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Date	: 17.06.2016

MODELLING AND ASSESSMENT OF TRANSFORMER DIFFERENTIAL PROTECTION IN POWER SYSTEM NETWORK USING PSCAD SOFTWARE

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

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2016

I declare that this report entitle *"Modelling and Assessment of Transformer Differential Protection in Power System Network Using PSCAD Software"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : MUHAMAD ROZAIRI BIN ZAKARIA

Date : 17.06.2016

To my beloved mother and father

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ABSTRACT

The transformer is commonly being used nowadays in order to transfer the electrical power from the power plant to transmission line and also distribute it to the people in the distribution system. The power transformer is an important electrical equipment that should be protected. It is because if there are fault current flow through the transformer, it can make the transformer damage and also will harm the human lives. The protection of transformers means that to protect the transformer from internal fault such as fault current. In order to analyze the protection performance for transformer, this thesis presents a modelling and assessment of transformer differential protection in the power system network using PSCAD software. The modelling of the protection system uses a dual slope current differential relay that acts as a protection tool. This dual slope current differential relay is used to monitor the current that enters and leaving the transformer on the primary side and secondary side. The simulation result shows that the relay not show the tripping signal when the transformer in balance condition or the current that flow through it is a normal current. When fault current exist, the dual slope current differential relay send the signal to circuit breaker to trip the circuit .The value of the online plotting graph for the relay shows the value of one. The PSCAD software is used because it is easy to model the circuit and simulate it to get the result. When the simulation is run, the location of fault can be determined. This is help to get more understanding about differential protection.

ABSTRAK

Transformer biasanya diguanakan pada hari ini untuk memindahkan tenaga elektrik daripada janakuasa kepada talian penghantaran dan juga diagihkan kepada orang ramai dalam bentuk sistem pembahagian. Transformer adalah barangan elektrik yang sangat penting untuk dilindungi. Ini kerana jika terdapat kesalahan arus yang mengalir melalui transformer, ia akan menyebabkan transformer rosak dan akan mengancam nyawa manusia. Perlindungan transformer adalah untuk melindungi transformer daripada kesalahan dalaman seperti kesalahan arus. Dalam usaha menganalisis prestasi perlindungan untuk transformer, thesis ini dilaksanakan untuk mereka dan menilai pembezaan perlindungan transformer dalam rangkaian sistem kuasa dengan menggunakan perisian PSCAD. Dalam mereka bentuk sistem perlindungan, pembezaan alat geganti digunakan untuk bertindak sebagai alat perlindungan. Pembezaan alat geganti digunakan untuk memantau arus keluar dan masuk pada transformer di bahagian pertama dan bahagian kedua. Keputusan simulasi menunjukkan alat geganti tidak menunjukkan isyarat pemutus bila transformer dalam keadaan yang seimbang atau arus mengalir melaluinya dalam keadaan normal. Bila arus kesalahan hadir, alat pembezaan akan menghantar isyarat kepada pemutus litar untuk memutuskan arus. Nilai pada graf alat geganti akan menunjukkan nilai satu. Perisian PSCAD digunakan kerana senang untuk mereka bentuk litar dan mensimulasikannya untuk mendapatkan keputusan. Bila simulasi berjalan, tempat berlakunya kesalahan boleh di tentukan. Ini dapat membantu untuk lebih memahami tentang perlindungan pembezaan.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

1.1.1 Power Transformer

A transformer is a device that transfers electrical energy from one voltage level to another voltage level. There are several types of transformers that are commonly being used such as step-up transformer, step-down transformer, and also auto- transformer which can be step- down or step-up transformer. This type of transformer can be determined by their turn of the winding. If the primary side of the transformer has more than of winding compared to the secondary side, which means that it is a step-down transformer. That also vice versa for step-up transformer.

For auto-transformer, it is very different with the other two types of transformer because it only have one winding. This type of transformer share the same common single winding and it acts as both the primary and secondary sides of the transformer. The single winding at least has three taps to make an electrical connection. The auto-transformer have the advantages compares to other types which it's smaller, lighter, and cheaper. It's also have a lower leakage reactance, lower excitation, lower losses, and increased VA rating.

