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Protection System on Connect Panel for Use 7KT Smart Multi Function Meter Based on PLC and HMI via Modbus RTU Communication

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Abstract

One function of the protection system is to avoid or reduce damage to electrical equipment due to abnormal conditions such as undervoltage, overvoltage, overcurrent, underfrequency and harmonics. This protection system requires a Smart 7KT Multi-Function Meter and a PLC. Where the Smart 7KT Multi-Function Meter is used for monitoring then transferred to the PLC and detecting any abnormalities in the system when a disturbance occurs then the Smart 7KT Multi-Function Meter will send data to the PLC, then send a signal to the circuit breaker to disconnect the network that is experiencing disturbance. While the PLC is used to execute data that has been taken by the Multi-function Meter Smart 7KT for control or control on the Multi-function Meter Smart 7KT. When a disturbance occurs, the program on the PLC will protect and the type of disturbance will be displayed on the HMI screen. The results of this project were successful in securing undervoltage disturbances of 314.2 V for line voltages, overvoltage of 412.1 V for line voltages, overcurrent of 1.6 A, and testing of THD voltage between phases V12 of 1.3%, THD V23 of 1.1%, and THD V13 of 1.1%, for THD currents of 14.6% for THD I1, THD I2 of 9.4%, and THD I3 of 10.6% which occur in the electric power installation network which causes damage to electrical equipment.

Keywords: Protection, undervoltage, overvoltage, overcurrent, THD

Introduction

Electrical energy is one of the most abundant energies used by humans throughout the world(Ellabban et al., 2014), the use of electrical energy is very varying as in industry, public places, education, as well household, equipment that uses electrical energy must have good power quality such as decent voltage, current, frequency and Good. To improve the good quality of electrical equipment electricity is equipped with protective devices that are used to protect equipment that is sensitive to damage(Eissa, 2015), electrical protection equipment on generally is voltage protection(Bhosale et al., 2018), current protection, frequency protection, and short circuit protection.

Protection of an electric power system is a safety system which is carried out on electrical equipment, which is installed on the electric power system(Rezaee Jordehi, 2016). For example, generators, transformers, networks transmission/distribution etc. to abnormal conditions of the system Alone. What is meant by abnormal conditions include: in the form of: short circuit, over/under voltage, overload, and frequency down/up system.

The function of the protection system is to avoid or to reduce damage to electrical equipment due to disturbances (conditions abnormal) the faster the reaction of the protection device used the less influence disturbances will have on possibilities equipment damage(Goh, 2017), to speed up localization of disturbed areas to be as small as possible, to provide electricity services with high reliability to consumers and also good electricity quality, and to protect humans (especially) from the dangers posed by electricity.

So that the protection system can be said to be good and correct (able to react quickly, precisely and cheaply), it is necessary to select carefully and considering factors, namely: type of channel, which is secured, the importance of the protected channel, the possibility the number of disturbances occurring, and the techno-economics of the system used (Tong et al., 2023). The main equipment used to detect and command the working protection equipment is a relay (Debnath et al., 2023). The function of the protection relay is determining immediately the termination/closure of distribution services every element of the electric power system if it encounters disturbances or conditions abnormal work (Zeng et al., 2023), which may result in equipment damage or will affecting the system/part of the system that is still operating normally.

Literature Review

In this research, we focus on developing a comprehensive protection system for in this research, we focus on developing a comprehensive protection system for three-phase electric motors using Programmable Logic Controller (PLC)(Prakoso, 2023) and Human Machine Interface (HMI)(Prasetyo, 2024) technology. The main concepts and components used in this research include:

System Protection

The protection system is electrical equipment that has the function of secure electrical power systems(Prasetyo, 2023), for example transformers, generators, transmission lines and other electrical equipment. The protection system is working by identifying and separating the parts of the network that occur disturbance. Failure of the protection system causes damage to electric power system (Xu et al., 2023), then to achieve the goal of the protection system good at overcoming disturbances in the electricity network as well as providing stability when normal conditions are needed main components of protection system equipment, such as CT, Potential 8 Transformer (PT), Circuit Breaker (CB), Power supply, Direct Current (DC)/ Alternating Current (AC), protection relay connected to recorder system, Supervisory Control And Data Acquisition (SCADA) and relay indication.

