International Journal of Research In Vocational Studies (IJRVOCAS)

Vol. 6, No. 2, August 2026, pp. 47~58
Print ISSN 2777-0168| Online ISSN 2777-0141| DOI prefix: 10.53893
https://journal.gpp.or.id/index.php/ijrvocas/index

Analytical Evaluation of Existing ANSI 50/51 Overcurrent Relay Settings for Coal Mill 2B Motor at STG-BB Power Plant, PT Pupuk Sriwidjaja Palembang

Rumiasih*, Andri S, Carlos RS, Mutiar, Siswandi & Arif EN
Electrical Engineering Department, State Polytechnic Sriwijaya, Indonesia

Email adrress:
rumiasih@polsri.ac.id (Rumiasih)

*Corresponding author

To cite this article:
Rumiasih, Andri S, Carlos RS, Mutiar, Siswandi, & Arif EN. (2026). Analytical Evaluation of Existing ANSI 50/51 Overcurrent Relay Settings for Coal Mill 2B Motor at STG-BB Power Plant, PT Pupuk Sriwidjaja Palembang. *International Journal of Research in Vocational Studies (IJRVOCAS), 6(2), 47–58. https://doi.org/10.53893/ijrvocas.v6i2.538.*

Received: 06 21, 2026; **Revised**: 07 08, 2026; **Accepted**: 07 17, 2026; **Published**: 08 22, 2026

Abstract: This study presents an analytical evaluation of the existing ANSI 50/51 overcurrent relay settings for the Coal Mill 2B motor at the STG-BB power plant of PT Pupuk Sriwidjaja Palembang. Direct trip testing was not conducted because the motor is part of an operating industrial installation. The evaluation combines a review of the existing relay settings, calculation of the manufacturer-defined Long Time Inverse characteristic, comparison with the reported motor starting current and starting time, and analysis of ten days of recorded operating current, voltage, and active power. The ANSI 51 pickup is 136 A, equivalent to approximately 1.03 times the 132 A motor nameplate current, with TMS = 0.025. The reported high-set ANSI 50 stage is 1,227.6 A, equivalent to 9.3 times the motor nameplate current, with a definite delay of 0.01 s. Using the MiCOM P225 Long Time Inverse characteristic, the calculated operating time at the reported starting current of 985.91 A is approximately 0.48 s, which is close to the upper end of the reported 0.3–0.5 s starting time. Therefore, starting-current ride-through cannot be conclusively verified from the available data. During the ten observation days, the recorded running current ranged from 76.93 A to 95.80 A, with an average of approximately 85.69 A, equivalent to 64.9% of the 132 A nameplate current. The observed current remained 40.20–59.07 A below the 136 A pickup. These results provide an analytical assessment of the existing relay settings under the observed operating conditions, but do not demonstrate complete selectivity, protection coordination, fault sensitivity, or overall relay reliability.

Keywords: Induction Motor; Overcurrent Relay; ANSI 50/51; Time-Current Characteristic (TCC); Long Time Inverse; MiCOM P225.

1. Introduction

Electric motors are important components in industrial processes because they serve as prime movers for production equipment. At the STG-BB power plant of PT Pupuk Sriwidjaja Palembang, the Coal Mill 2B motor is a 400 kW, 2.3 kV three-phase induction motor used in the coal-processing system.

During operation, abnormal current conditions may occur because of overloads, starting transients, or electrical faults. The motor is protected by a MiCOM P225 numerical relay that provides phase overcurrent protection through the ANSI 50/51 function.

The MiCOM P225 phase-overcurrent function has multiple thresholds and can use definite-time or inverse-time characteristics. The relay also provides separate motor-protection functions, including thermal overload (ANSI 49), excessive long-start protection, locked-rotor/stall protection, and unbalance protection. Therefore, ANSI 50/51 should not be interpreted as the sole protection against all motor thermal or mechanical conditions.

In this study, the analysis is limited to the existing phase-overcurrent settings and their relationship with the observed motor current. Direct trip testing was not conducted because an intentional trip could interrupt the coal-supply process. The evaluation therefore uses the existing relay settings, mathematical relay-characteristic calculations, reported starting data, and ten days of operating observations.

The evaluation focuses on the relationship between the motor nameplate current, the ANSI 51 pickup, the high-set ANSI 50 stage, and the observed operating current. The study also evaluates the calculated relay operating time for selected current values and compares the reported starting current with the inverse-time characteristic.

The objective is to provide an analytical assessment of the existing ANSI 50/51 settings under the observed operating conditions. The conclusions are intentionally limited to what can be supported without a direct field trip test, a complete short-circuit study, or a complete coordination study with upstream and downstream protective devices.

1.1 *Understanding Electric Motors*

An electric motor is an electromechanical machine that converts electrical energy into mechanical energy in the form of rotational motion. In industrial applications, electric motors are widely used as prime movers for various production processes [2]. The motor considered in this study is a three-phase induction motor used to drive Coal Mill 2B at the STG-BB power plant of PT Pupuk Sriwidjaja Palembang. The motor has a rated power of 400 kW and an operating voltage of 2.3 kV.

As an induction motor operates, its electrical current varies according to the operating load. Therefore, the motor rated current or Full Load Ampere (FLA) is an important parameter in evaluating its operating condition and in assessing the setting of its overcurrent protection. In this study, the motor nameplate FLA of 132 A is used as the reference value for evaluating the existing overcurrent relay setting.

1.2 *Operating Parameters and Motor Characteristics*

The operating condition of an electric motor can be evaluated using its rated operating parameters obtained from the motor nameplate. One of the main parameters is the Full Load Ampere (FLA) [9], which represents the rated current of the motor under its specified operating conditions. For the Coal Mill 2B motor investigated in this study, the nameplate FLA is 132 A. This value is used as the reference current for evaluating the actual operating current and the existing overcurrent relay pickup setting.

The operating current can also be expressed as a percentage of the motor rated current to provide an indication of the motor's current-based loading condition. The current-based load percentage is calculated using Equation (1) by the U.S. Department of Energy (2014):[10]

$$\boldsymbol{Load} = \left(\frac{I}{I_r}\right) \times \mathbf{100\%} \ldots\ldots\ldots\ldots \mathbf{(1)}$$

Where:

- Load Percentage of Motor Load (100%)
- I = Actual measured average RMS current (Ampere)
- I_r = Nominal full load current/Full load Ampere on the nameplate (Ampere)

The resulting percentage represents current-based loading and is used only to evaluate the observed operating condition of the motor.

1.3 *Electric Motor Faults and Protection Functions*

Electric motors may experience abnormal conditions that can generally be classified as electrical or mechanical faults. Electrical faults include phase-to-phase and phase-to-ground short circuits, while mechanical abnormalities such as excessive load or a locked rotor may also increase motor current. Different abnormal conditions require different protection functions [4].

The MiCOM P225 provides several motor-protection functions, including ANSI 46 unbalance, ANSI 49 thermal overload, ANSI 50/51 phase overcurrent, excessive long-start protection, and locked-rotor protection. This study specifically evaluates the phase-overcurrent function and does not treat ANSI 51 as a substitute for the relay's dedicated thermal or locked-rotor functions.