The power transformer sometimes faced a condition of abnormal thermal and electrical stresses. This happened because of gases that produce due to decomposition of transformer insulating oil. The buchhloz relay is used to detect and solve the problem. However, buchhloz relay does not have the ability to predict the condition of the total internal healthiness of power transformer. Dissolved Gas Analysis (DGA) of transformer oil can be used to predict the actual

condition of internal health of a transformer. This test will extracted the gases in oil and the quantity of gasses will be analyse in a specific amount of oil. The internal condition of transformer can be predict by observing the percentages of different gasses present in the oil.

1.1.2 Differential Protection of Power Transformer

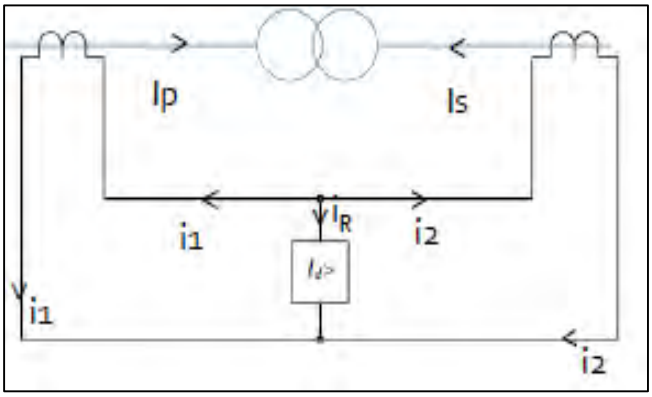

Figure 1.1: The relay for transformer protection.

In transformer protection, there are a lot type of protection and one of them is differential protection. The differential protection is a per unit protection that only protect the transformer. It compares the current on the primary side of a transformer with that on the secondary side. This protection only operate for internal fault or in protection zone and insensitive for any fault outside. The protection zone is between both sides of the current transformer.

The current from both side of primary and secondary current will flow through the relay. The differential relay will compare both current. In a normal condition, the primary current and secondary current will be the same and the current relay will be zero. So that, the relay will not operate. When a fault occurred in the protection zone, the primary and secondary current will not be same and the current relay will not equal to zero. The relay will operate and the current relay must higher than relay current setting.

1.1.3 PSCAD Software

PSCAD stand for Power System Computer Aided Design is a powerful and flexible graphical user interface to the world renowned, EMTDC solution engine. PSCAD is used by engineers, researches and students for planning, designing, developing new concepts, and testing ideas. This software is used to modelling and simulate the circuit. The circuit modelling in three phase and the three phase fault was placed close to the transformer. The three phase fault also was placed on the bus bar and the transmission line. A transformer will have three dual slope current differential because it represent for each phase. The graph for relay will show the graph in value of one when there are in fault condition.

1.2 Problem Statement

The PSCAD software is used in this project because it is the easiest way to model and to simulate the circuit compare with the field test. If the field test is conducted, the circuit cannot be modelling. The existing of power system network must be follow. The available protection system in the field is much complicated to understand. Therefore, with using the PSCAD software is easy to simulate it and get the result. The differential protection operation also can be understand clearly because the circuit can be modelling in any form.

1.3 Objective

The objective of this experiment is:

1. To understand the differential protection operation.
2. To model the transformer differential protection using PSCAD software.
3. To set the dual slope current differential relay to protect the transformer.

1.4 Significant of the Study

The overall study is about how to protect the transformer when in a fault condition. The fault condition can cause the transformer to damage. The PSCAD software is used for modelling and simulate the result. The dual slope current differential relay is used as an additional connection for transformer to create a protection system. This dual slope current differential relay function to monitor the current entering and leaving the power transformer. The properties of the value of the dual slope current differential relay must be determined based on the current entering and leaving the transformer. The calculation is made to verify the formula given at the dual slope differential relay. Based on the calculation for the power transformer, the dual slope differential relay allows the current flow through it in normal condition and for the fault condition the dual slope current differential relay will gives the signal to the circuit breaker to trip the circuit.

1.5 Thesis Outline

There are five chapters in this report, which are introduction, literature review, methodology, result and discussion, and the conclusion as the last chapter. The introduction chapter was explained the detail about the concept of transformer differential protection, problem statement, the scope of the project and the significance of the study. In second chapter is a literature review that pass researches are related to this project. Third chapter is a methodology that explains how to modelling the transformer differential protection using PSCAD software. Chapter four of project is to get the result from the modelling such as the simulation, graph relay and the value of current for each cases. Lastly, chapter five is to conclude about overall of the project and give a recommendation.

