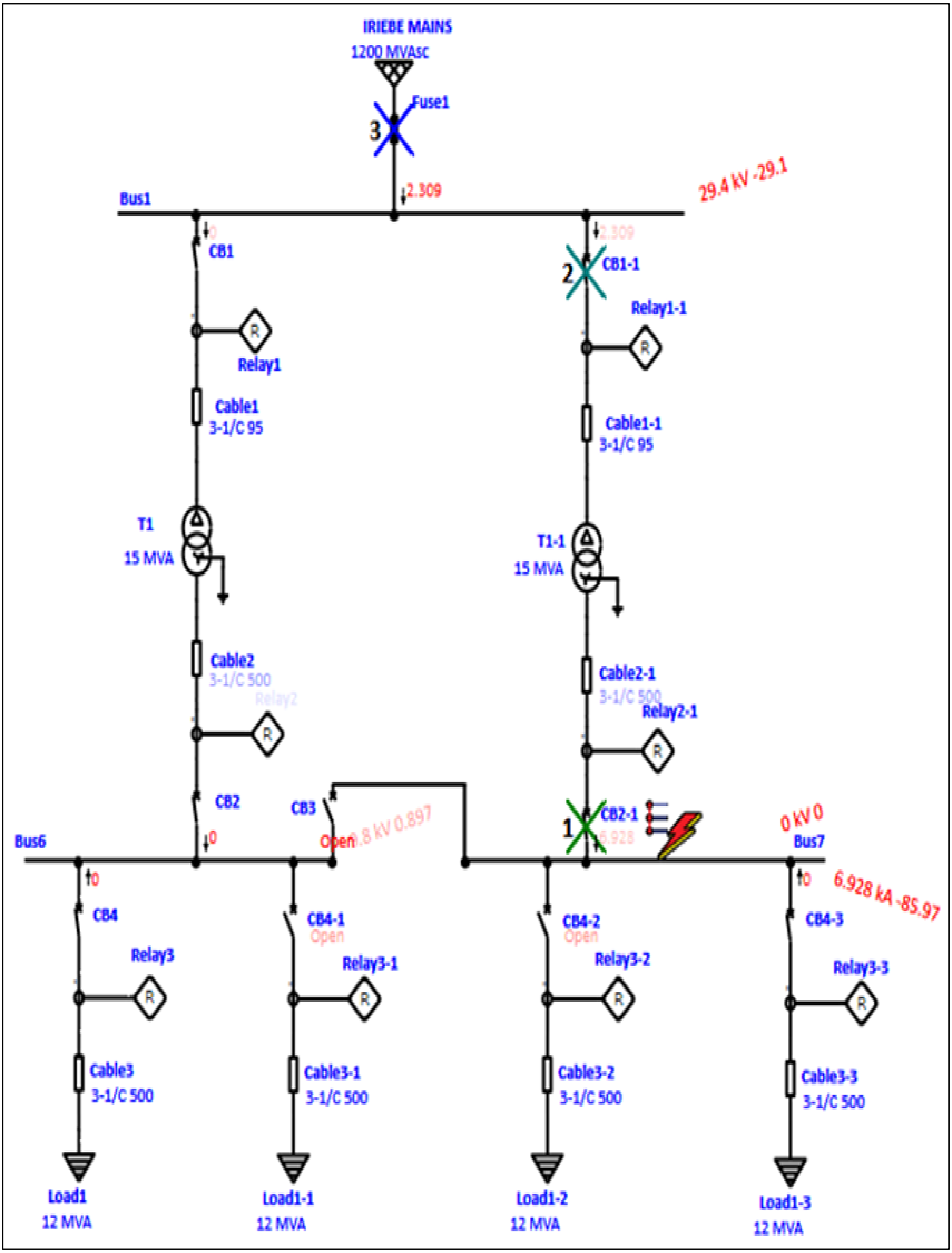

Fig 9 Relay Sequence of Operation with fault insertion on Bus7 after inputting Calculated Pickup and TMS values