Undervoltage Protection

In the electric power distribution rules, it is explained that for undervoltage is -10% of normal voltage(Poornima et al., 2018). Voltage protection more tasked with protecting electrical machines and generators 9 associated electricity connected to it, from the effects of increasing voltage which is not allowed.

Overvoltage can be caused by manual operation of the system incorrect excitation, incorrect operation of the automatic voltage regulator, load shedding (full) of the generator, separation of the generator from the system or during island operations, poor wiring, distance transformer far from consumers and loading excessive (Jha et al., 2024).

Overvoltage protection is a two-stage design and evaluate the positive sequence component U of the voltage. Voltage large excess starts fast travel; smaller voltage started the slow journey. Voltage and delay limit values time can be set individually for each stage.

Overvoltage Protection

In the electric power distribution rules, it is explained that for overvoltage is +5% of normal voltage(Hashemi & Østergaard, 2017). Undervoltage protection detects voltage drops in electrical machines and prevents them Unpermitted and possible operating conditions loss of stability. For this, the fundamental wave of the system positive sequence is what matters. The phase voltage is filtered by protection (Fourier analysis) and only fundamental waves evaluated. Of these, protection only detects the system positive sequence. This is called rated voltage (phase to phase).

Overcurrent

Overcurrent is the current flowing on a circuit exceeds the normal current when the load is full flows through the motor circuit. Overcurrent itself can occur due to overload or short circuit (short circuit) that occurs in the circuit. On electrical circuit for a motor, overcurrent (overcurrent). What arises is the current that flows through the circuit the magnitude exceeds the normal current of the motor when the motor is loaded full or better known as Full Load Amps (FLA). In Electrical power installations are explained to determine capacity breaker, namely the nominal current multiplied by 125% for a safety factor(Chou et al., 2017).

THD (Total Harmonic Distortion)

Total Harmonic Distortion is an intermediate percentage value harmonic components with fundamental components. The greater the THD percentage, the greater it is risk of equipment damage due to harmonics occurring in the current as well as voltage. The THD standard for voltage is not allowed +5%(Ruderman, 2015). Meanwhile, the THD standard for current cannot be +10% according to PLN standards. The cause of this harmonic wave is use of non-linear loads in power systems causes distortion in the sine waveform. Non-burden This linear model is modeled as a current source that injects current harmonics into the power system. More and more equipment Electronics used such as: TV, computers and tools saving power will further add harmonics to the current electricity, so the resulting THD will be greater.

PLC Mitsubishi FX3U

PLC is a control device that can be programmed for control processes or machine operations(Hudedmani et al., 2017). The program control of the PLC is Analyzes the input signal then adjusts the output state accordingly with the wishes of the user. In this system the PLC is used to execute programs when there is a disturbance in the electrical power installation network orders the relay to work to turn off the breaker.

HMI Mitsubishi GS2107

Human Machine Interface or HMI is a tool liaison and communication medium between machines and humans (Fabian et al., 2024). As a connecting medium, of course the HMI system can collect, and process data obtained from the controlled machine becomes information that is easy to understand by man. Apart from displaying data, HMI can also describe the process that is taking place on the machine controlled. For this reason, HMI must be made as similar as possible to machines that are controlled to make it easier for humans to operate and control the machine(Carsten & Martens, 2019). In this system HMI is used to display results monitoring voltage, current, frequency and THD from Multi-Function Meter Smart 7KT and enter the set points that will be input on PLC.

Research Method

In this research, the research stages start from literature study, needs analysis, tool design, tool testing to get results. From this stage, the tool design model is obtained as follows.