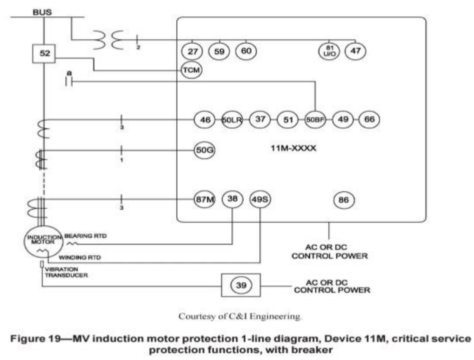

Figure 1. 1 *Medium-voltage induction motor protection scheme with multiple protection functions [4]*

The figure shows that motor protection is not limited to a single protection function. Different protection elements are applied according to the type and characteristics of the abnormal condition. Among these functions, ANSI 50 and ANSI 51 are overcurrent protection functions that are directly related to the current conditions of the motor. ANSI 50 is associated with high-current fault protection, while ANSI 51 provides time-overcurrent protection based on a predetermined pickup and operating-time characteristic [4].

In this study, the analysis is specifically focused on the ANSI 50 and ANSI 51 functions of the MiCOM P225 relay installed on the Coal Mill 2B motor. Other protection functions shown in Figure 1.2 are not evaluated because they are outside the scope of this study. The evaluation is performed using the existing relay settings, mathematical analysis of the relay operating characteristic, and the observed motor operating current.

1.4 *Electrical Power Protection Systems*

An electrical power protection system is a system of electrical equipment designed to detect abnormal conditions or faults in a system and then automatically disconnect (isolate) the affected section. The primary purpose of a protection system is to minimize damage to the faulted equipment, prevent the fault from spreading to healthy systems, and ensure the safety of operational personnel near the equipment [4].

1.5 *Basic Protection System Requirements*

To effectively protect essential equipment such as a coal mill motor, a protection system must meet four fundamental requirements:

1. Sensitivity: The protection system must have high sensitivity to detect even the smallest fault current within its protection zone, but must not operate under normal load conditions or during normal starting current surges.
2. Selectivity: The protection relay must be able to distinguish whether a fault occurs within its protection zone or outside it. If a fault occurs within its protection zone, the relay must disconnect only the circuit closest to the fault point, thus avoiding disrupting the continuity of power supply to other equipment.
3. Speed: The disconnection response time must be as fast as possible to limit the damaging heat energy generated by circuit faults. Fast disconnection times also help maintain the stability of the plant's overall electrical system.
4. Reliability: The protection system must be guaranteed to always operate correctly (without tripping) when (dependability), and must be guaranteed not to operate when there is no disturbance (security).

1.6 *Main Components of a Protection System*

A protection system cannot operate alone; it is a combination of several integrated components. These main components include:

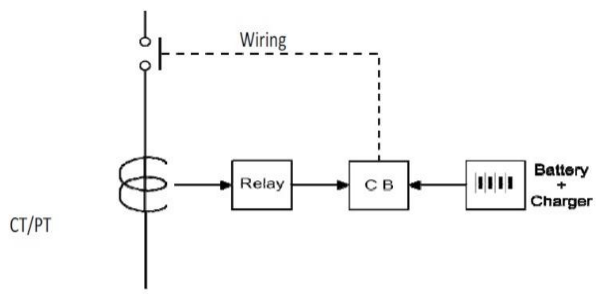

Figure 1. 2 *Block Diagram of Protection System Component Relationships* [11]

1. Current Transformer (CT) and Potential Transformer (PT): Function as sensors that reduce the high current and voltage from the network to a smaller, safer secondary voltage (usually 1A or 5A for CT, and 110V for PT) so that it can be read by the relay instrument.
2. Protection Relay: Acts as the "brain" of the protection system. The relay's job is to compare the current/voltage from the CT/PT with the set value (setting/pickup). If the measured value exceeds the setting, the relay will send a trip signal.
3. Circuit Breaker (CB): Acts as the "muscle" or executor. After receiving a trip signal from the relay, the mechanical mechanism on the circuit breaker (CB) opens its main contacts to interrupt the load current or fault current within milliseconds.

1.7 *Electrical Faults (Overcurrent and Short Circuit)*

Electrical faults often occur suddenly and have the potential for significant damage in a very short time. The most common types of electrical faults include:[9]

1. Phase-to-Phase Fault: Occurs due to insulation failure, causing two or three phases to be directly connected. This fault produces very high currents (fault currents) and can damage motor terminals and windings within milliseconds.
2. Phase-to-Ground Fault: This is the most common type of fault, where one of the phases is connected to the motor frame or ground due to broken or damp insulation.
3. Voltage Unbalance: An imbalance in the phase voltage supply will trigger the appearance of negative sequence currents, which can cause significant overheating of the rotor.

To mitigate this electrical fault, the protection system must operate with instantaneous characteristics. This aims to prevent damage the motor and prevent the disturbance from spreading to the larger electrical system in the power plant area.

1.8 *Overcurrent Relay (OCR) Operating Principle*

An Overcurrent Relay (OCR) operates when measured current exceeds a programmed threshold. In the MiCOM P225, the phase-overcurrent function compares measured phase current with programmed thresholds and applies the selected definite-time or inverse-time characteristic.

The relay receives current information through the phase CT inputs. The P225 documentation states that the phase-current measurements are displayed as true RMS values after applying the configured phase-CT ratio. When a programmed threshold is exceeded and the associated time delay expires, the relay can issue a trip signal to the circuit breaker.

1.9 *Protection Codes for Induction Motors Based on ANSI/IEEE C37.2 Standards*

IEEE C37.2 assigns function numbers used to identify protection and control functions in power systems. In this study, ANSI 50 refers to the high-current/instantaneous overcurrent function, while ANSI 51 refers to time overcurrent. The actual MiCOM P225 implementation groups phase overcurrent under the [50/51] function and provides multiple thresholds with configurable time characteristics [5].

1. ANSI 50 (high-set overcurrent): This function is intended for high-current fault conditions and may be configured with a very short or definite-time delay. In the present study, the high-set stage is represented by the reported 1,227.6 A primary setting with a 0.01 s definite delay; therefore, it is more precise to describe it as a high-set definite-time stage rather than an ideal zero-delay instantaneous trip.
2. ANSI 51 (time overcurrent): This function uses a time-current characteristic in which the operating time decreases as the measured current increases above the pickup threshold. The present study evaluates the ANSI 51 stage using the Schneider Electric Long Time Inverse characteristic with TMS = 0.025.

Table 1. 1 *Relay Function Codes According to ANSI IEEE C37.2 Standard*

ANSI/IEEE C37.2	
Function	**Description**
46	*Phase Balance Current*
47	*Phase Sequence Voltage*
49	*Thermal*
50	*Instantaneous Over Current*
50G	*Ground Instantaneous Over Current*
51	*Time Over Current*
51G	*Ground Time Over Current*
51N	*Neutral Time Over Current*
59	*Overvoltage*

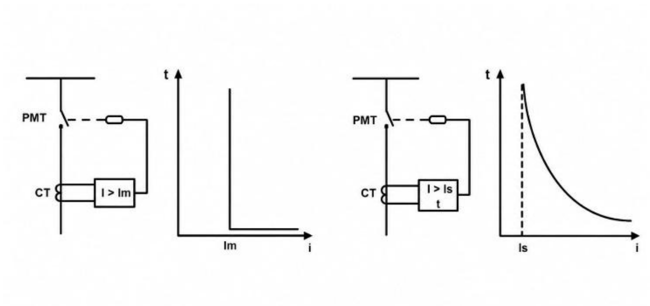

Figure 1. 3 *Representative Characteristic Curves of ANSI 50 and ANSI 51 Overcurrent Protection* [1]

The two functions are complementary: the time-overcurrent stage addresses currents above the pickup over a calculated delay, while the high-set stage is intended for substantially higher fault currents. Thermal overload, locked-rotor, and unbalance conditions are handled by dedicated protection functions in the MiCOM P225 and are outside the main scope of this analysis.