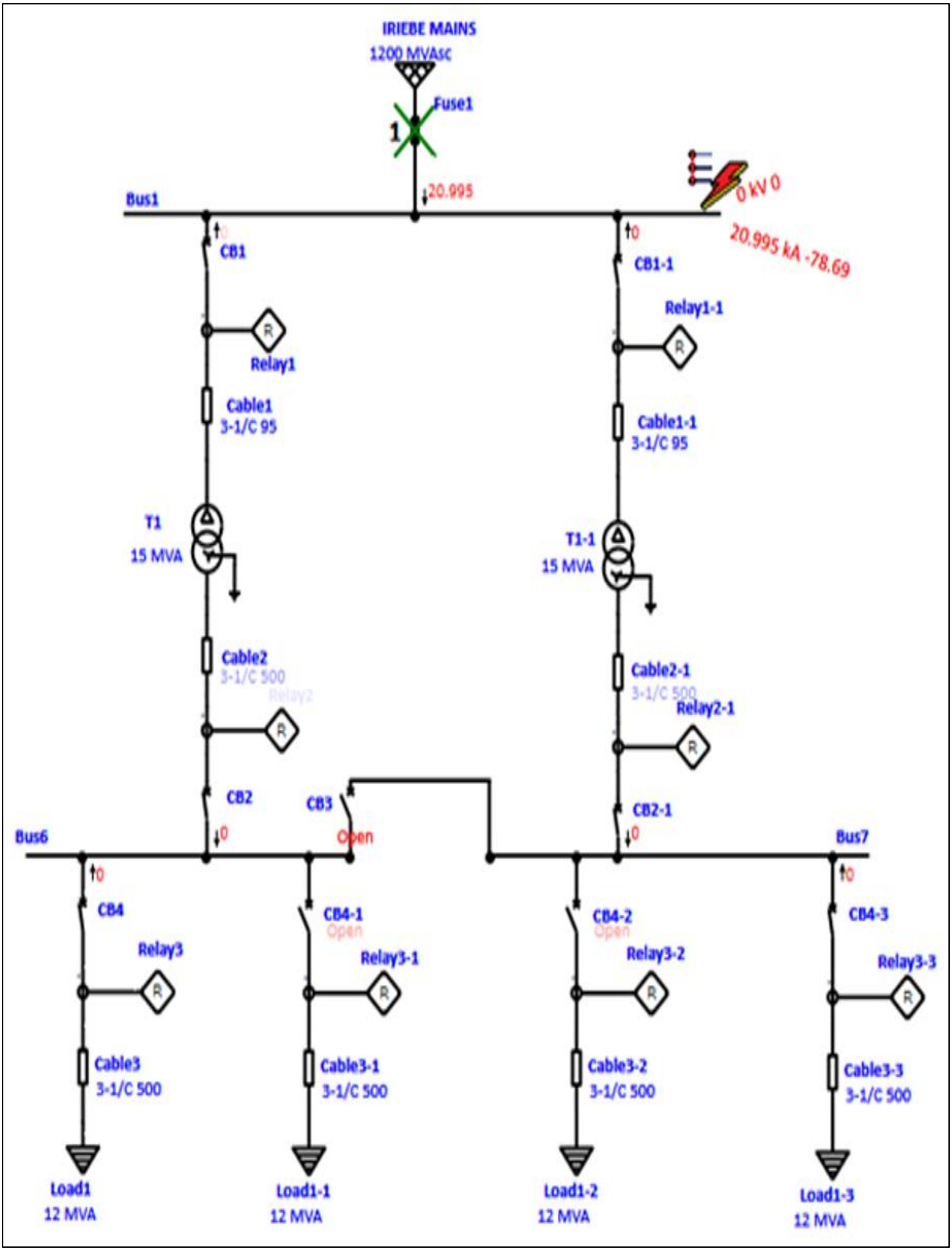

Fig 10 Relay Sequence of Operation with fault insertion on Bus1 after inputting Calculated Pickup and TMS values