Here are the general stages in the system testing process:

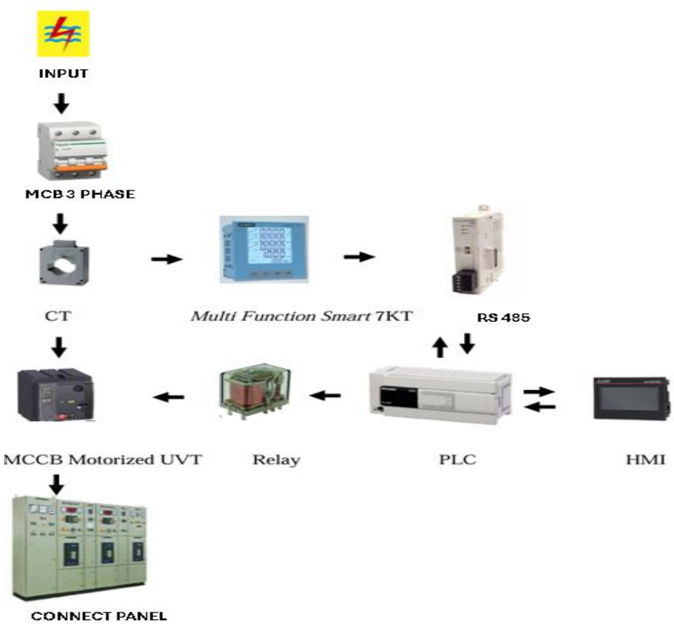


Figure 1. Block Diagram

The block diagram can be explained as follows:

1. The input is used as a control circuit source.
2. CT (Current Transformer) is used as a current meter which enters the network.
3. 3 Phase MCB is used as safety in power circuits.
4. Multi-function Meter Smart 7KT is used for monitoring then transferred to the PLC and detects its presence abnormality in the system when a disturbance occurs then Multi-function Meter Smart 7KT will send data to the PLC, then sends a signal to the breaker (circuit breaker) to disconnect the network that is experiencing disturbance.
5. PLC is used to execute the data that has been taken by Multi-function Meter Smart 7KT for control or control on the Multi-function Meter Smart 7KT.
6. RS485 is used as a link between the PLC and Multi-Function Meter Smart 7KT.
7. HMI is used to display voltage monitoring results, current, frequency and THD from the Multi-function Meter Smart 7KT and enter the set point that will be input to the PLC.
8. The relay is used to trigger the coil on the upper breaker commands from the PLC.
9. Divider Panels are used as connectors, dividers, protection, and load breaker.

Result and Discussion

For research to obtain good results, a method is needed research or planning for making tools up to collecting data for research. Figure 2 is an undervoltage and overvoltage test circuit.

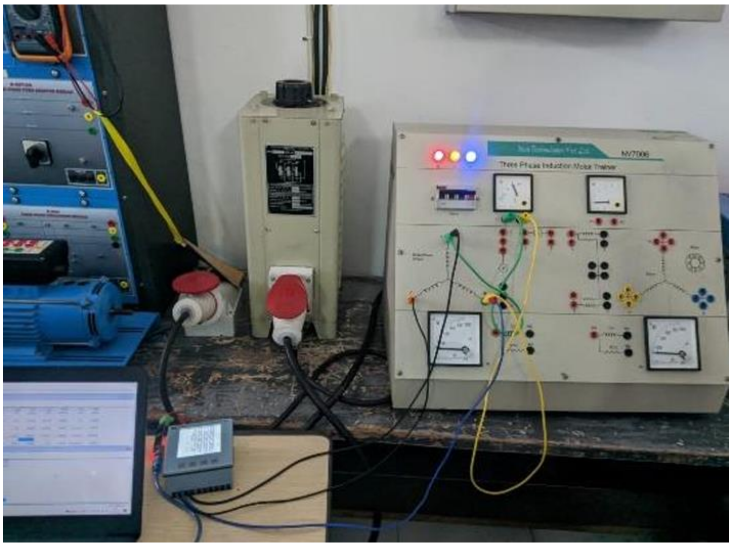


Figure 2. Undervoltage and Overvoltage Testing

Table 1. Under Voltage Test Results for line-to-line voltage

No.	**Variation**	**Value**
1	Voltage V12	270 V
2	Voltage V23	263 V
3	Voltage V31	269 V

