Study Coordination Design of Over Current Relay on The Kiln Area Electrical System

Raihan Putri[1], **Endri Juliadi**[1✉], **Misbahul Jannah**[1], **D. R. Ramji**[2], **Waleed Khalid Ahmed Al-Ani**[3,4]

[1] Departement of Electrical Engineering, Malikussaleh University, Bukit Indah, Lhokseumawe, 24351, Indonesia.

[2] Holy Mary Institute of Technology and Science, Hyderabad, India

[3] School of Computer and communication Engineering, Universiti Malaysia Perlis, Khangar, Malaysia

[4] Ministry on Industry and Minerals the State Company for Glass & Refractories, Republic of Iraq

raihan@unimal.ac.id; endrijuliadi21@gmail.com; mjannah@unimal.ac.id; ramji.dr@hmgi.ac.in; waleedkh1971@gmail.com

✉Corresponding Author: **endrijuliadi21@gmail.com** | Phone: **+6282382341432**

Abstract

PT. Semen Padang is one of the largest cement producers in western Indonesia, along with the development of the cement industry PT. Semen Padang added a new Indarung VI factory to support the production process to meet market demand. With the addition of this new factory, a good safety design is needed in the design of the electrical system so that production continuity is not disturbed and reliability values are high. Therefore, over-current protection coordination studies are needed on the electrical system of the kiln area at Trafo 2 Indarung VI PT. Semen Padang to get a safe and reliable system. In the final task, this time will be done modeling, simulation of load flow and short circuit, calculation of relay settings, and simulation of coordination of overcurrent protection phase interference in the electrical system kiln area in Transformer 2 Factory Indarung VI PT. Semen Padang. The plot results of the coordination of the time flow curve obtained through the results of analysis and manual calculations recommended tuning pick-up overcurrent relayand grading time overcurrent relaytuning phase interference. Grading time between overcurrent relay is coordinated by 0.2 seconds. With the protection coordination setting, the electrical system of the kiln area at the Indarung VI factory PT. Semen Padang is safer and more reliable.

Keywords: interference; coordination of protection; overcurrent relayphase disorders;

Introduction

PT. Semen Padang is a member of PT Semen Indonesia located in Padang, West Sumatra. PT. Semen Padang is a company that provides cement products to the community. National cement demand, which increases by 6 percent annually, has encouraged the company to build a new Indarung VI plant with a cement capacity of 3 million tons per year with a total load of 30 MW. Previously PT. Semen Padang already has a factory with a total load of 60 MW resulting in a production capacity of 6.9 million tons per year, which has been connected to the PLN grid system (Anon n.d.).

Equipment in the cement industry generally has electrical capacity according to their respective ratings. This requires good protection planning so that the tool is not contaminated with interference is not under the rating and can damage the equipment. Security and reliability in electrical systems is a need that must be met in the industrial field to maintain the continuity and safety of workers and other equipment. To get a reliable electrical system, a protection system is also needed that is also reliable in handling interference. Disruptions to the electrical power system vary greatly in type and nature. If the disorder that occurs is permanent, then the equipment affected by the disorder must be repaired or replaced first. Meanwhile, if the disruption is temporary, then the equipment affected by the disruption is ready to be operated again after CB (Circuit Breaker) decides on the disruption. These disturbances can interfere with the continuity of the distribution of electric power. To isolate the part that is experiencing interference and minimize the damage, it is necessary to coordinate good protection. Protection coordination is the selection or regulation of safety equipment that aims to obtain high selectivity in localizing disturbances that occur so as not to expand so that the continuity of the system is maintained (IEEE Std 242 2001).

The design of the new factory Indarung VI, then a study is needed for the setting and coordination of protection in the new plant. In this final task will be carried out calculations and simulations of coordination of overcurrent relay protection on the electrical system in the kiln area of the Indarung VI PT plant. Semen Padang so that it gets a reliable protection system, working fast, sensitive and selective in securing the industrial electrical system.

Literature Review
Protection System

System protection in electric power systems aims to secure equipment and electrical systems thoroughly from damage due to current interference. When there is a disruption to the electrical system, the protection relay must be able to isolate the current of interference by operating a power breaker (Circuit Breaker) so that damage to the equipment can

be prevented and continuity of service/supply of electric power can be maintained properly (IEEE Std 242 2001).

The reliability of an electrical safety system in a company is very vital, especially if the company has implemented interconnection to its electrical system. This is because the electrical system in a company is very vulnerable to interference. These disorders come from inside or outside the system. The disturbance can be temporary or a permanent disorder. A temporary disorder is a disorder that occurs in a short time and then the system can work normally again. While the permanent disorder is a disorder that occurs for a long time (permanent). The electric power protection system works by disconnecting and isolating the area of the system affected by the disruption so that other areas of the system that are still healthy are not affected by interference so that the continuity of electricity distribution is maintained, and the system that is still healthy can still operate. To increase the reliability of the protection system, proper coordination is needed between relay protection with another protection relay by considering Coordination Time intervals (Mahindhara, Pujiantara, and Priyadi 2015).

Causes of Disruption to the Electrical Power System

Reference (IEEE Std 242 2001) mentions that in a 3 phase electric power system, disturbances that can cause overcurrent that can occur include overload and short circuit.

Over Load Disruption

The overload is likely to occur because the current flowing in the electric power system is greater than the capacity of the electrical equipment itself and protection equipment. The current that occurs exceeds nominal. This overload disorder does not include pure interference, but if not secured it can damage the equipment if exposed. Things like this can be prevented, namely doing the selection of equipment used, adjusted to the electricity supply that is flowed to a system (Tjahjono *et al.* 2017).

Short Circuit Disruption

According to IEC 60909-0, a short circuit is a conductive path either intentionally or unintentionally between two or more conductors that forces the difference in electrical potential between the conductive parts must be equal or close to zero (ISO 527-2 2003).

Short Circuit Flow Calculation

The calculation of short circuit flows depends on the type of short circuit disorder that occurs. There are several types of short circuits, namely short circuit disruption 3 phases, short circuits between phases, short circuits two phases to the ground, and short circuits one phase to the ground (Ninla Elmawati Falabiba 2019) (B. de Metz-Noblat, Dumas, and Poulain 2011).