1.10 Time-Current Characteristic (TCC)

The operating time of an inverse-time overcurrent relay is determined from the relationship between measured current and the programmed pickup. IEC 60255-151:2009 defines functional requirements for over/under-current protection, while the MiCOM P225 technical manual provides the specific mathematical characteristics and coefficients implemented by the relay [3].

For the MiCOM P225, the technical manual lists several IDMT characteristics. The Long Time Inverse characteristic used in this study is identified by Schneider Electric with K = 120, α = 1, and L = 0. The calculation is therefore performed using the manufacturer-specific equation rather than treating the LTI curve as a generic IEC curve [8].

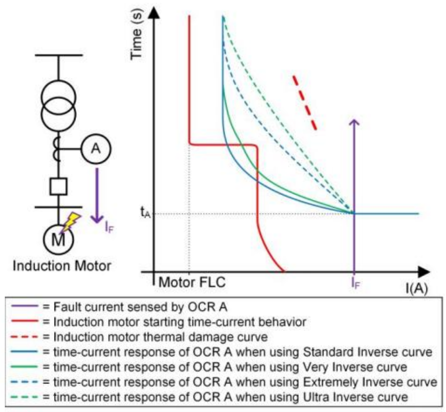

Figure 1.4 *Single-line diagram and time-current curves for OCR with induction motor as a protected equipment [7]*

Table 1.2 *MiCOM P225 IDMT curve coefficients used in this study [1][7] [8]*

MiCOM P225 IDMT Curve Coefficients

Type of curve	Standard	K	α	L
Short time inverse	Schneider Electric	0.05	0.04	0
Standard inverse	IEC	0.14	0.02	0
Very inverse	IEC	13.5	1	0
Extremely inverse	IEC	80	2	0
Long time inverse	Schneider Electric	120	1	0

Standard inverse and other inverse characteristics have different slopes and are selected according to the protection application. The present study does not claim that one curve is universally optimal for all induction motors; it evaluates the existing Schneider Electric Long Time Inverse characteristic configured in the relay.

The choice of an inverse-time characteristic for motor protection should be considered together with motor starting current, starting duration, thermal limits, and coordination with other protective devices. These elements are only partially available in the present study.

The Schneider Electric Long Time Inverse characteristic used in this analysis is the curve implemented in the MiCOM P225 manual. Its coefficients are K = 120, α = 1, and L = 0. For the selected curve, the operating time is calculated as:[8]

$$t = T \times \left[\frac{K}{\left(\left(\frac{I}{Is} \right)^{\alpha} - 1 \right)} + L \right] \text{........ (2)}$$

For this study: T = TMS = 0.025, K = 120, α = 1, and L = 0. The ratio I/Is is dimensionless. The equation is evaluated only above the relay's operating region; values below pickup are classified as no operation rather than assigned a negative or nonphysical trip time.

Where:

- *t = relay operating time (s)*
- T = Time Multiplier Setting (TMS)
- *I = measured current (A)*
- *Is = programmed pickup current (A)*
- *K = curve constant*
- α = curve exponent
- L = curve constant used by the selected characteristic

1.11 Numerical (Digital) Protection Relay Technology

Numerical relays process current and voltage signals from instrument transformers using digital measurement and embedded algorithms. The MiCOM P225 provides configurable protection functions, event records, measurements, and CT/VT ratio settings. Its phase-current measurements are displayed using the configured phase-CT ratio.

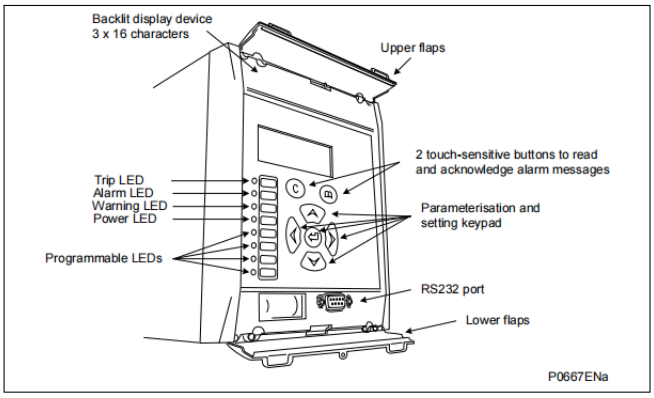

Figure 1. 4 *Front Panel Of The MiCOM P22x Relay* [8]

Unlike their predecessors, numerical relays work by converting analog current and voltage values from an instrument transformer (CT/PT) into digital signals via an Analog-to-Digital Converter (ADC). This digital signal is then mathematically processed by a microprocessor based on an embedded algorithm or software.

1.11.1 Pickup Current Setting

The pickup current is the threshold at which the phase-overcurrent function begins its protection characteristic. In this study, the motor nameplate Full Load Ampere (FLA) of 132 A is kept distinct from the CT/relay base quantities. The existing ANSI 51 pickup is evaluated as an implemented setting rather than proposed as a new design value.

$$I_{set(Primary)} = K \times I_n \quad (3)$$

Where K is the safety factor, depending on the motor's operational characteristics and the manufacturer's standard recommendations.

I_{set} = 1.03 × 132 A = 135.96 A ≈ 136 A

The reported setting is therefore approximately 1.03 times the motor nameplate current. Because the available data do not document the complete CT secondary rating, accuracy class, burden, and exact relay-side parameterization, the primary pickup value is used as the reproducible reference for this analytical study.

2. Research Methods

2.1 Process Flowchart

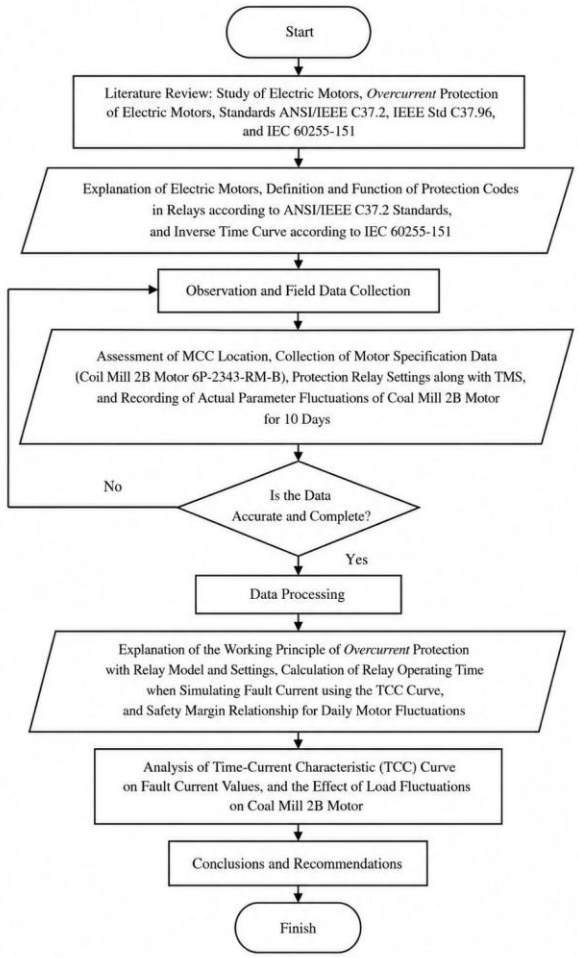

Figure 2. 1 *Data Collection Process Flowchart*

2.2 Methods

This research procedure consists of four systematic steps.

