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Power System Protection Laboratory: Design for Diploma Course in Politeknik Merlimau

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ABSTRACT

Power system protection is a branch of electrical power engineering that deals with the protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network. Power System Protection is taught in polytechnic as a final semester subject for diploma student in electrical engineering, which consists of theoretical and practical work. As part of the syllabus, the course learning outcome on practical work is to produce students that can handle any practical work related to common protection system applied to power distribution system equipment. Most practical work related to Power System Protection subject is done using simulation environment, where the actual performance of protection equipment cannot be measured. This paper presents the configuration of Power System Protection laboratory that involves six experimental set of practical work for diploma student of Electrical Engineering Department in Politeknik Merlimau. Emphasis is given into the stand alone test for relay protection experimental set and fault current relay experimental set. This laboratory is appropriate in facilitate the teaching process to demonstrate the realistic operating characteristics of equipment protection switching and dynamic response system to relay protection to the students.
KEYWORDS: Power System Protection, Practical Work, Diploma Student, Polytechnic.

INTRODUCTION

The essential part of the design of power supply network is the calculation of the currents, which flow in the components when faults of various types occur. The magnitude of the fault currents give the protection engineer the current setting for the protection to be used and information of the rating of the circuit breakers. If faults occur on the system, the engineer observing the presence of the fault can operate the appropriate circuit breakers to remove the faulty or plant from the network.

Fault in power system resulting in high currents and also possible loss [15] of synchronism must be isolated in the minimum of time. Power system protection in electrical supply is required to detect abnormal currents and voltages. In the case of abnormality, the appropriate circuit breakers should be opened [1-2]. In large interconnected network, considerable design [16] knowledge and skill are required to remove the faulty part from the network and leave the healthy remainder working intact. Therefore, high priority should be placed in designing the curriculum structure of this subject. It is imperative for future engineers to have vast understanding of power system protection to ensure the continuous supply and high efficiency of power system delivered to consumers[3-4].

Future engineers must have knowledge that goes beyond mere theory as Power System Protection is a compulsory subject for diploma in electrical engineering in polytechnic where practical work is a main component in this subject. The subject aims to provide students with the knowledge and exposure of electrical power protection equipment. The focus are on the common protection system applied to power distribution system, switching equipment and their operation. However, it is impossible to bring students to conduct laboratory work in the field [5]. This is due to Power System Protection involves mostly large appliances and it is connected to the electricity provider. Thus, most laboratories that involve Power system Protection utilise only simulation to explain the theory that had been taught in classroom [6-8, 12, 14, 17]. However, it is difficult to evaluate the actual performance of protection equipment just through computer simulation or bench top testing. A physical lab is very important in providing a better understanding for the subject of power system protection. This paper presents the configuration of power system protection laboratory for diploma student of electrical engineering department in polytechnic. The practical laboratories include six experimental sets that are carried out during the semester. This laboratory is an ideal facility to demonstrate and teach more realistic operating characteristics of protection and switching equipment and more importantly dynamic response of protective relay systems.

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Overview of Power System Protection Subject

Power System Protection is a final year subject for Diploma of Electrical Engineering at Politeknik Merlimau in Malaysia. This subject is conducted over 15 weeks per semester. It consists of 30 hours of theory delivery and 30 hours of hands on practical work. The theories are covered by five chapters namely Introduction of Power system Protection, MVA Fault Calculation Method, Basic Protection and Switching Equipment, Protective Relays and Line/Machine [13] protection scheme respectively. Students' cognitive knowledge on theory is tested using a theory test, four quizzes and one case study. The hands on practical work consist of six routine labs. In the beginning of the semester, three routine labs will be conducted. It is basic hands on practical on the basics of protection of distribution power system. The remaining three practical works consists of calculation of time multiplier setting and over current with particular curve to be set to the relay. This practical work will be conducted mid-semester after students have gained adequate theoretical knowledge.