Safety Relay

Relay is part of the electrical power system equipment used to signal circuit breaker, to disconnect and connect the distribution service to the electrical power system element. This relay will signal to the circuit breaker to disconnect the electric power system in case of interference. Relay protection consists of an operating element and a set of contacts. The operating element receives current input from the current transformer or voltage from the voltage transformer or a combination of the two (Setiawati, Margo Pujiantara and P T.Petrokimia 2016).

Overcurrent Relay

An overcurrent relay is a relay used to detect more load interference overload or short circuits. In an electric power system, a safety system is needed that can reduce and anticipate the occurrence of a disturbance. One safety relay that can be used to secure the system from short circuit interference is the overcurrent relay. This overcurrent relay will work alongside a CT *(current transformer)*. This overcurrent relay operates when there is currently flowing on the circuit exceeding the allowed setting limit. The use of overcurrent relay in industrial electrical systems must be adjusted based on the coordination of relay that has been set correctly. So when in the system there is a relay disorder this can work quickly. Overcurrent relaywill work when fulfilling the following conditions:

$$If > Ip \qquad \text{relay work} \qquad (trip)$$
$$If < Ip \qquad \text{not working} \qquad (block)$$

Where IP is a working current or pick-up current, expressed according to the secondary roll of the current transformer (CT) connected to the relay. And If is a nuisance current flowing on the primary side of CT, which is then converted to a secondary roll of CT to be compared to I pick up. Overcurrent relay is used to secure equipment parts of the electric power system, such as generators, utilities, transformers, motors, etc (Sinaga 2016) (Industri 2016).

Coordination of time on analog overcurrent relay based on IEEE 242 for the minimum time difference between 0.3 to 0.4 seconds, while for microprocessor-based digital overcurrent relay between 0.2 to 0.3 seconds (IEEE Std 242 2001).

Overcurrent Relay Settings

Overcurrent relay has a function as a short circuit interference safety, but in some ways, this overcurrent relay can serve as overload safety. The function of this overcurrent relay in addition to being the main safety to protect the secured part also serves as a backup safety in the next section. This is when the overcurrent is used in the medium voltage distribution system. But on high voltage transmission lines, the overcurrent relay is functional as a backup, where the

distance relayis the main safety (Sinaga 2016). The overcurrent relay setting has differences according to the type of overcurrent relay used.

Inverse Time Overcurrent Relay Settings

Overcurrent Relayinverse time is set so that the relay does not work when the loading conditions are maximum and works when the current flowing to the equipment exceeds the maximum current of the equipment. In other words, overcurrent relayinverse time works to protect equipment and systems from overload interference. Therefore, in this relay setting the current setting must be greater than the maximum load current (Full Load Ampere / FLA).

Overcurrent relaytime inverses have pick-up settings and time dials. The pick up current setting on the overcurrent relay is determined by the selection of taps, shown in the following equations:

$$Tap = \frac{Iset}{CT\ primary} \tag{1}$$

An Iset is the pickup current specified in the Ampere. According to standard BS 142, the limit of determination of I set is as follows:

$$1.05\ FLA < Iset < 1.4\ FLA \tag{2}$$

The time dial setting will determine the operating time of the inverse time relay. The determination of the time dial of each curve characteristics the overcurrent relay the inverse time is done by first determining the required operating time. According to IEC 60255-3 and British Standard 142, the time dial value can be determined using the following equations:

$$td = \frac{k \times T}{\beta \times \left[\left(\frac{I}{Iset} \right)^{\alpha} - 1 \right]} \tag{3}$$

Where:
- td = Operating time (seconds)
- T = time dial
- I = current value (Ampere)
- Iset = pickup current (Ampere)
- k = inverse coefficient 1 (see Table 2.2)
- α = inverse coefficient 2 (see Table 2.2)
- β = inverse coefficient 3 (see Table 2.2)

Table 1. IEC Standard Inverse Relay Curve Coefficient (ISO 527-2 2003)

Curve Type	Coefficient		
	k	α	β
Standard Inverse	0,14	0,02	2,970
Very Inverse	13,50	1,00	1,500
Extremely Inverse	80,00	2,00	0,808

The coefficient of the curve may differ depending on the relay model used. for example, for an Alstom p120 relay, with the same TDS formula, the coefficient of β is worth 1 for each type of curve (Electric n.d.).

In the IEEE standard std 242-2001, there are several characteristics of the inverse curve, namely long time inverse, very inverse, short time inverse, and extreme inverse. For the use of curves the characteristics can also be combined with the overcurrent relay instant time described in the following image.
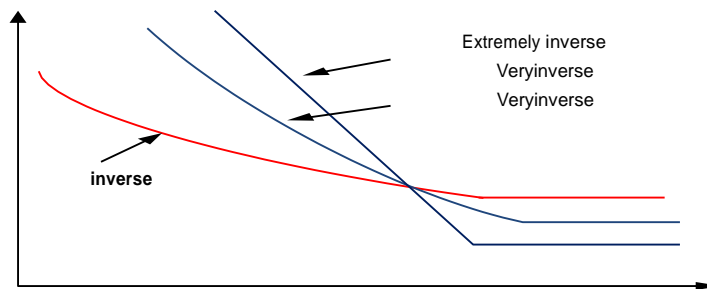

Figure 1. Characteristics of standard inverse, very inverse, and extremely inverse (IEEE Std 242 2001)

Instant Overcurrent Relay Settings

Instant overcurrent relay is set to work in an instant or a certain time when the flowing current exceeds the pickup current. Instant time overcurrent relay is usually used to protect equipment or systems from short circuit overcurrent interference. In determining this instant pickup setting is used minimum circuit current (Isc min) which is a short circuit

current of 2 phases at minimum generation. The pickup settings on this relay are set as:

1,6 FLA <Iset< 0.8 Isc min (4)

The following are the characteristics of overcurrent relayinstant time, seen in **Figure 2.**
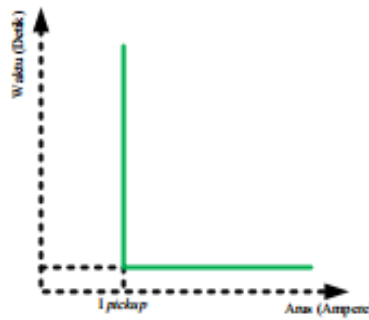

Figure 2. Characteristics of overcurrentrelayInstant Time (Brand and De Mesmaeker 2013)

Coordination of Rele By Flow and Time

In the use of a safety relay, there must be good coordination. Good coordination is the main safety relay and backup safety relay should not work simultaneously. Therefore, there is a need to set a delay time between the main relay and the backup relay. This time delay setting is commonly called the lag time setting (Δt) or grading time. According to the IEEE 242 (IEEE Std 242 2001) standard, the grading time difference setting is 0.2 – 0.35 seconds. With the following specifications:

Opening time CB : 0.04 – 0.1s (2-5 cycle)
Overtravel of rele : 0.1s
Safety factors : 0.12-0.22s

For microprocessor-based relay Overtravel time from the relay is ignored. So the total time needed is 0.2-0.4s.