1. Problem identification and literature review were conducted using IEEE C37.2, IEEE C37.96, IEC 60255-151, and the MiCOM P225 technical manual as the main technical references.
2. Field data collection included the motor nameplate specifications, existing MiCOM P225 settings, reported motor starting data, and daily operating parameters recorded over a ten-day observation period.
3. Data processing consisted of calculating the existing ANSI 51 Long Time Inverse operating characteristic, comparing the calculated response with the reported

starting current and starting time, and comparing the observed running current with the 136 A pickup.

4. The results were interpreted to determine what can be supported by the available analytical and operational data. Because no direct trip test and no complete system coordination or short-circuit study were performed, the conclusions are limited accordingly.

The specifications of the electric motor from which data will be collected are as follows:

Table 2. 1 *Motor Coal Mill 2B 6P-2343-RM-B Specification Data*

Technical Parameters	Unit	Value
Output (Daya)	400	kW
Voltage	2300	V
Frequency	50	Hz
Speed	993.0	rpm
Current	132	A
Power Factor	0.79	-
Starting Current	985.91	A
Motor type Code	HXR 400LJ6	
Motor type	Squirrel cage Motor	

Figure 2.3 *Motor Coal Mill 2B 6P-2343-RM-B Specification Data*

Figure 2.3 *Motor Coal Mill 2B 6P-2343-RM-B*

Table 2. 2 *MiCOM P225 Relay Information*

Parameter	Value
Relay model	MiCOM P225
Phase overcurrent function	[50/51] three-phase non-directional phase overcurrent
Phase CT primary used in study	160 A (reported plant data; CT/relay scaling to be verified)
Phase CT secondary	Not documented in the available study data; MiCOM P225 supports 1 A or 5 A inputs
ANSI 51 pickup	136 A primary
ANSI 51 characteristic	Schneider Electric Long Time Inverse; TMS = 0.025
High-set ANSI 50 stage	1,227.6 A primary; reported as 9.3 × 132 A
High-set delay	0.01 s definite time

TEKNO SAINS

STUDI EVALUASI SISTEM PEMBANGKIT DAN JARINGAN KELISTRIKAN PT. PUPUK SRIWIDJAJA PALEMBANG

FINAL REPORT

R-BUSTIE 6P-1001 / 2001	STG	6P-1001-MVSG	MICOM	P127	200:5	Overcurrent	Ground	OC1					0.100	20.00	0.6 s
R-6P-1411-GB	STG	6P-1001-MVSG	MICOM	P127	250:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.770	192.500	1.100	8.130	2032.50	0.1 s
R-6P-1411-GB	STG	6P-1001-MVSG	MICOM	P127	80:5	Overcurrent	Ground	OC1					0.375	30.00	0.1 s
R-6P-1343-RM-A	STG	6P-1001-MVSG	MICOM	P127	160:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.850	136.000	0.225	10.500	1680.00	0.1 s
R-6P-1343-RM-A	STG	6P-1001-MVSG	MICOM	P127	160:5	Overcurrent	Ground	OC1					0.190	30.40	0.1 s
R-6P-1343-RM-B	STG	6P-1001-MVSG	MICOM	P127	160:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	2.800	448.000	0.200	10.500	1680.00	0.01 s
R-6P-1343-RM-B	STG	6P-1001-MVSG	MICOM	P127	160:5	Overcurrent	Ground	OC1					0.100	16.00	0.6 s
R-Q1M2	STG	6P-2001-MVSG	MICOM	P127	3150:5	Overcurrent	Phase	OC1	IEC - Extremely Inverse	1.000	3150.000	0.125	2.430	7654.50	0.3 s
R-Q1M2	STG	6P-2001-MVSG	MICOM	P127	400:5	Overcurrent	Ground	OC1					0.075	30.00	0.3 s
R-6P-2001-LVTR	STG	6P-2001-MVSG	MICOM	P127	1250:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.600	750.000	0.025	5.200	6500.00	0.1 s
R-6P-2001-LVTR	STG	6P-2001-MVSG	MICOM	P127	100:5	Overcurrent	Ground	OC1					0.100	10.00	0.6 s
R-6P-2461-GB	STG	6P-2001-MVSG	MICOM	P127	500:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.940	470.000	1.250	5.980	2990.00	0.1 s
R-6P-2461-GB	STG	6P-2001-MVSG	MICOM	P127	100:5	Overcurrent	Ground	OC1					0.300	30.00	0.1 s
R-6P-2401-GB	STG	6P-2001-MVSG	MICOM	P127	500:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.740	370.000	0.675	5.200	2600.00	0.1 s
R-6P-2401-GB	STG	6P-2001-MVSG	MICOM	P127	100:5	Overcurrent	Ground	OC1					0.300	30.00	0.1 s
R-6P-2411-GB	STG	6P-2001-MVSG	MICOM	P127	250:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.770	192.500	1.100	8.130	2032.50	0.1 s
R-6P-2411-GB	STG	6P-2001-MVSG	MICOM	P127	80:5	Overcurrent	Ground	OC1					0.375	30.00	0.1 s
R-6P-2343-RM-A	STG	6P-2001-MVSG	MICOM	P127	160:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.850	136.000	0.225	10.500	1680.00	0.1 s
R-6P-2343-RM-A	STG	6P-2001-MVSG	MICOM	P127	160:5	Overcurrent	Ground	OC1					0.190	30.40	0.1 s
R-6P-2343-RM-B	STG	6P-2001-MVSG	MICOM	P127	160:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.850	136.000	0.225	10.500	1680.00	0.1 s
R-6P-2343-RM-B	STG	6P-2001-MVSG	MICOM	P127	160:5	Overcurrent	Ground	OC1					0.190	30.40	0.1 s
R-Q1M3	STG	6P-3001-MVSG	MICOM	P127	3150:5	Overcurrent	Phase	OC1	IEC - Long Time Inverse	0.760	2394.000	0.025	4.000	12600.00	0.3 s
R-Q1M3	STG	6P-3001-MVSG	MICOM	P127	400:5	Overcurrent	Ground	OC1					0.080	32.00	0.3 s

Doc. No.: PUSRI-FINAL-2021-ITS | Revision: B | Page 120 of 141

Figure 2. 4 *Protection relay function settings in the STG-BB area.*

Table 2. 3 *TMS Information and Inverse Curve on Relay*

Brand Relay	CT Ratio	Type Protection	Curve Type Inverse	Setting ANSI 51	Setting Value	Value TMS	Setting ANSI 51	Value Setting	Instantaneous Time
MICOM	160A/5A	Over Current	IEC-Long Time Inverse	0,850	136 (A)	0,225	10,5	1.680 (A)	0,1 s
Motor Coal Mill 2B-6P-2343-RM-B – STG (6P-2001-MVSG)									