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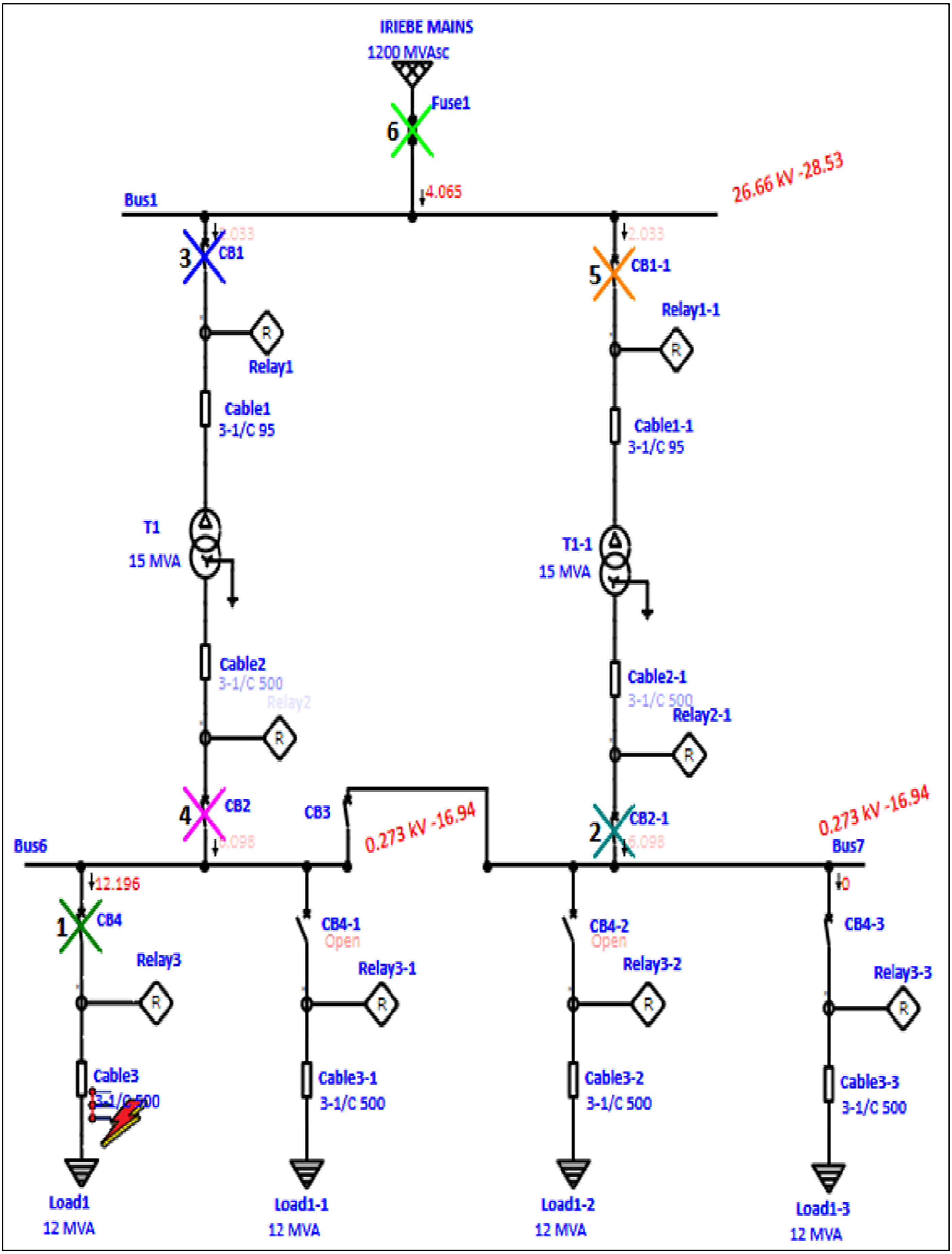


Fig 11 Relay Sequence of Operation with fault insertion on Load 1 before inputting Calculated Pickup and TMS values