1.6 Scope

This project is emphasis on model the circuit for the transformer differential protection by using the PSCAD software. The dual slope current differential relay is used to protect the transformer from fault. The result of simulation in the form of plotting graph.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The transformer is one of the most important equipment that been used to increase and also decrease the voltage of the power system network. It's also important in the transfer the electrical power through a transmission line from the power plant. The fault sometimes occurs in power transformer that caused the transformer to damage and also human lives in danger. This chapter will study the recent development on transformer protection, inrush current and protective relay.

2.2 Types of Transformer Protection

2.2.1 Overcurrent Protection

The basic principle for overcurrent explained that the fault current is greater compared to load current because the load impedance is greater than the fault impedance. The overcurrent relay function to detect the fault current and overload current. This overload current consists of overload current and short circuit current. For overload current, the fault condition, runs through with a short period of time because of high current. Therefore, the power of high thermal and thermal equipment is disappeared. The thermal relay cannot detect it because of short time for a temperature to rise. The high stage overcurrent working as a backup protection. The main protection is a differential protection. When in low stage, the differential protection not trip and

also not for a backup protection if the fault through the transformer. The transformer would face the overloaded. Then, the whole power transformer must be disconnected from the power system network if the transformer circuit breaker does not trip. In the short circuit current, it‘s would include phase fault, earth faults and winding fault. The short circuit current difference is 5 to 20 times of the full load current. So that, fault clearance must be conducted [10].

2.2.2 Earth Fault Protection

The other types of the transformer protection are earth fault protection. This fault is the most frequent fault that occurred. Earth fault states that the current flow through neutral conductor of the grounded system. The earth fault detected by phase fault relay, but it lacks of sensitivity. To prevent this problem, the new relay that is earth fault relay are used to contact with current from residual component. This earth fault relay not affected by the unbalanced load conditions. The low setting is used because of the neutral earthing resistance. There are two types of earth fault protection which are restricted and unrestricted. For a restricted earth fault (REF), the both current transformer would have the same value of current under normal condition. If there has earth fault, some current will go through the current transformer and the sum of current could not be zero. Therefore, the faults between both current transformers can easily be known quickly. The restricted earth fault will not senses the fault that outside the restricted zone. This restricted earth fault is very sensitive differential protection. REF have many advantages which are it very fast protection and can isolate the winding faults very fast. Therefore, it can reduce the damage of the transformer and also the cost to repair it. The protection zone must be extended because the secondary current transformer is placed in the distribution board. So that, the main cable will be included. Without REF, the fault that occurred in the secondary winding cannot be detected. The reflected current on the primary are used to detect it. The winding fault will move its position to the neutral. The magnitude of the current cannot be detected because the primary current decreased rapidly. As the magnitude of the current for secondary is large, the whole winding can be protected by using REF. For the normal conditions, the current transformer is balanced and the high impedance relays have been implemented. The next earth fault protection is an unrestricted earth fault. This method is used to detect and sense the earth fault at any point in the power system network. If the earth fault

detected, the sum of three line's current is zero and the three secondary currents is also zero. The formula below shown in term of mathematical [5].

Ias + Ibs +Ics = 0

Irs = 0

Where,

Irs = residual current

Ias + Ibs + Ics = per phase currents (red, yellow, blue)

When a fault is occurring, the residual current is not zero. The figure below show that the earth fault relay is connected.

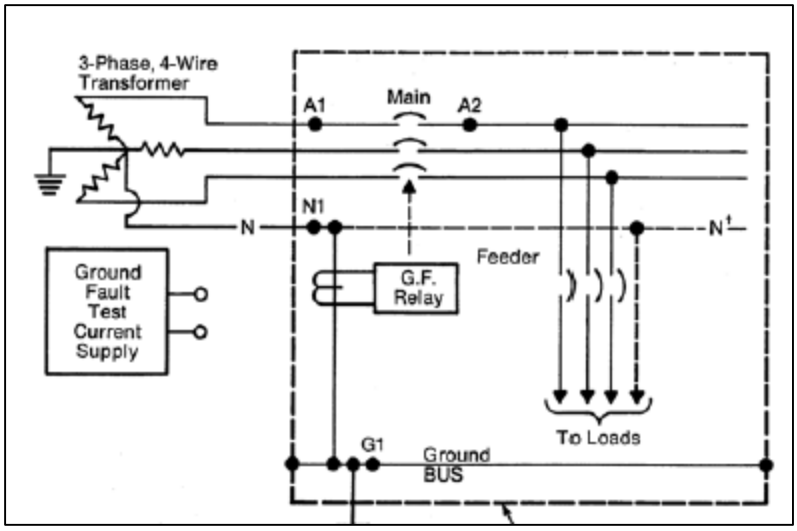

Figure 2.1: The typical earth fault protection schemes.