6P-2343-RM-B	6P-2343-RM-A	6P-2401-GB	6P-2411-GB	Tag Number		
Coal Mill 2B	Coal Mill 2A	FD Fan 2	PA Fan 2	Load Description		
400	400	1050	600	Rated Power (kW)		
2.3	2.3	2.3	2.3	Rated Voltage (kV)		
131.98	131.98	305.06	181.28	Rated Current (A)		
985.91	985.91	1525.31	906.38	Starting Current (A)		
0.3	0.3	14	16	Starting Time 100% U_n (sec)		
0.5	0.5	24	28	Starting Time 80% U_n (sec)		
10	10	16	16	Hot Stall Time (sec)		
3	3	3	3	Number of Starts per hour		
160	160	500	250	Phase CT Primary (A)		
5	5	5	5	Phase CT Secondary (A)		
80	80	100	80	ZCT Primary (A)		
5	5	5	5	ZCT Secondary (A)		
40	40	40	40	Ambient Temperature (°C)		
Micom P225	Micom P225	Micom P225	Micom P225	Protection Relay		
1.15	1.15	1.15	1.15	0.20 - 1.5 I_n	Thermal current treshold	(49)
7	7	7	7	1 - 180	Overload Time Constant (Minutes)	(49)
95	95	95	95	20 - 100 %	Thermal Alarm Threshold	(49)
40	40	40	40	20 - 100 %	Restart Inhibit Level	(49)
9.3	9.3	6.3	6.3	0.20 - 12.0 I_n	Start Current	(50/51)
0.01	0.01	0.01	0.01	0.01 - 100 sec	Operate Time	(50/51)
16	16	31	23	0.2 - 100 % I_n	Start Current, I_0	(50/51G)
0.05	0.05	0.05	0.05	0.01 - 100 sec	Operate Time, t_0	(50/51G)
0.8	0.8	0.8	0.8	0.04 - 0.80 I_n	Start Current, I_2	(46)
0.1	0.1	0.1	0.1	0.01 - 200 sec	Time Dial	(46)
1	1	1	1	1 - 120 min	Restart Inhibit Time	

RELAY SETTING FOR OUTGOING MOTOR OF 2.4 kV MEDIUM VOLTAGE SWITCHGEAR/MOTOR CONTROL CENTER

Figure 2.5 *Relay setting for outgoing motor of 2.4 kV*

Halaman : 2 dari 2

3. Data Aktual Running MOTOR COAL MILL 2B 6P-2343-RM-B

NO	Tanggal	Parameter Operasi Teknis			Keterangan
		Arus (A)	Tegangan (V)	Daya (kWatt)	
1	5 Mei 2026	85,38	2.417,4	215,3	Pengambilan 1x dalam sehari
2	6 Mei 2026	82,84	2.415	204	Pengambilan 1x dalam sehari
3	7 Mei 2026	83,04	2.419	205,1	Pengambilan 1x dalam sehari
4	8 Mei 2026	76,93	2.413,7	187,7	Pengambilan 1x dalam sehari
5	9 Mei 2026	82,92	2.418,6	204,5	Pengambilan 1x dalam sehari
6	12 Mei 2026	89,82	2.419,2	220,1	Pengambilan 1x dalam sehari
7	13 Mei 2026	91,56	2.418,6	267,8	Pengambilan 1x dalam sehari
8	18 Mei 2026	85,38	2.415,7	209,5	Pengambilan 1x dalam sehari
9	19 Mei 2026	95,8	2.416,6	276,6	Pengambilan 1x dalam sehari
10	21 Mei 2026	83,18	2.420	204,42	Pengambilan 1x dalam sehari
					Pengambilan 1x dalam sehari

Palembang, 25 Mei 2026

Pengambil Data
Mahasiswa

A. Eka Nanda
NIM. 062330310533

Mengetahui
Pembimbing Lapangan

M. Sulaiman
Badge No. 53025

Figure 2.6 *Actual Coal Mill Motor Data for 10 Days in the Observation Period*

3. Results and Discussion

3.1 *Operating Principle of the Overcurrent Protection System (ANSI 50/51)*

The MiCOM P225 implements phase overcurrent protection through the [50/51] function. The relay documentation states that the phase-overcurrent function has three thresholds and that the first two thresholds can be configured with definite-time or inverse-time characteristics, while the third threshold is definite-time only.

1. In the present study, the ANSI 51 stage is represented by a 136 A pickup with the Schneider Electric Long Time Inverse characteristic and TMS = 0.025.
2. The reported high-set ANSI 50 stage is 1,227.6 A primary, equivalent to 9.3 × 132 A, with a 0.01 s definite delay. Because the available study data do not document the complete CT secondary configuration, this value is treated as a reported primary setting and not converted to a relay-secondary current.

To clarify the decision-making mechanism and the execution of power interruption by the circuit breaker when an anomaly occurs, the logic flow of the protection system is presented in **Figure 3.1** Logic Flowchart below:

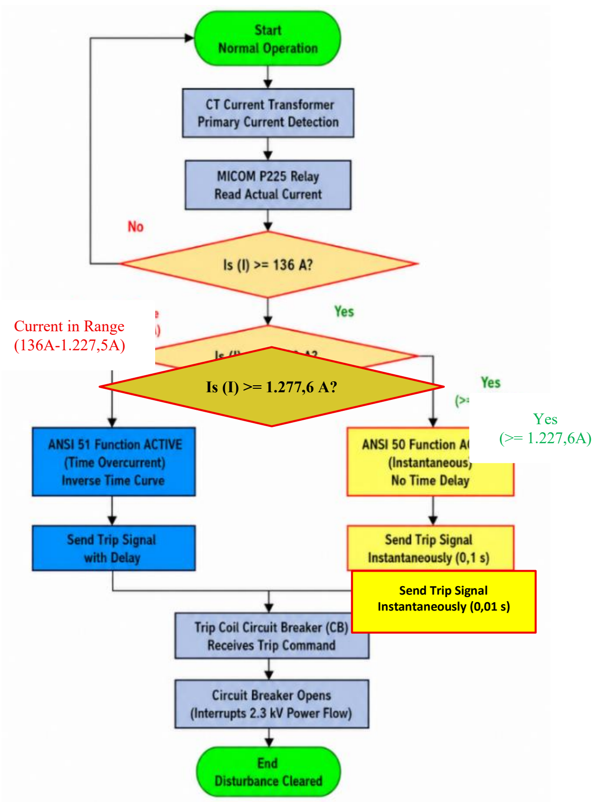

Figure 3. 1 *MiCOM P225-Motor Coal Mill 2B Relay Protection System Operation Logic Flowchart*

The operational mechanism of the electrical protection system is divided into four main stages as follows.

1. Current detection: the phase CTs provide the relay with the motor current signal. The MiCOM P225 applies the configured CT ratio when displaying measured phase current.
2. Logic processing: the relay compares the measured current with the programmed phase-overcurrent thresholds and applies the associated definite-time or inverse-time characteristic.
3. Fault Characteristic Classification Stage:
   a. ANSI 51 stage: when the current exceeds 136 A and remains below the high-set threshold, the relay follows the Long Time Inverse characteristic. This stage is evaluated here as phase overcurrent protection; the dedicated ANSI 49 thermal function and locked-rotor protection are outside the main scope.
   b. High-set ANSI 50 stage: when the current reaches or exceeds the reported 1,227.6 A threshold, the high-set definite-time stage is assumed to issue the protection signal after 0.01 s. The total circuit-breaker clearing time is not evaluated because breaker operating data were not available.
4. Protection limitation: without a prospective short-circuit study and coordination curves for other protective devices, the study cannot establish minimum-fault sensitivity, selectivity, or complete system coordination.