Electric Transient Analysis Program 12.6.0 (ETAP 12.6.0)

ETAP 12.6.0 (Electric Transient Analysis Program 12.6.0) is software used by an electric power system. This device can work offline i.e. for electric power simulation, and also in an online state for real-time data management.

Materials &Methods

In this study,several stages or steps will be done, namely literature study, data collection, single line diagram modeling, load flow analysis simulation, short circuit analysis simulation, relay setting calculation, simulation of protection relay coordination, analysis of the results of simulation of coordination of protection relay and conclusions.

The necessary data are transformer data, cable data, and single line diagrams in the kiln area of Indarung VI Factory PT. Semen Padang.

Electrical System in Kiln Area of Indarung Factory VI PT. Semen Padang has a total load of 30 MW and a power transformer capacity of 30 MVA supplied by PLN with a voltage of 150 kV. The distribution system used in this design is a radial distribution system with different distribution voltage levels. The MVA has a short PLN feeder of 2259.22 MVAsc. From a voltage of 150 kV is powered by a step-down transformer to a medium voltage of 6.3 kV. This medium voltage will be lowered by a step-down transformer to a low voltage of 0.4 kV. Cable data can be seen in table 2, transformer data in tables 3 and 4, and its single line diagram in **Figure 3**.

Table 2. Cable Data

No.	Cable Cable ID	Library	Size	#Phase	Length Adj.(m)
1	Cable to SS 428	6,0NCUS3	240	3	300
2	Cable to SS 448	6,0NCUS3	240	1	500
3	Cable to SS 731	6,0NCUS3	240	3	400
4	Cable to SS 468	6,0NCUS3	240	1	500

Table 3. Transformer Data 2 Winding

No.	Trafo	Rating			Impedance	
	Trafo ID	MVA	Primary (kV)	Secondary (kV)	Z (%)	X/R Ratio
1	Trafo GI 2	30	150	6,3	11,7	45
2	Dist. Trafo Kiln Feed-1	2	6,3	0,4	11,7	6
3	Dist. Trafo Dust Transport-1	2	6,3	0,4	11,7	6
4	Distribusi Trafo Cooler	2	6,3	0,4	11,7	6
5	Distribusi Trafo CCR	2	6,3	0,4	11,7	6
6	Trafo Booster Fan	0,63	6,3	0,7	11,7	1,5
7	Distribusi Trafo Coalmill	1,6	6,3	0,4	11,7	6

Table 4. Transformer Data 3 Winding

| No.	Trafo	Rating				Impedance	
	Trafo ID	MVA	Primary (kV)	Secondary (kV)	Tersier (kV)	Z (%)	X/R Ratio
1	Trafo for VFD1	1,7	6,3	6,3	6,3	11,7	11,7
2	Trafo for VFD2	1,7	6,3	6,3	6,3	11,7	11,7
3	Trafo for VFD Undergrate	5,3	6,3	0,7	0,7	11,7	11,7
4	Trafo for VFD Kiln Drive	1,5	6,3	0,7	0,7	11,7	11,7
5	Trafo for VFD5	1,7	6,3	6,3	6,3	11,7	11,7
6	Trafo for VFD6	1,7	6,3	6,3	6,3	11,7	11,7
7	Trafo for VFD9	1,7	6,3	6,3	6,3	11,7	11,7
8	Trafo for VFD10	1,7	6,3	6,3	6,3	11,7	11,7
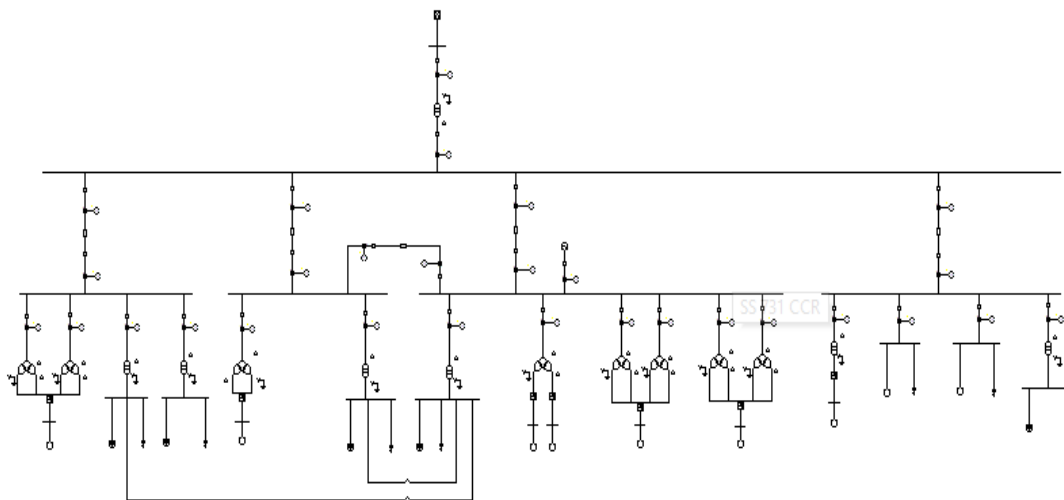
Figure 3. Single Line Diagram Of Electrical Systems In Kiln Area Of Indarung Factory VIPT. Semen Padang