METHODOLOGY

The practical laboratories include six experimental sets that were prepared during the semester. The objective of the first experiment is to demonstrate the basic equipment in the low voltage protection system. Second experiment involves simple fault calculation and to demonstrate the earth fault relay in the Three Phase System. The third experiment demonstrates the technique of switching the switchgear such as circuit breaker and isolator in the Three Phase System. The fourth and fifth experiments involve in manipulating the time multiplayer setting using the multiplier curve and graph. The last experiment is a platform to show and teach a more realistic operating characteristics of protection relay and switching equipment and more importantly dynamic response of protective relay systems.

The main focus of the practical experiment outcome is to provide student with the knowledge of relays configurations in protection system. There are two types of relays that are utilised in all of the practical experiments such as, Distribution Overcurrent relay and combined overcurrent Earth Fault relay. These relays are operated using 415V, 50 HZ and built in the EME4 education trainer depicted in **Error! Reference source not found.**.

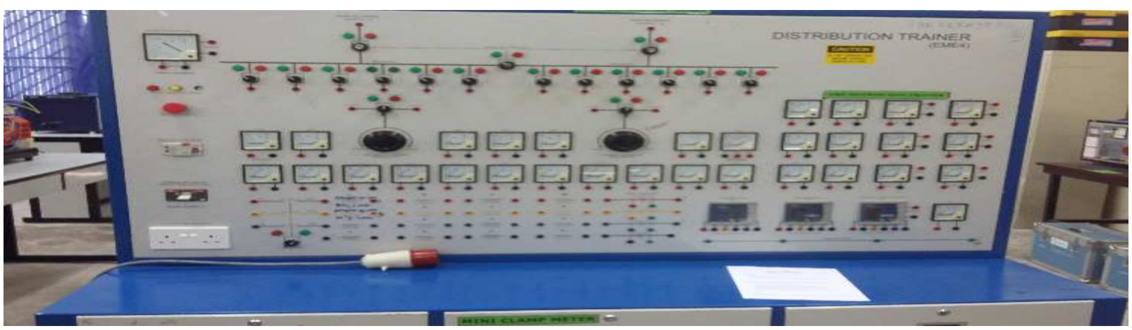

Figure 1: EME4 distribution trainer for education

Figure 1 depicts the set of educational trainers including metering, a basic protection equipment such as current transformer, relays and switchgear for low voltage three phase systems. This education trainers included complete protection system and suitable for low voltage 415V, 50Hz. In this paper, emphasis is given onto the stand alone test for relay protection experimental set and fault current experiment.

Inverse Definite Minimum Time (IDMT)

In this practical laboratory, the MK233A trainer has been used. This is a microprocessor based numerical overcurrent relay. This relay consists of independent low-set and high-set elements for overcurrent setting. The high-set element can be disabled by the user. The time current characteristics of the low set element are definite time or five selectable (IDMT) curves. The high-set element is a definite time or instantaneous relay [9].

Combined Overcurrent and Earth Fault Relay

The MK1000A or Combined Overcurrent and Earth fault relay has been chosen as an earth fault relay in this practical work. It seems similar to the IDMT relay. This relay provides three independent phase overcurrent elements and one non-directional earth fault element. All of these elements are connected to the current transformers of the feeder to be protected. The overcurrent and the earth-fault elements consist of independent low-set units and high-set units. The time current characteristic of the low-set units is selectable between

(IDMT) normal inverse curve 3/10, normal inverse curve 1.3/10, long time inverse curve, very inverse curve, extremely inverse curve and definite time. These curves are provided by the manufacturer of relay[10].

Standalone Relay Test: Experimental Setup

A similar laboratory practice is also conducted in Curtain University Australia where they have proposed several methods for motivating their student in taking a Power System Protection Course. The laboratory activities developed for the Power System Protections improve the learning experience of the electrical engineering undergraduate and postgraduate students enrolled in this course [11]. Similarly, Power System Protections Course at Politeknik Merlimau has two differences standalone tests for two relays. Firstly, Overcurrent standalone relay test with load connected. Secondly, Restrict Earth Fault relay test with load connected. These two standalone test have used IDMT relay and Combination of Overcurrent and Earth Fault Relay. For IDMT experiment student will be given a circuit as depicted in Figure 2. It shows the standardized circuit for IDMT over current experiment.