Table 3. 1 *Actual Coal Mill Motor Data for 10 Days in the Observation Period*

Date	Actual Motor Running Parameters			Information
	Current (A)	Power (kW)	Voltage (V)	
May 5, 2026	85,38	215,3	2.417,4	Observations were carried out between 10:00–10:30 WIB
May 6, 2026	82,84	204	2.415	
May 7, 2026	83,04	205,3	2.419	
May 8, 2026	76,93	187,7	2.413,7	
May 9, 2026	82,92	204,5	2.418,6	
May 12, 2026	89,82	220,1	2.419,2	
May 13, 2026	91,56	267,8	2.417,4	
May 18, 2026	85,38	209,5	2.415,7	
May 19, 2026	95,8	276,6	2.416,6	
May 20, 2026	83,18	204,42	2.420	

3.2 Relay Setting Parameter Calculation Analysis

The setting analysis distinguishes the physical motor nameplate current from the CT/relay base quantities. The motor nameplate FLA is 132 A. The plant data report a 160 A phase-CT primary rating. The ANSI 51 pickup is evaluated against the motor FLA, while the CT ratio and relay-side current representation remain a reproducibility item that should be verified from the relay configuration record.

Motor nameplate current:

$$I_{FLA} = 132\ A$$

ANSI 51 pickup setting: **Equation 3**

$$I_{set} = 1.03 \times 132\ A$$

$$I_{set} = 135.96\ A \approx 136\ A$$

High-set ANSI 50 setting:

I_{50} = 9.3 × 132 A = 1,227.6 A, with a reported definite delay of 0.01 s.

The existing relay setting is evaluated using the motor nameplate current as the reference current. The calculation shows the relationship between the motor FLA and the implemented ANSI 51 pickup.

Percentage of pickup above motor FLA:

$$\left[\frac{(Iset - IFLA)}{IFLA}\right] \times 100\% = \left[\frac{(136-132)}{132} 132\right] \times 100\% = 3.03\%$$

Thus, the existing ANSI 51 pickup is approximately 3.03% above the motor nameplate FLA. This describes the implemented setting and is not presented as a newly optimized setting.

High-set ANSI 50 setting relative to motor FLA:

$$\frac{150}{IFLA} = 1{,}227.6 \,/\, 132 = 9.30$$

Therefore, the reported high-set threshold is 9.3 times the motor nameplate current. The high-set delay used in the analysis is 0.01 s.

3.3 Long Time Inverse Curve Characteristic Analysis

The MiCOM P225 technical manual identifies the Schneider Electric Long Time Inverse characteristic with K = 120, α = 1, and L = 0. The TMS is set to 0.025. The operating-time equation used in this study is:

$$t = TMS \times \left[\frac{120}{\left(\left(\frac{I}{136}\right)^{1} - 1\right)}\right]$$

For I < 136 A, the relay is below the ANSI 51 pickup and the inverse-time equation is not interpreted as a physical trip time. At the pickup boundary, the mathematical expression approaches infinity. The P225 manual also notes a minimum guaranteed operating-current region for inverse characteristics around 1.1 *Is*, subject to tolerance.

$$t = TMS \frac{120}{\left(\frac{I}{I_s}\right) - 1}$$

The selected curve therefore shows decreasing operating time as the current increases above pickup. This analytical characteristic is used to evaluate selected current points and the reported motor starting current; it is not treated as proof of fault-clearing performance.

For the selected Long Time Inverse characteristic, the operating time is calculated from: Equation 2

$$t = TMS \times \left[\frac{K}{((I-Is)^{\alpha} - 1)} + L\right]$$

With TMS = 0.025, K = 120, α = 1, L = 0, and Is = 136 A, the equation becomes:

$$t = 0.025 \times \left[\frac{120}{\left(\left(\frac{I}{136}\right) - 10\right)}\right]$$

Example calculation at 150 A:

$$\frac{I}{IS} = \frac{150}{136} = 1.103$$

$$t = 0.025 \times \left[\frac{120}{(1.103-1)}\right] \approx 29.14\, s$$

This represents a current slightly above the ANSI 51 pickup. The calculated operating time decreases as current increases.

At the pickup boundary I = 136 A, the denominator approaches zero and the theoretical inverse-time equation tends toward infinity. Therefore, 136 A is treated as the pickup boundary rather than assigned a finite trip time.

For I < 136 A, the relay is below the ANSI 51 pickup and the protection status is classified as no operation. Negative operating times obtained by substituting sub-pickup currents into the inverse equation are not physically meaningful and are not used.

3.4 Disconnection Time Simulation and TCC Curve Generation

The relay operating time was calculated for selected current values using the Schneider Electric Long Time Inverse equation. The current ratio *I/Is* is dimensionless. For currents below the 136 A ANSI 51 pickup, the relay is classified as no operation. For currents above pickup and below the 1,227.6 A high-set threshold, the calculated operating time follows the Long Time Inverse characteristic. At the reported motor starting current of 985.91 A, the current ratio is $\frac{I}{Is} = \frac{985.91}{136} = 7.25$. Substitution into the Long Time Inverse equation gives t = 0.025 × 120 / (7.25 − 1) ≈ 0.48 s. At 1,227.6 A, the analysis changes to the reported high-set ANSI 50 definite-time stage of 0.01 s.

$$\frac{I}{Is} = \frac{1{,}227.6}{136} = 9.03$$

1. Current below pickup: I = 100 A

Result: I/Is = 100/136 = 0.74 < 1.00. The current is below the ANSI 51 pickup; therefore, no ANSI 51 operation is assigned.

$$t = 0.025 \times \left[120 — (7.25 - 1)\right] \approx 0.48\, s$$

$$\frac{I}{Is} = \frac{985.91}{136} = 7.25$$

2. Current slightly above pickup: I = 150 A

Result: I/Is = 150/136 = 1.10. The calculated ANSI 51 Long Time Inverse operating time is approximately 29.14 s.

$$t = 0.025 \times \left[120 — (1.103 - 1)\right] = 29.14\, s$$

$$\frac{I}{Is} = \frac{150}{136} = 1.103$$

3. Reported motor starting current: I = 985.91 A

Result: I/Is = 985.91/136 = 7.25. The calculated ANSI 51 Long Time Inverse operating time is approximately 0.48 s.

$$\frac{I}{Is} = \frac{100}{136} = 0.735 < 1.00$$

4. Reported high-set current: I = 1,227.6 A

Result: The current reaches the reported ANSI 50 high-set threshold. The analysis therefore uses the reported definite-time delay of 0.01 s rather than continuing the ANSI 51 inverse-time curve beyond the high-set threshold.

