UNIVERSITI PUTRA MALAYSIA

DIFFERENTIAL PROTECTION OF A THREE-PHASE POWER TRANSFORMER USING HALL EFFECT CURRENT TRANSDUCER

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In a power system, transformers and other electrical equipment need to be protected not only from short circuit, but also from abnormal operating conditions, such as over loading, and differential fault protection.

The differential protection relay works on the principle that in a healthy system, the current leaving a circuit is equal to the current entering the circuit. The differential protection can also be applied to a transformer (even though the primary and secondary currents are not equal), by rating the CTs according to the transformation ratio.

In a power system, the differential relay should operates only in its specified protection zone, and not for out of its protection zone, when short circuit fault occurs.

Differential protection zone for a transformer is in the limited zone between transformer primary side CTs and transformer secondary side CTs. If a short circuit fault occurs in this zone, then the differential relay will operate to protect transformer not to be damaged by the high circuit current.

This work has been focused on construction, normal operation of differential relay and on the problem when differential relay is functioning outside of its protection zone and a way of solving the problem, further to test its function by creating faults on nearby power system. This work has shown that if the current ratio of current transducers are not matched with the current of transformer, therefore it would cause the differential relay functions even though the faults occur outside the relay protection zone.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PERLINDUNGAN PERBEZAAN UNTUK PENGUBAH ELEKTRIK TIGA FASA MENGGUNAKAN TRANSDUSER KESAN HALL

Oleh

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Di dalam satu sistem kuasa, pengubah serta peralatan elektrik yang lain perlu dilindungi bukan sahaja dari litar pintas, juga dari keadaan kendalian yang luar biasa seperti keadaan beban lebih dan bila berlaku perbezaan arus.

Geganti perlindungan kebezaan arus berkendali berdasarkan prinsip bahawa di dalam satu sistem yang baik, arus yang memasuki satu litar adalah sama dengan arus yang meninggalkan litar tersebut. Kaedah perlindungan perbezaan arus boleh diaplikasikan kepada satu pengubah (walaupun arus primer dan arus sekunder adalah tidak sama), secara pengkadaran pengubah arus mengikut nisbah transformasi.

Geganti pembeza arus di dalam satu sistem kuasa, hanya berkendali di dalam zon perlindungan yang ditetapkan semasa kerosakan litar pintas berlaku dan bukan di luar zon perlindungan yang ditetapkan bila berlaku kerosakan litar pintas. Zon perlindungan perbezaan arus untuk satu pengubah terhad di dalam zon yang terbatas di antara sebelah primer dan sebelah sekunder pengubah-pengubah arus. Jika satu litar pintas berlaku di dalam zon tersebut, maka geganti pembeza arus akan berkendali untuk melindungi pengubah daripada kerosakan disebabkan arus litar yang tinggi.

Objektif tesis ini adalah untuk menumpukan kepada binaan geganti pembeza arus yang biasa dan masalah bila geganti pembeza berkendali di luar zon perlindungannya serta cara mengatasi masalah ini, dan melakukan ujian-ujian untuk memastikan fungsinya secara mengadakan kerosakan pada sistem kuasa yang berhampiran. Tesis ini menunjukkan bahawa, jika nisbah arus transduser tidak sepadan dengan arus sistem kuasa, geganti pembeza akan berkendali walaupun kerosakkan berlaku di luar zon perlindungan.

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I certify that an Examination Committee met on 26th March 2002 to conduct the final examination of Ali Asghar Fathollahi Fard on his Master of Science thesis entitled "Differential Protection of a Three Phase Power Transformer Using Hall Effect Current Transducer" in accordance Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Ali Asghar Fathollahi Fard

Date: 30 March, 2002

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LIST OF ABBREVIATIONS

A	Ampere
AC	Alternative current
Auto	Automatic
Aux	Auxiliary
C°	Degree Celsius
CT	Current transformer
DC	Direct current
G	Generator
HECT	Hall effect current transforrner
IEEE	Institute of electrical & electronic engineering
I / O	Input / Output
kVA	Kilo volt ampere
LED	Light emitted diode
PC	Personal computer
T	Transformer
VA	Volt ampere
VT	Voltage transformer

CHAPTER I

INTRODUCTION

1.1 Introduction

A system consists of generator, transformers, distribution lines and the grid system needs to be protected. Short circuits occur in power systems when equipment insulation fails, due to the system being over-voltages which can be caused by lightning or switching surges, insulating contamination, or by other mechanical and natural causes.