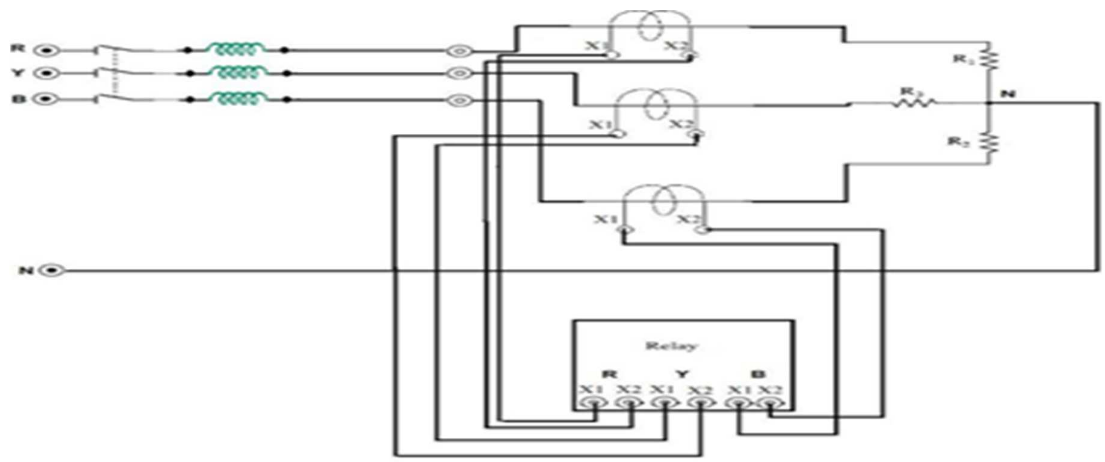

Figure2: Circuit connection for IDMT relay experiment

Each part of the setup is described below:

- Switchgear: Students need to identify which switch gear to be used in the circuit, including the rating of circuit breaker. It is important information for student to set the pickup current at the relay.
- Impedance of Transmission Line: The parameter of transmission line is important. It aims to make line used in the experiment is similar to real transmission line.
- Instrument Transformer: This equipment will convert the quantities parameter in the circuit such as current. The current transformer used in the circuit is step down ratio 10/5A. The value of ratio is suitable to the educational purpose. It also depends upon load to be connected to the system.
- Resistive load bank MV1100-external variable load applied to the circuit. This load is adjusted based on requirement of the experiment.

RESULTS AND DISCUSSION

For the first experiment for standalone of relays, the relay current setting is set to 1.5A. For different Time Multiplier Setting (TMS) of the relay and different load given in this experiment, the student are have to determine the trip time delaying (t_m) and calculate the time delaying (t_c) as (1):

$$t_c = \frac{0.14}{\left(\frac{I}{I>}\right)^{0.02} - 1}(TMS) \quad (1)$$

where I> represents relay current setting whereas I is current in relay coil. Then, the result is compared. Based on the relay data, students also need to calculate the plug setting value and pickup value of the relay.**Error! Reference source not found.**shows the four setting for TMS and different load current.

Table 1:Template example of measurement results for standalone of relays 1

No	T.M.S	I (A)Load	I (Amp) Relay Coil	t_m(S)	t_c (S)
1	0.05	3.6	1.8		

2	0.05	3.8	1.9
3	0.1	3.6	2.2
4	0.1	3.8	1.9

For the second experiment for standalone of relays is to measure the time delaying for different inverse curve graph (SVL) with same TMS value. In this experiment the TMS value is set constant at 0.1. The resistive load is adjusted until the relay coil value reach 1.6A. **Error! Reference source not found.** shows the data that must be collected upon this experiment. The trip time delaying ($t_{m)}$ is measured and the time delaying (t_c) is calculated as (2):

$$t_c = \frac{K}{\left(\frac{I}{I>}\right)^{\alpha} - 1}(TMS) \quad (2)$$

where I> is relay current setting and I is current in relay coil, α and K are constant as state in **Error! Reference source not found.**.