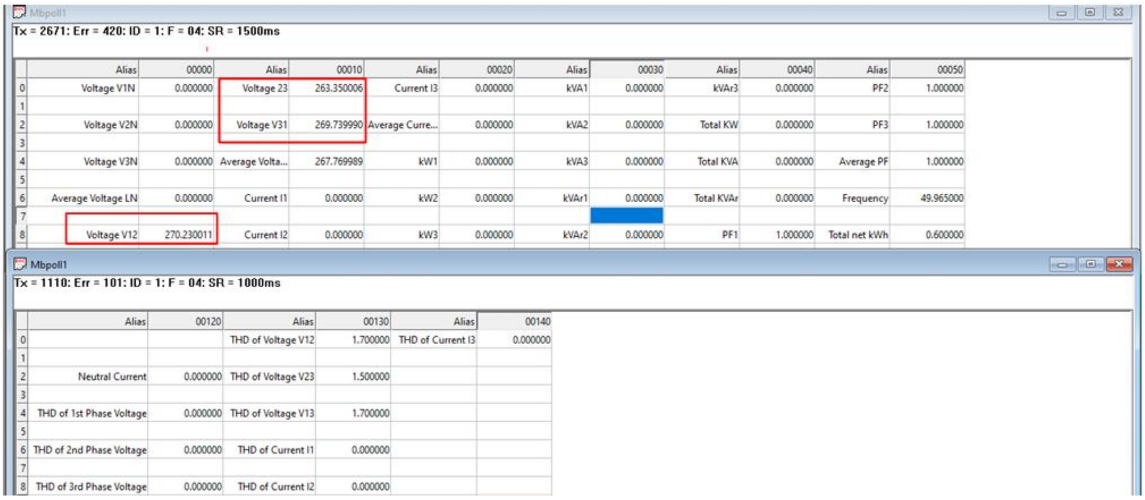


Figure 3. Undervoltage Test Data

In the troubleshooting test results using autotransformer obtained a value of V12 of 270 V, V23 of 263 V, and V31 is 269 V. These measurement values are used to trigger and activate undervoltage protection used to protect against danger and interference from the electric power network. At the undervoltage tolerance limit of - 10% of nominal voltage, so that the voltage resulting from troubleshooting has been exceeds the specified tolerance value and can be used for activates undervoltage protection.

Table 2. Over Voltage Measurement Results, line to line voltage

No.	Variation	Value
1	Voltage V12	428 V
2	Voltage V23	420 V
3	Voltage V31	428 V

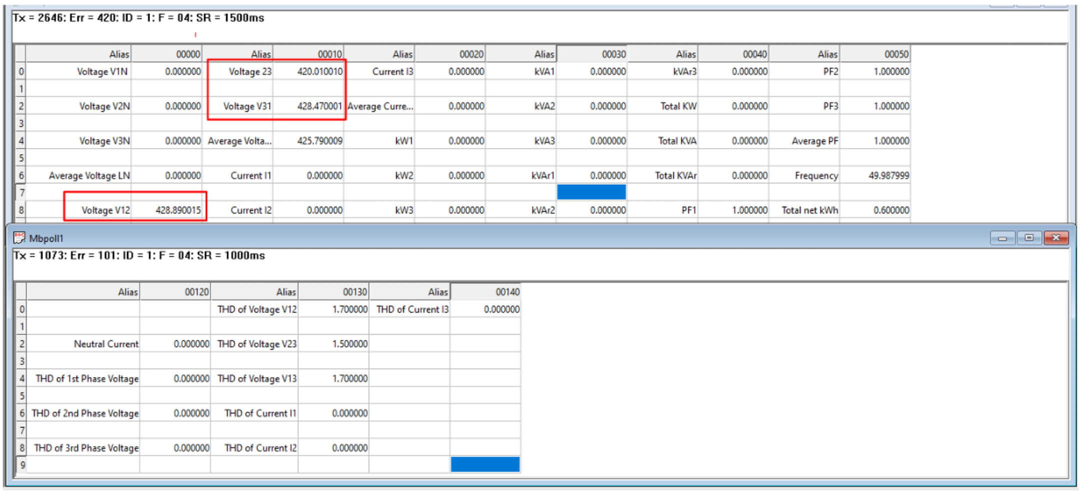


Figure 4. Overvoltage Test Data

In the troubleshooting test results using an auto transformer, the value of V12 was 428 V, V23 was 420 V, and V31 was 428 V. These measurement values used to trigger and activate overvoltage protection which is used to protect against danger and disturbance electric power network. At the overvoltage tolerance limit only of 5% of the nominal stress, so that the yield stress troubleshooting has exceeded the specified tolerance value and can be used to activate overvoltage protection.