However careful design, operation, and maintenance can help to minimize the occurrence of short circuits but they cannot eliminate them. In case of such short circuits, currents can be several orders of magnitude larger than normal operating currents and, if allowed to persist, may cause insulation damage, conductor melting fire, or even explosion. Although occurrence of short circuits is somewhat of a rare event, it is of utmost importance that steps be taken to remove the short circuits from a power system as quickly as possible.

In power systems, the short circuit removal process is executed automatically, that is, without human intervention. The equipment which is responsible for this short circuit removal process is collectively known as the protection system [1].

Many kinds of protective devices (e.g. relays) are being used in electrical power system to protect feeder, busbar, generator, transformer, motor, and transmission lines.

A relay is a device designed to produce sudden predetermined changes in one or more physical systems on the appearance of certain conditions in the physical system controlling it. The IEEE defines a relay as a device whose function is to detect defective lines or apparatus or other power system conditions of an abnormal or dangerous nature and to initiate appropriate control action [2].

One of the protection methods for a power transformer that is protected from differential input and output currents is by means of differential relay. Hence in this study the differential relay, its working principle and problems involved in the power system for protecting a power transformer, are discussed.

1.2 Background review

Differential relays are commonly used to protect generators, buses, and transformers. When the relay in any phase operates, all three phases of main circuit breaker will open, as well as the generator neutral and field breakers in a power plant protection [3].

The protection method used for power transformers depends on the transformer MVA rating. Fuses are often used to protect transformers with small MVA rating, whereas differential relays are commonly used to protect transformers with ratings larger than 10 MVA [4].

The differential relay (e.g. transformer differential relay which is called 87 or 87T) works on the principle that "in a healthy system", the current leaving a circuit is equal to the current entering the circuit" . This differential principle can also be applied to a transformer (even though the primary and secondary currents are not equal), by rating the Current Transformers (CTs) according to the transformation ratio. Two sets of CTs (of the corrected ratio) are installed on either side of the transformer in order to measure the 'differential' value between incoming and outgoing current [5].

The function of CT is to produce in its secondary winding a current Is, which is proportional to primary current I_p . CT is used in power system circuit, which is having high current of hundreds amperes range. CT minimum range standard is 20 A in primary to be converted to secondary current in 5 A range for convenience of measurement and to apply for protection relays [6].

1.3 Problems statement

A common problem in differential transformer protection is the mismatch of relay currents that occurs when standard CT ratios are used. If the primary voltage rating in a system is changed to a new value instead of previous one, because of some different design or whatever circuit changing in that particular system, then the primary current rated will be changed as well [5].

In this case, the primary winding needs a new rating of CT. This new CT gives a different rated condition, and will not be balanced to secondary winding CT. In this situation, the mismatch will go up, which is not suitable for differential protection and designing of current transformers. This problem will be discussed in more details later as in the calculation part.

For transformer differential protection in a large power system, the differential relay should operate only in its indicated protection zone, and not for out of its protection zone, such as on the load side, while short circuit fault occurs. The problem starts to show itself when transformer differential relay is functioning in out of its protection zone. This problem will be explicitly explained in the related areas of this study.

1.4 Objectives and ways to solve the problems

The objectives of this study are to work on those problems stated earlier and to solve the problems. The solutions presented will thoroughly explained the relay working principle and the activating points of the relay. Finally, the results of the solutions will be tested by using a manual fault trip on the transformer itself, and load side of practical circuit which has already been carried out by the author.

1.5 Scope of work

To achieve the objectives of this study, more details about differential fault against unit transformer, an electrical protection circuit with current transformers, have to be investigated by the researcher. This protection circuit requires a combination of protective functions and differential relay system. The practical circuit for transformer differential protection, have a three-phase transformer, six current transformer (CT), three auxiliary (matching) transformers, an automatic tripping switch (circuit breaker), and a device digital differential relay, which are being used for differential protection for the power transformer.

An electronic simulation circuit of transformer differential protection relay, is designed by the author. In this electronic circuit, six hall-effect transducers and six integrated-circuits as comparator circuits are used. A detailed explanation of the simulation circuit and theory of hall-effect will be discussed in chapter two.

This study will explain a way of determining current transformers for primary and secondary winding of any MVA rating of three-phase transformers with different connection in primary and secondary , which are widely used in power system.

A complete set of formulas, together with the calculations of current transformers ratio for differential relay of three-phase power transformer is presented in chapter three. In addition, this study also aim to introduce a method of calculation of auxiliary current transformers, to be matched with main CT in protection system. These auxiliary CTs are small and inexpensive devices since their primary and secondary windings are low-voltage low-current circuits.