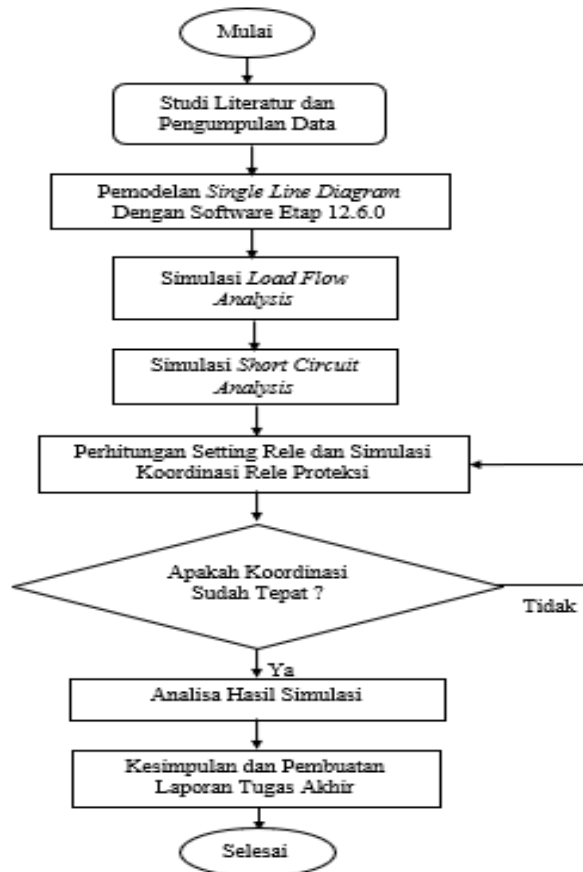The flow chart for this study is as follows:

Figure 4. Research Flow Diagram

Results and Discussion

Electrical System Modeling in Kiln Area of Indarung Factory VI PT. Semen Padang

Modeling of electrical systems in the Kiln area of Indarung Factory VI PT. Semen Padang is done by creating a single line diagram on ETAP 12.6 simulation software. In making a single line diagram, some equipment data is needed, namely cable data, transformers, PLN sources, and others.

The creation of the single line diagram can be known as the electrical system. After the modeling is completed then the next step is to perform a load flow analysis to find out the condition of the system has been in normal condition (steady-state), so that from the analysis can be known the voltage on the bus, transformer loading, bus loading, electrical power losses and power factors in each feeder. Here are the results of running load flow in ETAP 12.6.0 software.
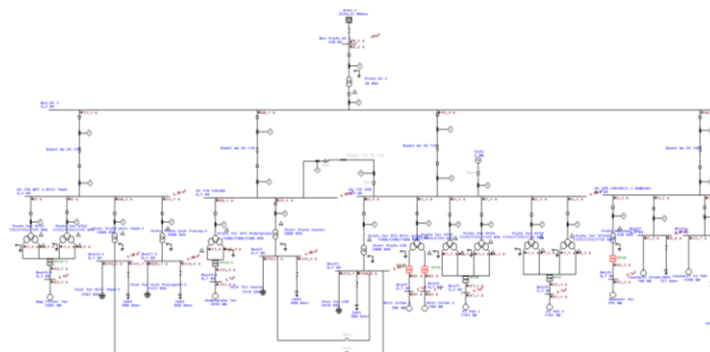

Figure 5. The results of running load flow of electrical systems in the Kiln area of Indarung Factory VI PT. Semen Padang

Typical Selection coordination of safety relay settings on electrical systems in the Kiln area of Indarung Factory VI PT. Semen Padang

To facilitate in setting relay coordination, it was selected some type that can represent coordination on the electrical system in the Kiln area of Indarung Factory VI PT. Semen Padang. This type will be a reference in the other relay coordination settings.

On the coordination of current safety over electrical systems in the Kiln area of Indarung Factory VI PT. Semen

Padang selected 4 typical that represent the entire electrical system that exists. Here are the typical coordination displayed in this final task, among others:

1) Coordination of current protection relay over phase interference than relay bag filter to relay primer Transformer GI 2. Coordinated relay is relay Bag Filter, relay incoming 428, relay 428 BHF & Kiln, relay incoming 6.3 kV, and relay primer Transformer GI 2. This is called typical 1.
2) Coordination of current protection relay over phase interference than relay undergrate cooler to relayprimary TransformerGI 2. Coordinated relay is relay undergrate fan cooler, relay incoming 448, relay 448 Cooler, relay incoming 6.3 kV, and relay primer Transformer GI 2. This is called typical 2.
3) Coordination of current protection relay over phase interference than relay kiln drive to relayprimaryTransformerGI 2. Coordinated relay is relay kiln drive, relay incoming 731, relay 731 CCR, relay incoming 6.3 kV, and relay primer Transformer GI 2. This is called typical 3.
4) Coordination of current protection relay over phase interference than relayCoalmill Distribution to relayprimaryTransformerGI 2. Coordinated relay is relayCoalmill Distribution, relay incoming 468, relay 468 Coalmill & Rawcoal, relay incoming 6.3 kV, and relay primer Transformer GI 2. This is called typical 4.

Short Circuit Disruption Flow Analysis

After conducting load flow analysis on the electrical system in the Kiln area of Indarung Factory VI PT. Semen Padang, then the next step is to perform a short circuit analysis using ETAP software as a basis to determine the setting of the overcurrent relay. There are two short hyphens used in the safety setting, namely the maximum short circuit current and the minimum short circuit current. The maximum short circuit is a short circuit of 3 phases at the time of 4 cycles and the minimum short circuit is a short circuit between phases (2 phases) at the time of 30 cycles.

Maximum Short Circuit 4 cycles

The maximum short circuit occurs during the electrical system in the Kiln area of Indarung Factory VI PT. Semen Padang works under normal circumstances. A maximum short circuit of 4 cycles is used for relay settings and lag settings of 0.08 - 0.5 s. The maximum short circuit is used as the largest possible short circuit current limit.

Short Circuit Minimum 30 cycles

Minimum Short Circuit occurs during the electrical system in the Kiln area of Indarung VI FACTORY PT. Semen Padang works under normal circumstances. This minimum short circuit of 30 cycles will be used as a limit of pickup current (setting) overcurrentrelaywith instant working time. Thus it is expected that if there is a short circuit disruption at the minimum disturbance current, the relay can work instantly or under the predetermined time delay setting.