Table 3. Overcurrent Measurement Results

No.	**Variation**	**Value**
1	Current I1	5.9 A
2	Current I2	6.1 A
3	Current I3	5.7 A

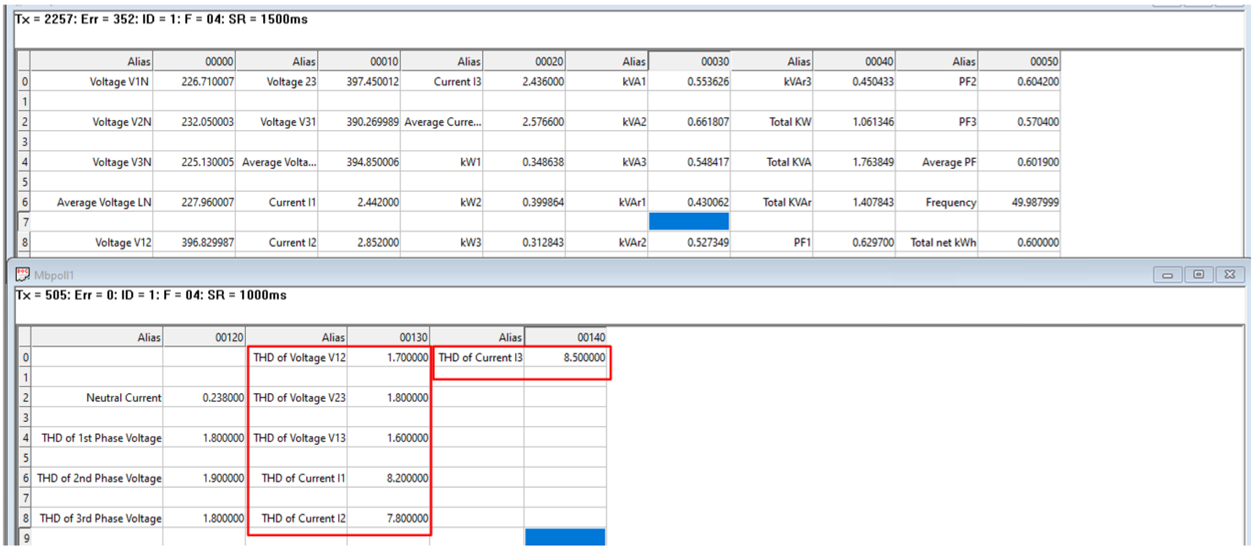
	Alias	00000	Alias	00010	Alias	00020	Alias	00030	Alias	00040	Alias	00050
0	Voltage V1N	227.509995	Voltage 23	395.839996	Current I3	5.746000	kVA1	1.342764	kVAr3	1.230226	PF2	0.296300
1												
2	Voltage V2N	231.009995	Voltage V31	389.519989	Average Curre...	5.932000	kVA2	1.420249	Total KW	1.210565	PF3	0.294200
3												
4	Voltage V3N	224.020004	Average Volta...	394.059998	kW1	0.410888	kVA3	1.287219	Total KVA	4.050232	Average PF	0.298800
5												
6	Average Voltage LN	227.509995	Current I1	5.902000	kW2	0.420894	kVAr1	1.278353	Total KVAr	3.865029	Frequency	49.976002
7												
8	Voltage V12	396.839996	Current I2	6.148000	kW3	0.378783	kVAr2	1.356450	PF1	0.306000	Total net kWh	0.600000
9												

Figure 5. Overcurrent Test Data

The results of the troubleshooting test using a motorbike 3 phase induction obtained a value of I1 of 5.9 A, I2 of 6.1 A, and I3 is 5.7. This measurement value is used to trigger and activate the overcurrent protection used to protect against dangers and disturbances from the power network electricity. At the overcurrent limit, a setpoint is set equal to the load installed, so the flow of troubleshooting results has exceeded the limit overcurrent set point is defined and can be used for activates overcurrent protection.