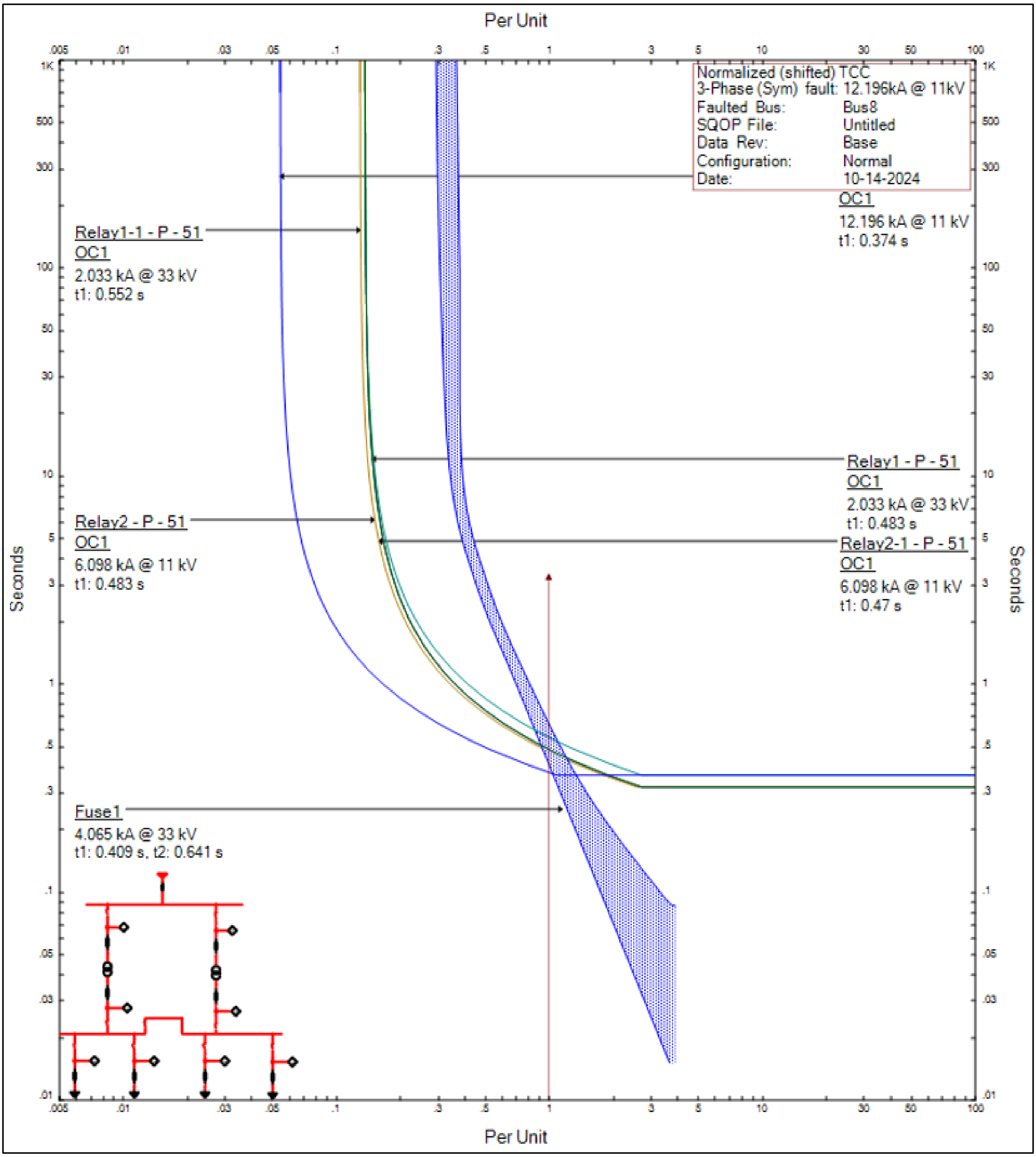
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV915

➢ *Time Current Characteristics (TCC) Curve Fitting*

Since the relay sequence of operation is coordinated after inputting calculated pickup and TMS values, a star view is created showing a graph containing the characteristic curve of several relays in the network. The shifting or adjustment of these relay curves in order to change the Pickup or TMS values to ensure proper coordination of the relays is known as TCC curve fitting.

From Fig 11 it is seen that Relay Sequence of Operation with fault insertion on Load 1 before inputting Calculated Pickup and TMS values are mis coordinated. In a properly coordinated system the sequence of operation of the relays should be relays above the point of fault.

From Fig 6-10 the relay curve of relay1, 1-1, 2, 2-1, 3, 3-1, 3-2 and relay3-3 are seen to have been adjusted and are properly coordinated.