Table 3.2 *Results of Simulation Calculation of Relay Operating Time against Current*

Current (I)	Current Ratio (I/I_s)	Relay Working Time (t)	ANSI Protection Status/Function
0 A	0.00	No operation	Below ANSI 51 pickup
50 A	0.37	No operation	Below ANSI 51 pickup
100 A	0.74	No operation	Below ANSI 51 pickup

125 A	0.92	No operation	Below ANSI 51 pickup
136 A	1.00	—	Pickup boundary; no physical trip time
150 A	1.10	29.14 s	ANSI 51 (Long Time Inverse)
175 A	1.29	10.46 s	ANSI 51 (Long Time Inverse)
200 A	1.47	6.38 s	ANSI 51 (Long Time Inverse)
225 A	1.65	4.58 s	ANSI 51 (Long Time Inverse)
250 A	1.84	3.58 s	ANSI 51 (Long Time Inverse)
500 A	3.68	1.12 s	ANSI 51 (Long Time Inverse)
985.91 A	7.25	0.48 s	ANSI 51 (Long Time Inverse)
1,000 A	7.35	0.47 s	ANSI 51 (Long Time Inverse)
1,227.6 A	9.03	0.01 s	High-set ANSI 50 stage (DT)
2,000 A	14.71	0.01 s	High-set ANSI 50 stage (DT)

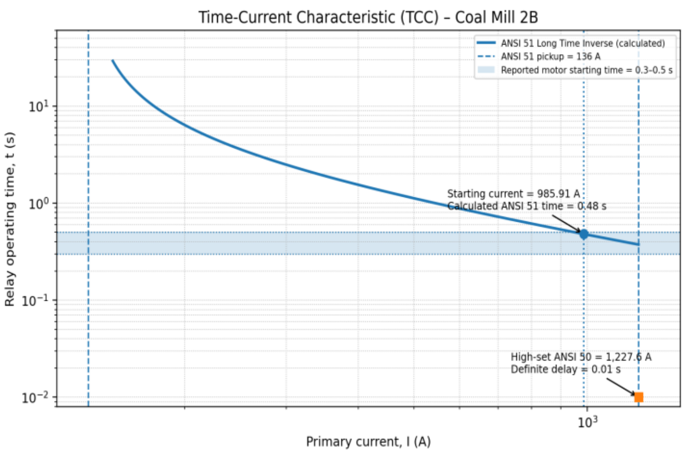

Figure 3.1 *Time-Current Characteristic of the Coal Mill 2B Motor*

The TCC represents the calculated operating characteristic of the existing ANSI 51 Long Time Inverse setting. The operating time decreases as current increases above the 136 A pickup. The reported starting current of 985.91 A corresponds to a calculated ANSI 51 operating time of approximately 0.48 s, while the reported high-set threshold of 1,227.6 A is associated with the 0.01 s definite-time stage.

a. The reported starting current of 985.91 A is below the 1,227.6 A high-set threshold but well above the 136 A ANSI 51 pickup. At this current, the calculated inverse-time operating time is approximately 0.48 s.
b. The reported motor starting duration is approximately 0.3–0.5 s. The calculated 0.48 s relay operating time therefore lies close to the upper limit of the reported starting interval. However, this comparison alone does not prove successful starting-current ride-through because the actual motor current-versus-time starting curve, relay event record, and direct trip response were not available.
c. The TCC shown here represents only the Coal Mill 2B motor relay characteristic. Because the time-current curves and settings of the upstream and downstream protective devices were not available, this figure cannot by itself establish selectivity or complete protection coordination.
d. The shaded 0.3–0.5 s interval in the revised TCC is the reported motor starting-time range, not a measured relay operating-time range. Its overlap with the calculated 0.48 s point indicates that starting-current ride-through requires verification rather than demonstrating that the relay will definitely ride through the complete starting transient.

3.5 Comparative Analysis of Relay Settings Against Daily Load Fluctuations

3.5.1 Operational Data Reading Procedure via MiCOM *P225 HMI*

Actual operating data for the Coal Mill 2B motor were collected through the MiCOM P225 HMI. The relay documentation states that MEASUREMENTS 1 provides phase-current and line-voltage measurements as true RMS values after applying the configured CT/VT ratios, while MEASUREMENTS 2 provides active power and other power quantities.

For this study, the ten observation records include current, active power, and voltage. The observation window was 10:00–10:30 WIB on each recorded day.

1. The measured current is used to calculate the current-based loading ratio, while voltage and active power are reported as supporting operating-condition information. The current-based loading ratio is an approximation and should not be interpreted as a direct measurement of mechanical load because motor load also depends on voltage, power factor, efficiency, and other operating variables.
2. MEASUREMENTS 2: Monitors the total Active Power (P) in kW.

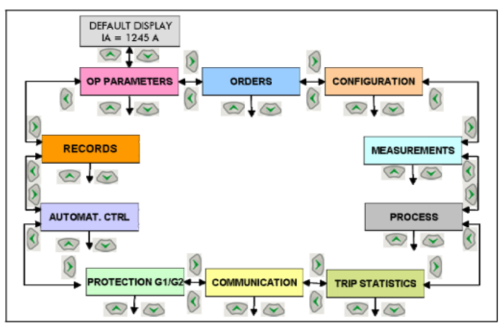

Figure 3. 2 *MiCOM P225 Display Organization Menu*

3.5.2 Operating-Current Comparison with the ANSI 51 Pickup

The ten observation records show that the running current remained below the 136 A ANSI 51 pickup. The corrected values in **Table 3.3** use 76.93 A for Day 4 and 83.18 A for Day 10, consistent with **Table 3.1** The average current from these ten corrected values is approximately 85.69 A, or 64.9% of the 132 A nameplate current.

Across the ten observations, current ranges from 76.93 A to 95.80 A. The average current is approximately 85.69 A, corresponding to 64.9% of the 132 A nameplate current. The smallest margin to the ANSI 51 pickup occurs on Day 9: 136 − 95.80 = 40.20 A.

The same calculation procedure is applied to the other nine observation records. **Table 3.3** presents the resulting current-based loading and margin to pickup.

Margin to ANSI 51 pickup *= I_{set} − I = 136 − 85.38 = 50.62 A*

Current-based loading *= (I / IFLA) × 100% = (85.38 / 132) × 100% = 64.68%*

A representative calculation is provided for Day 1, while the remaining observation days are summarized in ***Table 3.3*** *to avoid repeating identical arithmetic.*

Table 3. 2 *Evaluation Results of Percentage Loading and Daily Safety Margin*

Day Observation	Current Actual (A)	Current-based Loading (%)	Pickup Limit (A)	Operating-current Margin to Pickup (A)
Day 1	85.38	64.7	136	50.62
Day 2	82.84	62.8	136	53.16
Day 3	83.04	62.9	136	52.96
Day 4	76.93	58.3	136	59.07
Day 5	82.92	62.8	136	53.08
Day 6	89.82	68.0	136	46.18
Day 7	91.56	69.4	136	44.44
Day 8	85.38	64.7	136	50.62
Day 9	95.80	72.6	136	40.20
Day 10	83.18	63.0	136	52.82

The observed current ranged from 76.93 A to 95.8 A. The corresponding operating-current margin to the 136 A pickup ranged from 40.20 A to 59.07 A. This comparison shows that the sampled normal operating current was below the ANSI 51 pickup during the ten observation records. It does not demonstrate false-trip immunity during starting, transient overloads, faults, or changing process conditions.