Table 4. THD Measurement Results

No.	**Variation**	**Value**
1	THD Of Voltage V12	1.7 %
2	THD Of Voltage V23	1.8 %
3	THD Of Voltage V13	1.6 %
4	THD Of Current I1	8.2 %
5	THD Of Current I2	7.8 %
6	THD Of Current I3	8.5 %


Tx = 2257: Err = 352: ID = 1: F = 04: SR = 1500ms

	Alias	00000	Alias	00010	Alias	00020	Alias	00030	Alias	00040	Alias	00050
0	Voltage V1N	226.710007	Voltage 23	397.450012	Current I3	2.436000	kVA1	0.553626	kVAr3	0.450433	PF2	0.604200
1												
2	Voltage V2N	232.050003	Voltage V31	390.269989	Average Curre...	2.576600	kVA2	0.661807	Total KW	1.061346	PF3	0.570400
3												
4	Voltage V3N	225.130005	Average Volta...	394.850006	kW1	0.348638	kVA3	0.548417	Total KVA	1.763849	Average PF	0.601900
5												
6	Average Voltage LN	227.960007	Current I1	2.442000	kW2	0.399864	kVAr1	0.430062	Total KVAr	1.407843	Frequency	49.987999
7												
8	Voltage V12	396.829987	Current I2	2.852000	kW3	0.312843	kVAr2	0.527349	PF1	0.629700	Total net kWh	0.600000

Mbpoll1

Tx = 505: Err = 0: ID = 1: F = 04: SR = 1000ms

	Alias	00120	Alias	00130	Alias	00140
0			THD of Voltage V12	1.700000	THD of Current I3	8.500000
1						
2	Neutral Current	0.238000	THD of Voltage V23	1.800000		
3						
4	THD of 1st Phase Voltage	1.800000	THD of Voltage V13	1.600000		
5						
6	THD of 2nd Phase Voltage	1.900000	THD of Current I1	8.200000		
7						
8	THD of 3rd Phase Voltage	1.800000	THD of Current I2	7.800000		
9						

Figure 6. THD Test Data

The results of the troubleshooting test using a motorbike 3 phase induction obtained a THD value of V12 voltage of 1.7%, The THD of the V23 voltage is 1.8%, and the THD of the V13 voltage is 1.6%. Meanwhile, the THD of current I1 is 8.2%, the THD of current I2 is 7.8%, and the I3 current THD is 8.5%. The measurement value used to trigger and activate protection on THD which is used to protect against danger and disturbance electric power network. At the THD voltage limit that is not allowed +5%, while the THD standard for current cannot be +10%., So the voltage resulting from troubleshooting has exceeded the value tolerances are set and can be used to activate THD protection.

Conclusion

Based on the results of testing and analysis carried out on work system, then conclusions can be drawn overvoltage protection system is measured at 412.1 V for voltage line, undervoltage of 314.2 V for line voltage, measured overcurrent of 1.6 A, for testing the THD voltage between V12 phases of 1.3%, THD V23 is 1.1%, and THD V13 is 1.1%, for current THD of 14.6% for THD I1, THD I2 of 9.4%, and THD I3 of 10.6%. Can be designed using the Multi-Function Meter Smart 7KT PLC and HMI based via MODBUS RTU communication. Data from The Smart 7KT Multi-Function Meter can be transferred to the PLC for use protects the split switch panel. After that, the HMI can display the data monitoring and protection according to the data on the Multi-Function Meter Smart 7KT. The tool that has been created is suitable for implementation on the switchboard panel as security for the electric power network.

Declaration of conflicting interest

The authors declare that there is no conflict of interest in this work.

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