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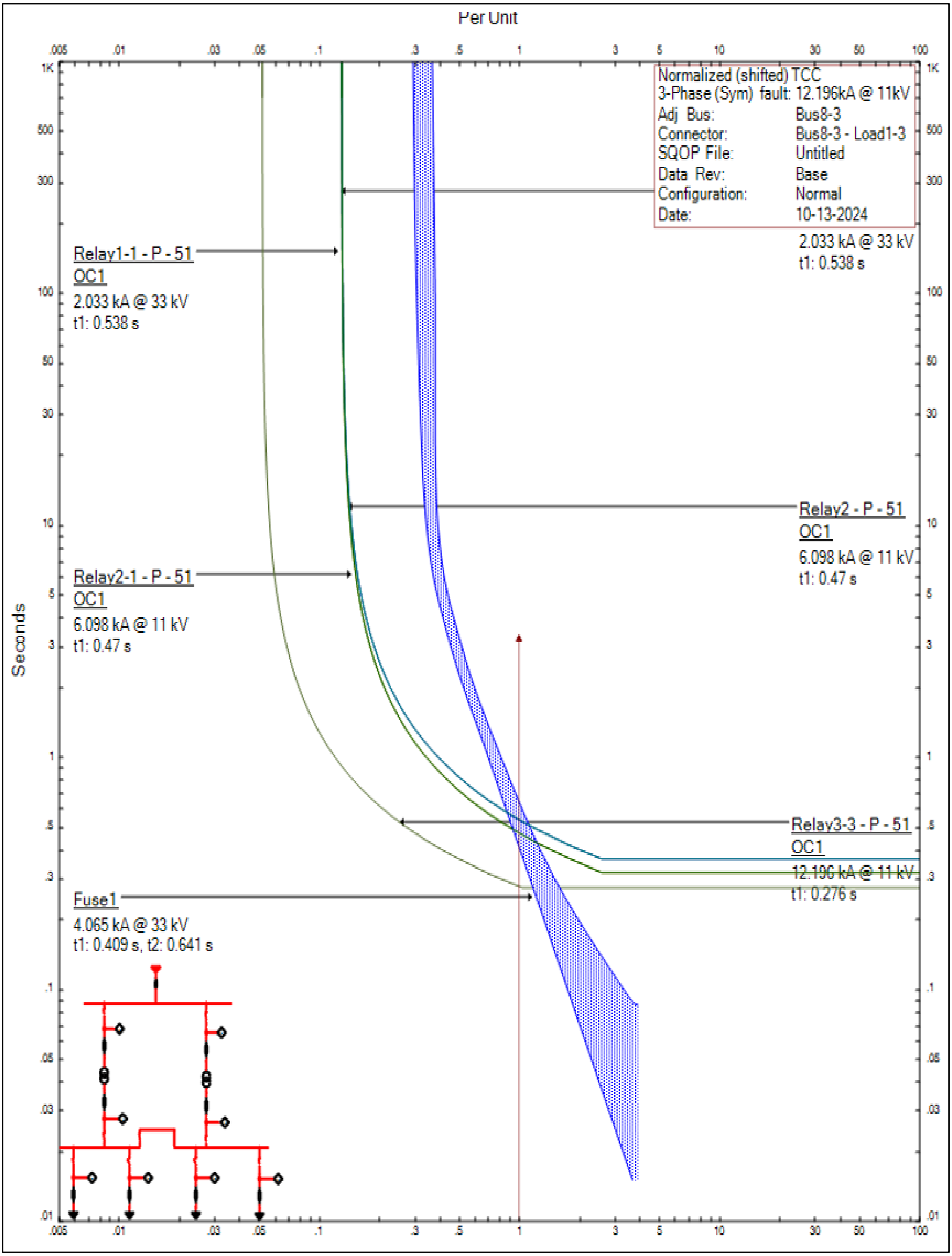


Fig 12 TCC Curve with fault insertion on Bus4 before TCC Curve fitting (Left) and after TCC Curve fitting (Right)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV915

III. RESULTS AND DISCUSSION

Fig 6-11 shows that the relays are properly coordinated for fault insertion on Load1 to Load1-3 and Bus6, 7 & 1 respectively after inputting the calculated values for pickup and TMS while Fig 11 for fault insertion on Load 1 before inputting Calculated Pickup and TMS values are not properly coordinated before inputting calculated pickup and TMS values. Hence the need for TCC curve fitting to ensure proper coordination of relays irrespective of the fault location.

After the TCC curve fitting is done as shown on Fig 12 proper operation of relays for fault in all location in the 33KV injection substation network as shown in Fig 6-10.

➤ *Fault Insertion on Load1 (12MVA)*

Though the relay coordination for fault insertion on Load1 shown in Figure 6 is excellent, a critical look at the sequence of operation is still necessary. All the relays protecting the Chiller trip first between 281msec to 351msec. Followed by Relay2-1 which tripped at 470msec. Next, Relay-2 and Relay-1 trips with a trip time of 483msec and 552msec respectively. The sequence of operation is correct and the time margin between the relays are satisfactory.

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on bus: Bus8

Data Rev.: Base Config: Normal Date: 10-14-2024

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
281	Relay3	12.196	281		Phase - OC1 - 51
351	CB4		70.0		Tripped by Relay3 Phase - OC1 - 51
470	Relay2-1	6.098	470		Phase - OC1 - 51
483	Relay2	6.098	483		Phase - OC1 - 51
540	CB2-1		70.0		Tripped by Relay2-1 Phase - OC1 - 51
552	Relay1	2.033	552		Phase - OC1 - 51
552	Relay1-1	2.033	552		Phase - OC1 - 51
553	CB2		70.0		Tripped by Relay2 Phase - OC1 - 51
617	CB1		65.0		Tripped by Relay1 Phase - OC1 - 51
617	CB1-1		65.0		Tripped by Relay1-1 Phase - OC1 - 51
641	Fuse1	4.065	409	641	

Plate 2 Sequence of Operation with fault on Load1

➤ *Fault Insertion on Load1-3*

Similarly for fault insertion on Load1-3 the relay sequence of operation shown in Fig 7 are proper. A closer look at the sequence of operation between them shown in plate 3 shows that Relay3-3 which is connected directly to Load1-3 trips at 281msec. The trip time interval between relay3-3 and relay2-1 is 189msec. Same goes for relay-2 and relay-1 the trip time interval between them is as low as 69msec.