Besides, through this study, it will also introduce the transformer protective relays which are used in power system, but the emphasis will be on the differential protection and on differential relay.

CHAPTER II

LITERATURE REVIEW

2.1 Generator and transformer protective relays

The functions of the generator and transforner protection and metering circuits are to:

1. isolate and thereby prevent damage to the generator and transforner under certain internal and external fault conditions

2. ensure the safety of plant personal, and

3. annunciate an alarn when a fault occurs. Action to remedy the fault prevents it from deteriorating and causing further damage [6].

The generator, generator-transformer and the unit-transformer are referred to as a 'unit system' and the protection relays and devices which protect this equipment are collectivity referred to as a unit protection system[6].

When a short circuit fault occurs, the current flowing through the affected circuit increases substantially. Similarly, when an open circuit fault occurs, the voltage in the affected circuits changes substantially. The protective relays sense any abnormal current and voltage in their circuits and initiate either an alarm if the fault is minor or tripping of associated equipment.

In electrical systems, continuous and accurate measurement of important parameters such as voltage, current and power is essential for the safe operation of systems and equipment. These are usually provided by instrument transformers (current transformer and potential transformers) which provide inputs to protective relays and other metering instrument.

Circuit breakers and instrument transformers, along with protective relays, form the protective circuits for power plant systems. Instrument transformers perform two primary function:

1. they insulate instrument, relays and meters from line voltage and
2. they transform the line current or voltage to values suitable for measurement on standard instrument, meters and relays.

A current transformer or CT supplies the instrument or relay connected to its secondary winding with a current proportional to its primary current but small enough to be safe for the instrument or relay.

The secondary of a current transformer is usually designed for a rated current of 5 A. Its primary winding is connected in series with the line. Normally there is no separate primary winding. The main current carrying busbar which passes through the secondary winding, becomes the single-turn primary winding.

A potential transformer or PT (also called voltage transformer or VT) supplies the instrument or relay connected to its secondary winding with a voltage proportional to the primary voltage but small enough for it to be safe for the instrument or relay. The secondary of a potential transformer is usually designed for a rated voltage of 115V. A potential transformer primary winding is connected in parallel with the line. Figure 2.1 shows how current and voltage transformers and wattmeters are applied to measure current, voltage and power respectively.

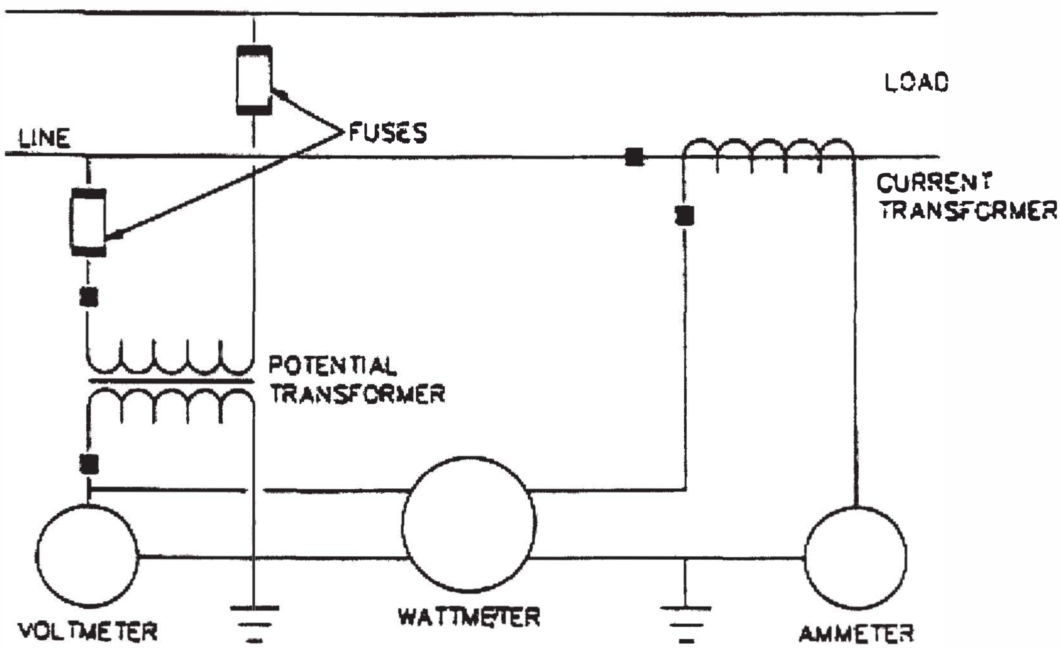

Figure 2.1: CT and PT connection [6]