2.2.3 Differential Protection

Hamed Dashti, et.al [1] agree that a transformer is the most important equipment in electrical system. The low impedance of the differential protection is usually been used for transformer protection. The transformer protection with the large scale is important devices to protect the substation and the operating time is limited to 20ms [2]. A differential protection to protect the transformer is using second harmonic retrain and fifth harmonics to block the schemes. The differential protection is one of the types of protection for specified zone or for a piece of equipment. This method is to determine the difference between input and output current. The internal faults from the zone that differential will be high. Sometimes, the value of differential current can be high without an internal fault. This is happened because of the characteristics of current transformer that function to measure the input and output current and also the transformer being protected [3]. The ferromagnetic magnet circuit cause the transformer differential protection to action in 100%. However, the setting value for relay still can improve the differential protection. For the high voltage side, it has no load during differential protection. High voltage side become the transformer differential protection [4]. The last transformer protection types is differential protection. The basic principle of differential protection is in normal condition, the current can flow without any disturbance to the protection zone. The current through relay is zero. The relay would not operate for an external fault. The relay will operate between two current transformers in fault condition [10].

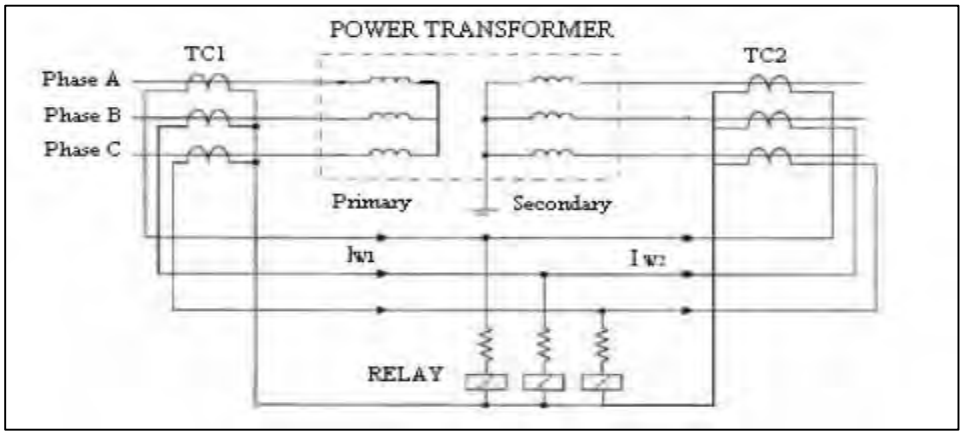

Figure 2.2: Simple diagram for transformer differential protection.

Protective relay or specifically the dual slope differential relay is the most important component in the power system network. The main function of the relay is to reduce the harmful damage to electrical equipment and other things when an electrical fault occurs. The design of the relay for protection system is to prevent or to clear the electrical fault as fast as possible. Therefore, to prove it, the high speed relay has been widely used with the upstream protective device. The most effective ways to protect the electrical equipment based on the operating speed is by using differential relays. The differential protection for the transformer is tripping the power system network because of the unbalanced current from current transformer on the both sides. The current transformer is saturated due to unbalance currents. For transformer differential protection concept, one side of current transformer is high voltage, whereas the other side is low voltage. From that, each side of the transformer has the different turn ratios and different accuracy class. The wave shape of output current for both sides could be different because of current transformer saturation. This problem could make the differential relay activate. In order to avoid this problem, the engineer that worked with protection unit must consider the size of the current transformer based on applicable standard such as IEEE C37.110. Nowadays, the modern microprocessor relay could prevent the unwanted trip because the current transformer was modified for algorithm detection. The relay could block the trip for output signal for an external fault. The current transformer should be enough for stable protection in system stability [11].

2.3 Inrush Current

The inrush current happened when the transformer energize under no load condition and also because of fault from external. These inrush current have harmonic-rich current that that generated when the transformer in energization condition which the transformer cores are driven into saturation. This inrush current has a bad effect for transformer such as potential damage or life for transformer would be short and also the power quality of the system was reduced [5][8].