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on bus: Bus8-3

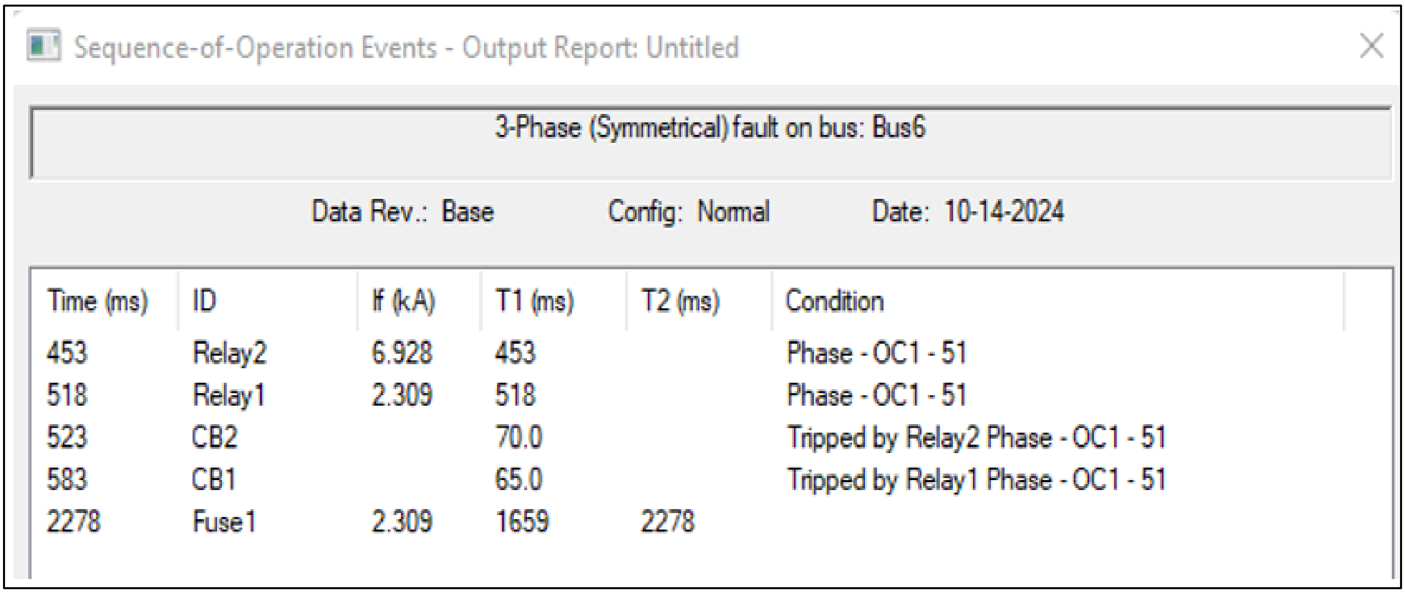
Data Rev.: Base Config: Normal Date: 10-14-2024

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
281	Relay3-3	12.196	281		Phase - OC1 - 51
351	CB4-3		70.0		Tripped by Relay3-3 Phase - OC1 - 51
470	Relay2-1	6.098	470		Phase - OC1 - 51
483	Relay2	6.098	483		Phase - OC1 - 51
540	CB2-1		70.0		Tripped by Relay2-1 Phase - OC1 - 51
552	Relay1	2.033	552		Phase - OC1 - 51
552	Relay1-1	2.033	552		Phase - OC1 - 51
553	CB2		70.0		Tripped by Relay2 Phase - OC1 - 51
617	CB1		65.0		Tripped by Relay1 Phase - OC1 - 51
617	CB1-1		65.0		Tripped by Relay1-1 Phase - OC1 - 51
641	Fuse1	4.065	409	641	

Plate 3 Sequence of Operation with fault on Load1-3

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV915

For fault insertion on BUS6, BUS7 and BUS1 as shown in Fig 8-10, the relay sequence of operation is well coordinated and their sequence of operation are shown in the figures below.