To determine the relay setting required full load flow data, maximum interference, and minimum interference current. The results of the simulation of full load flow, a maximum short circuit of 4 cycles, and a minimum short circuit of 30 cycles can be seen in **Table 5.**

Table 5. Data from simulation of full load flow, minimum short circuit of 4 cycles, and minimum short circuit of 30 cycles

Main Feeder	SubFeeder	Isc. max 4 cycle(kA)	Isc. min30 cycles (kA)	FLA current (full load ampere)
SS 468, Coalmill & Rawcoal		22,47	18,23	428,20
Incoming 468		18,17	14,64	428,20
	Bus Coalmill Booster Fan (6,3 kV)	18,17	14,64	57,74
	Bus Coalmill drive (6,3 kV)	18,17	14,64	80,56
	Bus Coalmill ID FAN (6,3 kV)	18,17	14,64	143,3
	Bus TrafoDistribusi (6,3 kV)	18,17	14,64	146,6
SS 448, Cooler		22,47	18,23	669
Incoming 448		17,79	14,64	669
	Bus Undergrate Fan Cooler (6,3 kV)	17,79	14,64	485,7
	Bus 448 COOLER Trafo Distribusi 2000 kVA (6,3 kV)	17,79	14,64	183,3
SS 428, BHF& Kiln		22,47	18,23	682,8
Incoming 428		21,42	17,42	682,8

		21,42	17,42	
	Bus Bag Filter Fan (6,3 kV)			158,1
	Bus Kiln Feed (6,3 kV)	21,42	17,42	183,3
		21,42	17,42	
	Bus Dust Transport (6,3 kV)			183,3
SS 731, CCR		22,47	18,23	953,2
Incoming 731		21,06	17,16	953,2
		21,06	17,16	
	Bus 731 CCR Trafo Distribusi 2000 kVA (6,3 kV)			183,3
	Bus Kiln Drive (6,3 kV)	21,06	17,16	137,5
	Bus ID FAN 1 (6,3 kV)	21,06	17,16	158,1
	Bus ID FAN 2 (6,3 kV)	21,06	17,16	158,1
Incoming	6,3 kV	22,47	18,23	2749
Trafo GI 2	150 kV	8,75	7,53	115,5

Coordination of Overcurrent Relay Phase Disorders

Coordination of overcurrent relay phase interference in the selection of safety equipment that aims to isolate a system in the event of overcurrent phase-only interference. The disruption that occurs can be in the form of overload interference and short circuit interference. So that the design of good and appropriate protection coordination will ensure the reliability and continuity of industrial processes.

In this coordination,the system is done setting current and time on overcurrent relay (50/51). The parameters calculated are the high set value and the time dial. As for the time delay selected grading time 0.2s between the main relay with the relay back up in the hope that the relay does not work simultaneously when there is a disturbance.

After getting the calculation of the values on the parameters that have been determined for setting overcurrent relay, then the next step is to the plot time-current curve on star-protective device coordination contained in the ETAP 12.6.0 simulation software. Good and correct relay coordination must take into account the relay above or below so as not to intersect. Safety relay should pay attention to the charging current (inrush current) on the transformer. So that it can be seen and known the right coordination set.

Coordination of Overcurrent Relay Typical Phase Disorder 1

To facilitate analysis, typical coordination 1 is divided into two parts, namely typical 1a and typical 1b. In Figure 6. below is a typical 1a image consisting of 3 high voltage circuit breakers (HVCB) that are driven using a relay. The relay which will be coordinated in figure 6. consists of 3 pieces of the relay, including relay Bag Filter, relay incoming 428, relay 428 BHF & Kiln.
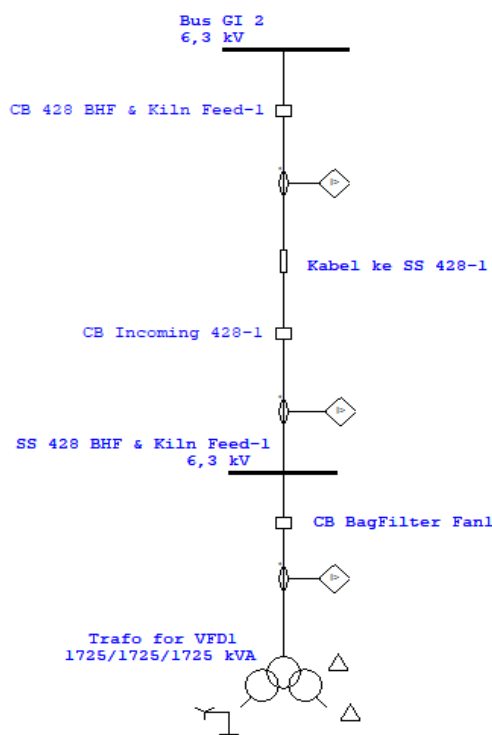

Figure 6. Typical Relay Coordination 1a

In determining the current setting and overcurrent relay time, calculations are done manually, as follows:

➢ **Relay Bag Filter Fan 1**

Manufacturer : Alstom
Type : P120
CurveType : IEC Very Inverse
FLA prim. Trafo Bag Filter : 158.1 A
CT Ratio : 200 / 5
Isc min SS 428 BHF & Kiln Feed : 17,42 kA (6,3 kV)
Isc max SS 428 BHF & Kiln Feed : 21,42kA (6,3 kV)

Time Overcurrent Pickup
1,05 x FLA prim. Trafo Bag Filter < Iset < 1,4 x FLA prim. Trafo Bag Filter
1,05 x 158,1 < Iset < 1,4 x 158,1
166,005 < Iset < 221,34
Selected Iset = 200 A

$$\text{Tap} = \frac{\text{Iset}}{\text{CTprimary}} = \frac{200}{200} = 1$$

Time Dial
Selected operating time (t_d) = 0,1 s

$$t_d = \frac{k \times TDS}{\beta \times \left(\left(\frac{I}{\text{Iset}}\right)^\alpha - 1\right)}$$

$$TDS = \frac{t_d \times \beta \times \left(\left(\frac{\text{Isc max}}{\text{Iset}}\right)^\alpha - 1\right)}{k}$$

$$TDS = \frac{0,1 \times 1 \times \left(\left(\frac{21420}{200}\right)^1 - 1\right)}{13,5}$$