Table 2: Template example of measurement results for standalone of relays 2

No	T.M.S	SVL Graph	I (Amp) Relay Coil	t_m (S)	t_c (S)
1	0.1	00(normal3/10)			
2	0.1	02(Long time inverse)			
3	0.1	03 (Very inverse)			
4	0.1	04 (Extremely inverse)			

Table 3: Value of α and K to determine the degree of inverse in IDMT curves

Type of Curve	α	K
Normal inverse	0.02	0.14
Very inverse	1.0	13.5
Extremely inverse	2.0	80.0
Long-time inverse	1.0	120.0

Fault Current Relay: Experimental Setup

The fault current experimental setup is depicted in Figure3. The VA fault for the system is first calculated and the relay is set as **Error! Reference source not found.**. In this experiment, the three-phase balanced Resistive Load bank is first set to 120ohm. The relay coil is set to 1A, under ON mode of isolator and circuit breaker. Then, the earth fault current from Sverkers is created to 1.31A and the operating time of the relay is measure. From this experiment, students are able to identify the shortest time for multiplier plug setting to trip the circuit breaker. From this experiment, the dynamic response of earth fault current relay can be analysed.

Table 4: Template example of measurement results for fault current relay

Function Switch	Earth Fault LowI > (AMP)	Multiplier/Delay Low(s)	Earth Fault High(AMP)	tm (S)
1	1.30	0.05		
2	1.30	0.1		
3	1.30	0.2		
4	3.5	0.3		

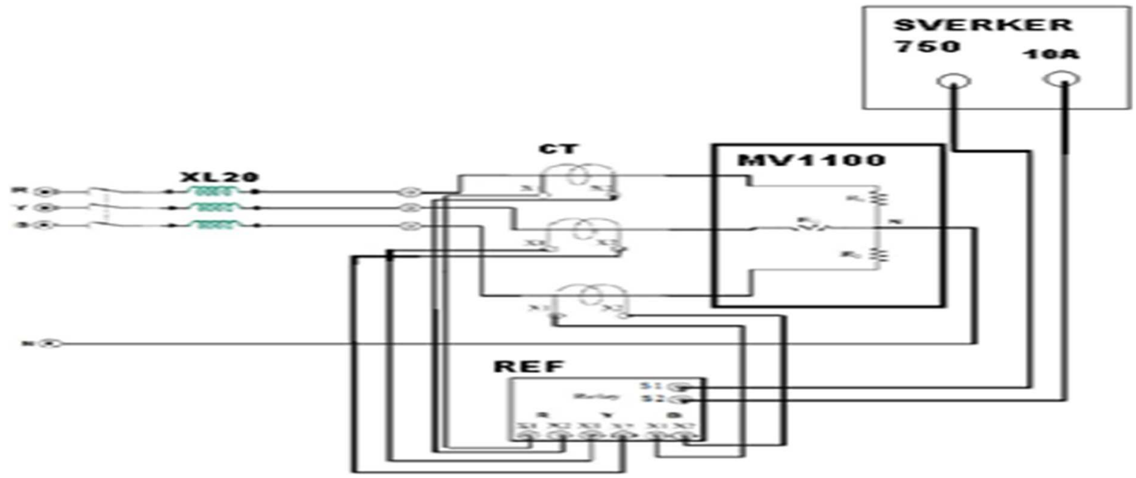

Figure3: Circuit connection for fault current relay experiment

CONCLUSION

An overview and practical experiment developed for Power System Protection have been revealed in this paper. This paper describes the detailed practical work that includes the standalone relay test for over current and earth fault. The main objective of this prac is to give students knowledge of several relay configurations in protection system and these s experiments facilitate to improve the learning experience of students enrolled in this Power System Protection subject at PoliteknikMerlimau. Moreover, this practical work can be developed and applied to other institution. Finally, the Authors hope that the information and knowledge sharing provided in this paper can be utilized by others lecturers of PSP courses to develop a similar technique and improve the student learning experience.

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