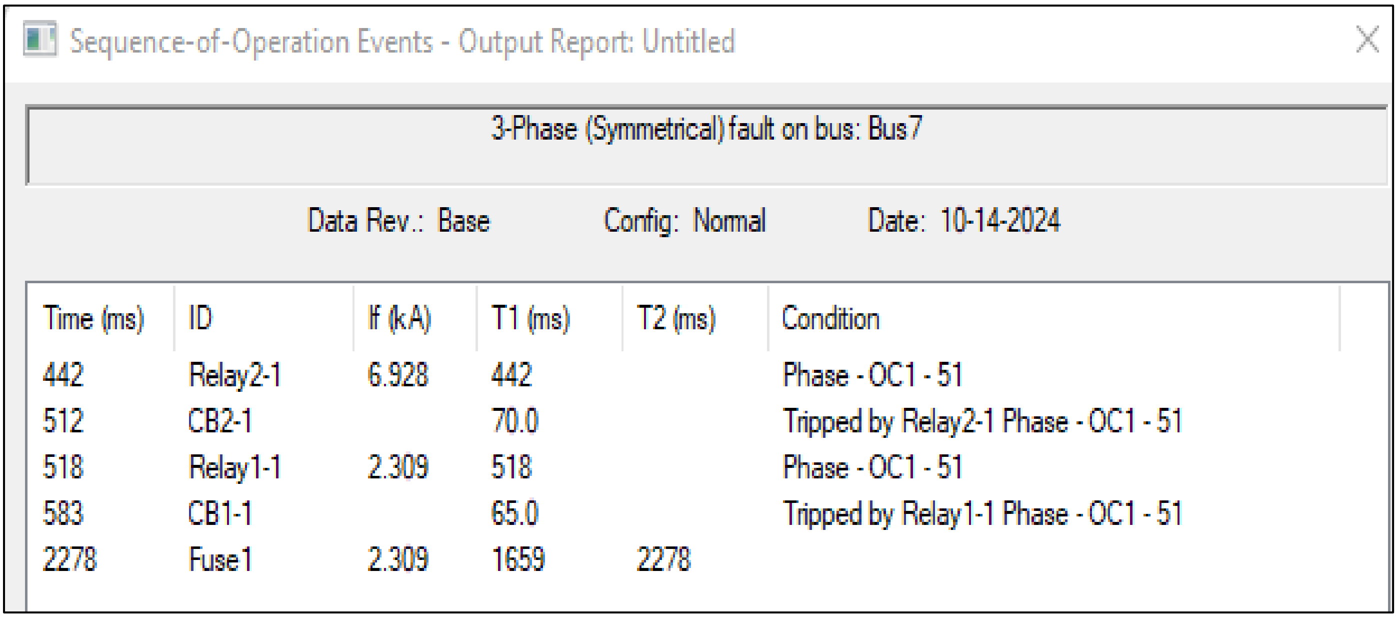

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on bus: Bus6

Data Rev.: Base Config: Normal Date: 10-14-2024

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
453	Relay2	6.928	453		Phase - OC1 - 51
518	Relay1	2.309	518		Phase - OC1 - 51
523	CB2		70.0		Tripped by Relay2 Phase - OC1 - 51
583	CB1		65.0		Tripped by Relay1 Phase - OC1 - 51
2278	Fuse1	2.309	1659	2278	