The transformer is an equipment that has an electromagnetic induction because of the static electrical tools. The core of magnetic flux is in maximum value when the instantaneous voltage is zero because the iron core not change fast. The core is saturated when in winding excitation current

condition. It produces a flux that needed the greater excitation current. At the adverse closing moment, core flux density and excitation current is increasing. Therefore lastly the inrush current is produced [4].

Internal fault for transformer include winding insulation and winding defect have a failed result in ground fault or turn to turn fault. This insulation happen because of several reason such as magnetizing inrush current, lightning strikes and many more [6]. To avoid the relay from malfunction, the inrush current and fault current must be identify. The harmonic restrain method is used as a technique to solve the problem [7]. The magnetizing inrush current can cause the differential protection of power transformer to be mal-operation [8]. The inrush current is exist in transformer. It value for magnitude and duration based on residual field present and the point on the ac cycle at the re-energization [10].

The excitation inrush current basically is:

- The value of the inrush current is very big.
- Time axis side reveals the excitation inrush current waveform.
- Second harmonic current is higher and obvious.
- “Intermittent corner” is excited inrush current wave between adjacent waveform.

The transformer excitation inrush current is a problem that cannot be prevented for transformer high voltage test. Therefore, the differential relay that acts as a protection tool must understand a high voltage test for transformer to operate effectively [5].The inrush current produce when the transformer is switch on. The magnitude, shape, and duration of inrush current depend on the following factors [9]:

- The power transformer size.
- The source impedance.
- The condition when the transformer is switched.
- The core material.

The inrush current can be emerge in three phases and also in a grounded neutral. The magnitude of current is different for both three phases and grounded neutral. The maximum inrush current can be produced when the switching occurs at the zero crossing of the voltage and when

the new flux from the inrush current get the same direction. Inrush current have a large dc component and rich in harmonics [9].

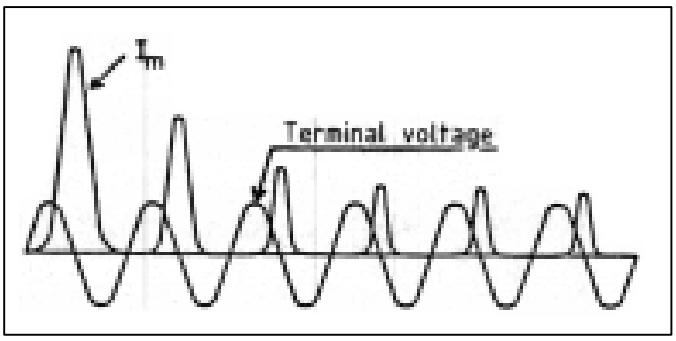

Figure 2.3: Theoretical inrush current Im.

2.4 Buchholz Relay

Nishant Kumar, et.al [12] agree that a buchholz relay is a gas and oil operated device which connected in the pipe work. This buchholz relay is placed between the conservator and the transformer tank. This relay is completely filled with oil.

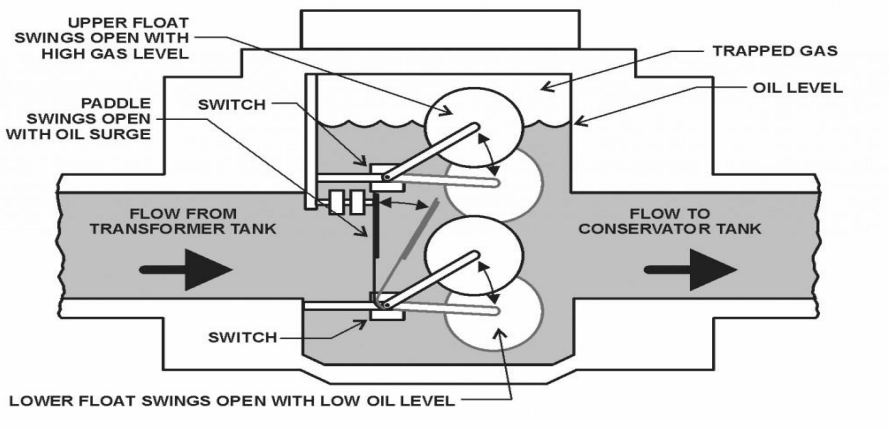

Figure 2.4: The inner part of buchhloz relay.