TDS = 0,79 s

Instantaneous Pickup
1,6 x FLA prim. Trafo Bag Filter < Iset < 0,8 x Isc min SS 428 BHF & Kiln Feed
1,6 x 158,1 < Iset < 0,8 x 17420
252,96 < Iset < 13936
Selected Iset = 2000 A

$$\text{Tap} = \frac{\text{Iset}}{\text{CTprimary}} = \frac{2000}{200} = 10$$

Time Delay
Selected Time Delay = 0,1 s

➢ **Rele Incoming 428**

Manufacturer : Alstom
Type : P120
CurveType : IEC Very Inverse
FLA SS 428 BHF & Kiln Feed : 682,8 A
CT Ratio : 1000 / 5
Isc min SS 428 BHF & Kiln Feed : 17,42 kA (6,3 kV)
Isc max SS 428 BHF & Kiln Feed : 21,42kA (6,3 kV)

Time Overcurrent Pickup
1,05 x FLA SS 428 BHF & Kiln Feed< Iset < 1,4 x FLA SS 428 BHF & Kiln Feed
1,05 x 682,8< Iset < 1,4 x 682,8
716,94 < Iset < 955,92
Selected Iset = 800 A

$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{800}{1000} = 0,8$$

Time Dial
Selected operating time (t_d) = 0,3 s

$$t_d = \frac{k \times TDS}{\beta \times \left(\left(\frac{I}{\text{Iset}}\right)^\alpha - 1\right)}$$

$$TDS = \frac{t_d \times \beta \times \left(\left(\frac{\text{Isc max}}{\text{Iset}}\right)^\alpha - 1\right)}{k}$$

$$TDS = \frac{0,3 \times 1 \times \left(\left(\frac{21420}{800}\right)^1 - 1\right)}{13,5}$$

TDS = 0,57 s

Instantaneous Pickup
1,6 x FLA SS 428 BHF & Kiln Feed< Iset< 0,8 x Isc min SS 428 BHF & Kiln Feed
1,6 x 682,8 < Iset < 0,8 x 17420
1092,48 < Iset < 13936
Selected Iset = 4000 A
$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{4000}{1000} = 4$$

Time Delay
Selected Time Delay= 0,3 s

➢ **Rele 428 BHF & Kiln**

Manufacturer	: Alstom
Type	: P120
CurveType	: IEC Very Inverse
FLA SS 428 BHF & Kiln Feed	: 682,8 A
CT Ratio	: 2000 / 5
Isc min Bus GI 2	: 18,23 kA (6,3 kV)
Isc max Bus GI 2	: 22,47kA (6,3 kV)

Time Overcurrent Pickup
1,05 x FLA SS 428 BHF & Kiln Feed< Iset < 1,4 x FLA SS 428 BHF & Kiln Feed
1,05 x 682,8< Iset < 1,4 x 682,8
716,94 < Iset < 955,92
Selected Iset = 860 A
$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{860}{2000} = 0,43$$

Time Dial
Selected operating time (t_d) = 0,5 s
$$t_d = \frac{k \times TDS}{\beta \times \left(\left(\frac{I}{Iset}\right)^{\propto} - 1\right)}$$

$$TDS = \frac{t_d \times \beta \times \left(\left(\frac{\text{Isc max}}{\text{Iset}}\right)^{\propto} - 1\right)}{k}$$

$$TDS = \frac{0,5 \times 1 \times \left(\left(\frac{22470}{860}\right)^{1} - 1\right)}{13,5}$$

TDS = 0,93 s

Instantaneous Pickup
1,6 x FLA SS 428 BHF & Kiln Feed< Iset< 0,8 x Isc min Bus GI 2
1,6 x 682,8 < Iset < 0,8 x 18230
1092,48 < Iset < 14584
Selected Iset = 6000 A
$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{6000}{2000} = 3$$

Time Delay
Selected Time Delay = 0,5 s

Based on the results of the calculations above, the TCC plot is carried out to get more precise protection coordination. The typical TCC plot result 1a is shown in **Figure 7**.
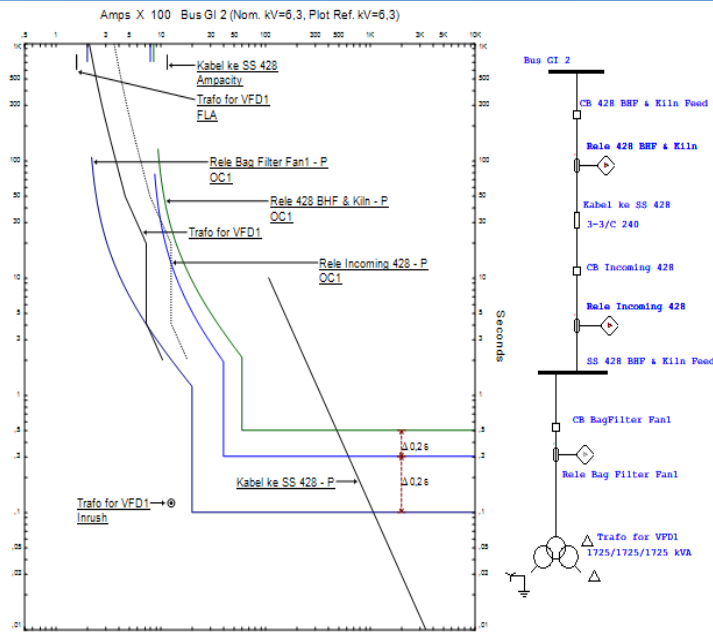
Figure 7. Plot results setting relay on typical 1a

The plot results of the typical TCC curve 1a can be seen in the image above, where there are red circles that can explain the coordination of the typical relay. The red circle describes:

1. Circle 1 explains about the relay Bag Filter Fan 1 will not trip if the transformer for VFD1 is fully burdened because the lowset of the relay is on the right of the FLA transformer.
2. Circle 2 indicates the grading time of the relay using 0.2 s.
3. Circle 3 describes the Rele Bag Filter Fan 1 as a safety on the primary side of the transformer and the inrush current of the transformer for VFD1 when it was first to energize. From the curve, it can be said that the relay will not trip when there is a surge of current due to the inrush transformer.