Plate 4 Sequence of Operation with fault on BUS6

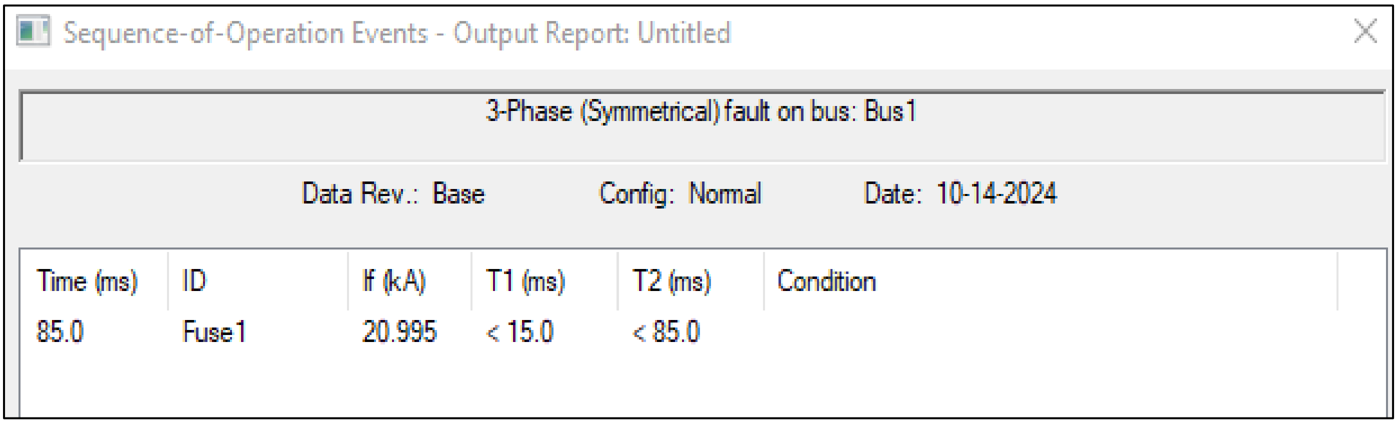

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on bus: Bus7

Data Rev.: Base Config: Normal Date: 10-14-2024

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
442	Relay2-1	6.928	442		Phase - OC1 - 51
512	CB2-1		70.0		Tripped by Relay2-1 Phase - OC1 - 51
518	Relay1-1	2.309	518		Phase - OC1 - 51
583	CB1-1		65.0		Tripped by Relay1-1 Phase - OC1 - 51
2278	Fuse1	2.309	1659	2278	

Plate 5 Sequence of Operation with fault on BUS7


Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on bus: Bus1

Data Rev.: Base Config: Normal Date: 10-14-2024

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
85.0	Fuse1	20.995	< 15.0	< 85.0	

Plate 6 Sequence of Operation with fault on BUS1

Table 6 All Relay data and settings

Designated Bus	Relay ID	Manufacturer & Model	PT / CT Ratio	Settings Group	Device Function	Trip Element	Level /Stage	Base Current Settin	Curve	OCR (51, 51V), OLR (49, Acc.)			OCR (50), OLR (50, Jam)		
										Pickup	Prim. Amps	Time Delay	Pickup	Prim. Amps	Time Delay
Bus1	Relay1	Schneider Electric Sepam Series 10	400:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.695	278.000	0.160			
Bus1	Relay1	Schneider Electric Sepam Series 10	400:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.160	0.020	0.050	20.00	0.05 s
Bus6	Relay2	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.695	834.000	0.140			
Bus6	Relay2	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.480	0.020	0.050	60.00	0.05 s
Bus6	Relay3	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.556	667.200	0.120			
Bus6	Relay3	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.480	0.020	0.050	60.00	0.05 s
Bus1	Relay1-1	Schneider Electric Sepam Series 10	400:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.695	278.000	0.160			
Bus1	Relay1-1	Schneider Electric Sepam Series 10	400:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.160	0.020	0.050	20.00	0.05 s
Bus7	Relay2-1	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.660	792.000	0.140			
Bus7	Relay2-1	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.480	0.020	0.050	60.00	0.05 s
Bus6	Relay3-1	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.556	667.200	0.120			
Bus6	Relay3-1	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.480	0.020	0.050	60.00	0.05 s
Bus7	Relay3-2	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.556	667.200	0.120			
Bus7	Relay3-2	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.480	0.020	0.050	60.00	0.05 s
Bus7	Relay3-3	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Phase	OC1		IEC Standard Inverse Time SIT/A	0.556	667.200	0.120			
Bus7	Relay3-3	Schneider Electric Sepam Series 10	1200:1		Overcurrent	Ground	OC1		IEC Extremly Inverse Time EIT/C	0.000	0.480	0.020	0.050	60.00	0.05 s

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In Table 4 device model, settings and CTs ratios for all the relays are shown.

IV. CONCLUSION

In the event of fault occurrence in the 33KV Iriebe substation Network, irrespective of the fault location protection of the network has been assured through fault analysis and protection coordination study.

The 33kV network has been protected through the selection of appropriate CT size, calculation of pickup and TMS values and TCC curve fitting. They are various relay curve but the IEC standard Inverse curve was used in this project. From the result obtained it is seen that in some cases, the use of calculated pickup and TMS values may not guarantee a perfect relay coordination hence, the reliance on TCC Curve fitting. Even in cases where the relays are already operating sequentially TCC curve fitting can improve the effectiveness of the relays by reducing the trip time intervals between relays ensuring not just sequential but timely interruption of fault current.

RECOMMENDATIONS

➢ *The Following are my Recommendations;*

- It is necessary to conduct a comprehensive load flow study to understand the power flow within the system under normal and fault conditions. This provides a basis for setting relays and identifying potential weak points.
- The rules for TCC Curve fitting might not be very clear hence, professional and highly skilled personnel are required to perform this task.
- Set the TCC of the upstream and downstream relays such that the nearest relay to the fault operates first while the upstream relays only operate if the downstream relays fail.

Relays in the 33kV Network can still be coordinated without changing calculated Pickup values to avoid nuisance tripping.

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