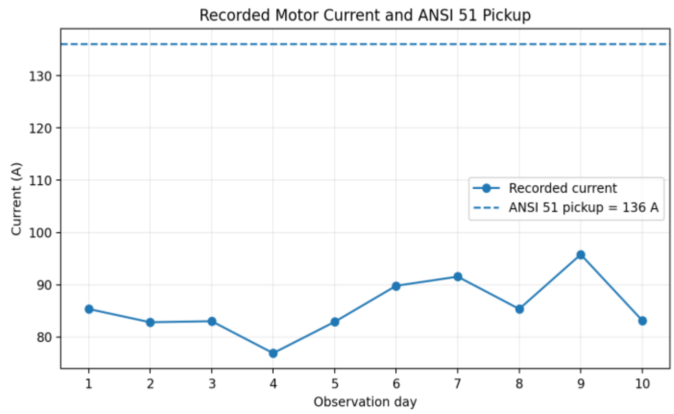

Figure 3.2 *Comparison of Recorded Motor Current with the 136 A ANSI 51 Pickup*

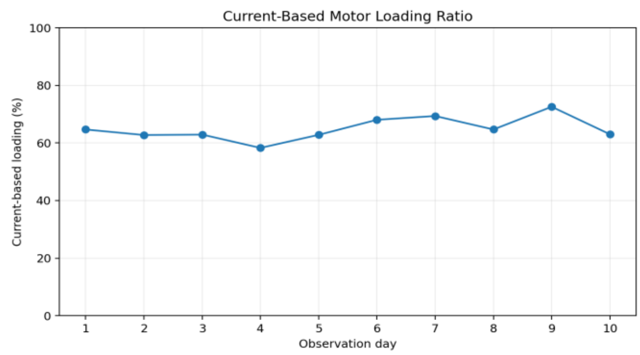

Figure 3.3 *Current-Based Motor Loading Ratio during the Ten Observation Records*

4. Conclusion

1. The existing ANSI 51 pickup of 136 A is approximately 1.03 times the 132 A motor nameplate current, while the reported high-set ANSI 50 stage is 1,227.6 A with a 0.01 s definite delay. These values describe the implemented relay settings and are not presented as a newly optimized protection design.
2. Based on the Schneider Electric Long Time Inverse characteristic of the MiCOM P225 (K = 120, α = 1, L = 0, TMS = 0.025), the calculated ANSI 51 operating time at the reported starting current of 985.91 A is approximately 0.48 s. Because the reported motor starting duration is 0.3–0.5 s, the calculated point lies close to the upper limit of the starting interval. However, starting-current ride-through cannot be conclusively verified because the actual current-versus-time starting curve, relay event/trip record, and direct trip test were not available.
3. During the ten observation records, the running current ranged from 76.93 A to 95.80 A, with an average of approximately 85.69 A, equivalent to 64.9% of the 132 A nameplate current. The operating-current margin to the 136 A ANSI 51 pickup ranged from 40.20 A to 59.07 A. These results show that the sampled normal operating current remained below the existing ANSI 51 pickup

during the observation period, but they do not prove immunity from false trips during starting, transient overloads, faults, or other unobserved operating conditions.

4. Complete protection selectivity and coordination cannot be established from the available data because the time-current characteristics and settings of the upstream and downstream protective devices were not available. A complete coordination assessment would also require the relevant motor starting/locked-rotor, equipment-damage, feeder, breaker, and upstream/downstream protection characteristics on a common TCC.
5. Minimum-fault sensitivity, CT saturation performance, total breaker clearing time, and overall relay dependability/security were not directly validated. The available data do not include a complete short-circuit study or sufficient CT secondary configuration, accuracy class, burden, and relay-side scaling information. Therefore, the study should be interpreted as an analytical evaluation of the existing ANSI 50/51 settings and the sampled operating current, rather than as proof of complete protection coordination, fault sensitivity, starting ride-through, or overall relay reliability.

ACKNOWLEDGEMENT

Our thanks as writers to Electrical Engineering, Electrical Engineering Study Program, Politeknik Negeri Sriwijaya for providing research facilities and writers and journals that we made references for as material in this research.

References

[1] Aiyub, S., Yaman, & Maimun. (2019). Penggunaan Aiyub, S., Yaman, & Maimun. (2019). Penggunaan Relay Arus Lebih Tipe SEL-351A sebagai Proteksi pada Motor Induksi 3 Phasa. Prosiding Seminar Nasional Politeknik Negeri Lhokseumawe, 3(1), 67–74.http://ejurnal.pnl.ac.id/semnaspnl/article/view/1669%0Ahttp://ejurnal.pnl.ac.id/semnaspnl/article/viewFile/1669/1435.

[2] Bagia, I. Nyoman, & Parsa, I. Made. (2018). Motor-Motor Listrik. CV. Rasi Terbit. *LISTRIK*. Edited by D. Manesi. CV. Rasi Terbit, 2018. Hal 1.

[3] IEC. (2009). IEC 60255-151:2009, Measuring relays and protection equipment – Part 151: Functional requirements for over/under current protection. International Electrotechnical Commission.

[4] IEEE Power and Energy Society. (2012). IEEE Std C37.96-2012, IEEE Guide for AC Motor Protection. IEEE Standards Association. *Ansi IEEE C37.2 - Protection Relais Codes | PDF*. Diakses pada 27 Februari 2026.

[5] IEEE Power and Energy Society. (2022). IEEE Std C37.2-2022, IEEE Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations. IEEE Standards Association.*IEEE ComputerSociety* (Vol. 2022, Number November). Hal 12, 18, 37, 39, dan 49. *http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4610935%5Cnhttp://ieeexplore.ieee.org/servlet/opac?punumber=4610933*.

[6] Joostberens, J., Heyduk, A., Boron, S., & Bauerek, A. (2020). Optimal selection of time-current characteristic of overcurrent protection for induction motors in drives of mining machines with prolonged starting time. Energies, 13(17). (2020). Optimal selection of time-current characteristic of Overcurrent protection for induction motors in drives of mining machines with prolonged starting time. *Energies*, *13*(17). Hal 1-3. *https://doi.org/10.3390/en13174466*

[7] Mahindhara, V. R., Pujiantara, M., & Priyadi, A. (2015). Algorithm Pada Sistem Kelistrikan PT. Pupuk. 5(2). ISSN: 2337-3539. *Algorithm Pada Sistem Kelistrikan PT . Pupuk*. *5*(2). Vol. 5, No. 2. hal B53-B53. ISSN: 2337-3539.

[8] Schneider Electric. (2018). MiCOM P220/P225 Technical Manual, P22x/EN M/G66, Software Version V12. *INFORMATION MiCOM P225*. (2018). P22x/EN GS/E56 Page 4/20, P22x/EN TD/G66 Page 20/38, dan P22x/EN FT/D55 Page 7/54.

[9] Siswoyo. (2008). Teknik Listrik Industri Jilid 2. Direktorat Pembinaan Sekolah Menengah Kejuruan. *2 SMK Direktorat Pembinaa Sekolah Menengah Kejuruan*. hal 5.2-5.7. ISBN: 978-979-060-081-2.

[10] U.S. Department of Energy. (2014). Determining Electric Motor Load Ranges. Motor Challenge. Electric Motor Load Ranges. *Motor Challenge*. *https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf*. Hal 3.

[11] AIM. (2010). *KOMPONEN-KOMPONEN PROTEKSI*. DUNIA ELEKTRO. *KOMPONEN-KOMPONEN PROTEKSI ~ Dunia Elektro*. Diakses pada 20 April 2026.