Based on the results of the plot in Figure 7, it can be concluded that:

- Relay Bag Filter Fan 1 serves as a transformer protector for VFD1 on the primary side against more full load current. In addition, this relay serves as a protector of the SS 428 BHF & Kiln Feed-1 bus when there is a shorter circuit current on the main side transformer terminal for VFD1. At the time the transformer for VFD1 is inrushed then this relay does not work.
- The relay Incoming 428 serves as a protector against the shorter currents that occur on the SS 428 BHF &Kiln Feed-1 bus. In addition, this relay also serves as a backup relay Bag Filter Fan 1 if it fails to work. If there is a maximum short circuit flow on the SS 428 BHF & Kiln Feed-1 bus, then this relay still works first.
- The Relay 428 BHF & Kiln serves as a protector against the shorter currents that occur on GI 2 buses and as a backup of the relayincoming 428 when it fails to work.
- The plot results of the TCC curve show that they do not overlap each other, referring to the IEEE 242-2001 standard that the minimum working time difference between the main relay and the backup relay is 0.2 – 0.4 seconds.

Relay testing is performed with a circuit breaker (CB). This aims to find out whether the relay is connected to CB in sequence or not. If there is a disruption to the transformer or on the distribution network, CB located near the source of the disruption will trip sequentially to the source. Here Figure 4.4 shows CB trip testing using a source of interference on a typical 1a VFD 1 transformer.
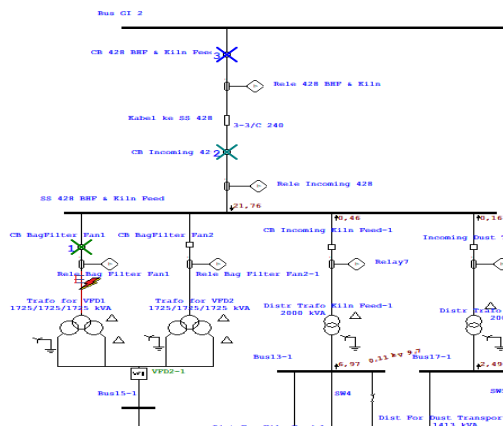

Figure 8. Testing with the source of interference on the transformer for VFD1 typical 1a

It can be seen that the CB that is experiencing a trip is the CB closest to the position of interference which is said to be the relaycoordination is considered to work well. The first CB as the main relay that experienced a trip was CB Bag Filter Fan1 which was active after the Relay Bag Filter Fan1 detected full overload current. The next CB to work is CB Incoming 428 and the last is CB 428 BHF and Kiln Feed, both as backups of the first CB when it fails to work. With the results of this test, it can be considered that the coordination of relay protection of the position of interference on the Transformer for VFD1 works very well becausethe CB trip is the closest CB to the interference position.

In Figure 9. below is a typical 1b image consisting of 2 new HVCBs and 1 HVCB on a typical 1a. The coordinated relay is relay 428 BHF & Kiln, relay incoming 6.3 kV, and relay primer Trafo GI 2.
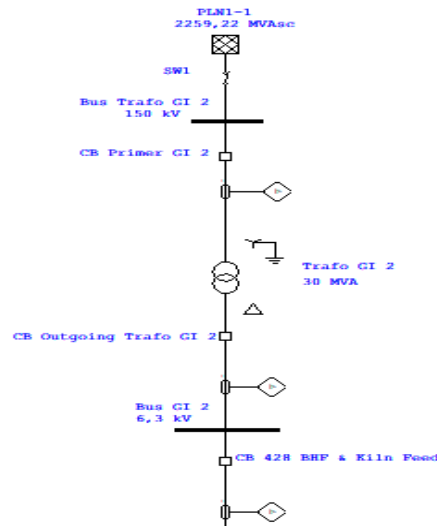

Figure 9. Typical Relay Coordination 1b

Manual calculations are performed for current setting and rele time, as follows:
➢ **Rele Incoming 6,3 kV**

Manufacturer	: Alstom
Type	: P120
CurveType	: IEC Very Inverse
FLA sec. Trafo GI 2	: 2749 A
CT Ratio	: 3000 / 5
Isc min Bus GI 2	: 18,23 kA (6,3 kV)
Isc max Bus GI 2	: 22,47kA (6,3 kV)

Time Overcurrent Pickup

1,05 x FLA sec. Trafo GI 2< Iset < 1,4 x FLA sec. Trafo GI 2

1,05 x 2749< Iset < 1,4 x 2749

2886,45 < Iset < 3848,6

Selected Iset = 3000 A

$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{3000}{3000} = 1$$

Time Dial

Selected operating time (t_d) = 0,7 s

$$t_d = \frac{k \text{ x TDS}}{\beta \text{ x } \left(\left(\frac{I}{\text{Iset}} \right)^{\propto} - 1 \right)}$$

$$\text{TDS} = \frac{t_d \text{ x } \beta \text{ x } \left(\left(\frac{\text{Isc max}}{\text{Iset}} \right)^{\propto} - 1 \right)}{k}$$

$$\text{TDS} = \frac{0,7 \text{ x } 1 \text{ x } \left(\left(\frac{22470}{3000} \right)^1 - 1 \right)}{13,5}$$

TDS = 0,34 s

Instantaneous Pickup

1,6 x FLA sec. Trafo GI 2< Iset< 0,8 x Isc min Bus GI 2

1,6 x 2749 < Iset < 0,8 x 18230

4398,4 < Iset < 14584

Selected Iset = 13800 A

$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{13800}{3000} = 4,6$$

Time Delay
Selected Time Delay = 0,7 s

➢ **Rele Primer Trafo GI 2**

Manufacturer	: Alstom
Type	: P120
CurveType	: IEC Very Inverse
FLA prim. Trafo GI 2	: 115,5 A
CT Ratio	: 300 / 5
Isc min Bus Utama Trafo GI 2	: 7,53 kA (150 kV)
Isc max Bus Utama Trafo GI 2	: 8,75kA (150 kV)
Isc max Bus GI 2	: 22,47kA (6,3 kV)
➢ Konversi ke 150 kV	: $22,47 \times \left(\frac{6,3}{150}\right) = 0,944$ kA

Time Overcurrent Pickup
1,05 x FLA prim. Trafo GI 2< Iset < 1,4 x FLA prim. Trafo GI 2
1,05 x 115,5< Iset < 1,4 x 115,5
121,275 < Iset < 161,7
Selected Iset = 150 A

$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{150}{300} = 0,5$$

Time Dial
Selected operating time(t_d) = 0,1 s

$$t_d = \frac{k \times TDS}{\beta \times \left(\left(\frac{I}{Iset}\right)^{\propto} - 1\right)}$$

$$TDS = \frac{t_d \times \beta \times \left(\left(\frac{Isc\ max}{Iset}\right)^{\propto} - 1\right)}{k}$$

$$TDS = \frac{0,1 \times 1 \times \left(\left(\frac{8750}{150}\right)^{1} - 1\right)}{13,5}$$

TDS = 0,42 s

Instantaneous Pickup
Isc max Bus GI 2< Iset< 0,8 x Isc min Bus Utama Trafo GI 2
944 < Iset < 0,8 x 7530
944 < Iset < 6024
Selected Iset = 1200 A

$$\text{Tap} = \frac{\text{Iset}}{\text{CT primary}} = \frac{1200}{300} = 4$$

Time Delay
Selected Time Delay = 0,1 s

Based on the results of the calculations above, the TCC plot is carried out to get more precise protection coordination. The typical TCC plot result 1b is shown in Figure 10. below.
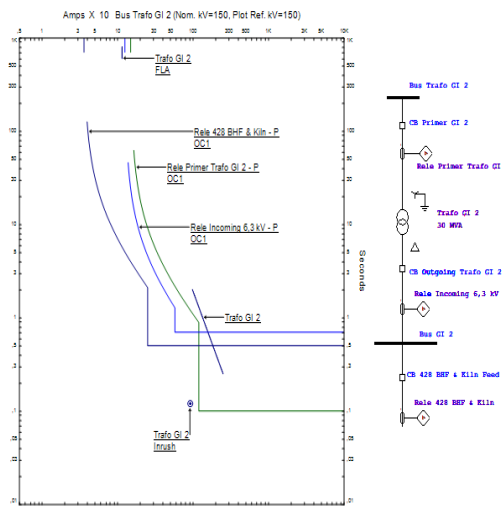

Figure 10. Plot results setting relay on typical 1b

The plot results of a typical TCC curve 1b can be seen in the figure above, where there are red circles that can explain the coordination of the typical relay. The red circle describes:

1. Circle 1 explains about the primary relay of the GI 2 transformer will not trip if the GI 2 transformer is fully burdened because the lowset of the relay is on the right side of the FLA transformer.
2. Circle 2 indicates the grading time of the relay using 0.2 s.
3. Circle 3 describes the primary relay of the GI 2 transformer as a safety on the primary side of the transformer and the inrush current of the GI 2 transformer when it was first di energize. From the curve, it can be said that the relay will not trip when there is a surge of current due to the inrush transformer.

Based on the plot results in Figure 10, it can be concluded that:

- The 6.3 kV Incoming Rele serves as a GI 2 transformer protector on the secondary side against more full load currents and shorter-circuit currents that occur on GI 2 buses. In addition, this relay also serves as a backup relay 428 BHF & Kiln if it fails to work. If there is a maximum short circuit flow on the GI 2 bus, then this relay still works first.
- The GI 2 transformer serves as a gi 2 transformer protector on the primary side against more full load currents. In addition, this relay serves also as a protector of the GI 2 transformer bus when there is a shorter circuit current on the primary side GI 2 transformer terminal and as a backup relay Incoming 6.3 kV if it fails to work. At the time the GI 2 transformer is inrushed then this relay does not work.
- The plot results of the TCC curve show that they do not overlap each other, referring to the IEEE 242-2001 standard that the minimum working time difference between the main relay and the backup relay is 0.2 – 0.4 seconds.

Relay testing is performed with a circuit breaker (CB). This aims to find out whether the relay is connected to CB in sequence or not. If there is a disruption to the transformer or on the distribution network, CB located near the source of the disruption will trip sequentially to the source. Figure 4.7 shows CB trip testing using a source of interference on the connector between CT4 and the cable to SS 428 typical 1b.
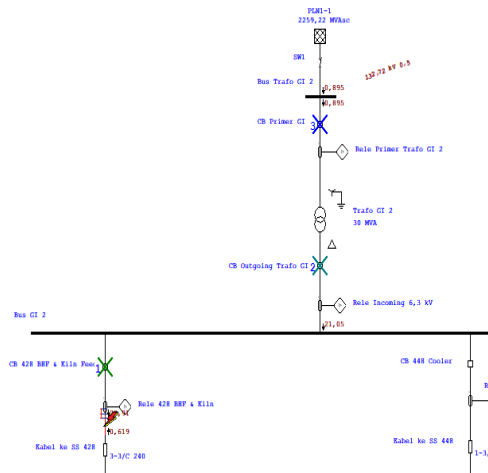

Figure 11. Testing With The Source Of Interference On The Connector Between Ct4 And Cable To Ss 428 Typical 1b

It can be seen that the CB that is experiencing a trip is the CB closest to the position of interference which is said to be the relaycoordination is considered to work well. The first CB as the main relay to experience a trip, namely CB 428 BHF and Kiln Feed which are active after relay 428 BHF and Kiln Feed detect the current of interference. The next CB that works is the CB Outgoing GI transformer and the last is the primary CB GI, both as backups of the first CB when it fails to work. With the results of this test, it can be considered that the coordination of relay protection position interference on the connector between CT4 and cable to SS 428 works very well because CB trip is the closest CB to the interference position.

Conclusions

Based on the results of studies and analysis of coordination of more current safety relay on the electricity system of kiln area at Indarung VI Factory PT. Semen Padang that has been done than can be concluded as follows:

1. In the design of protection coordination modeling many things to consider ranging from a load flow system to know the amount of current flowing on each feeder, short circuit is used for setting instant relay of more current, transformer inrush current, and transformer damage curve.
2. In the current setting more phase disorders each type has been selected coordination from the relay primer transformer with a voltage of 6.3 kV to the PLN source relay. In every type has been done proper calculations so that in the event of a minimum phase disruption then the relay that is nearby can work. When inrush transformer, the relay does not work. Each typical uses HVCB and for its settings on their respective relay.

3. The grading time used for coordination of the work of the safety relay is 0.2 seconds. This is considered appropriate because a Grading time of 0.2 - 0.4 seconds can give enough time to the main safety relay to finish breaking the interference first. So that the trip event simultaneously between the main safety relay and the backup relay at the time of short circuit disruption can be avoided and coordination of work between the relay can run well. Grading time selection of 0.2 and 0.3 seconds is considered the most appropriate considering that the relay used is a digital relay. Grading time selection of 0.2 seconds by the IEEE 242 standard.

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