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Differential Relay Protection for Prototype Transformer

***Abstract**. This paper represents the differential protection relay that used to protect the prototype-Terco power transformer. Matlab/Simulink is used to simulate the protection system. The power differential protection algorithm has been simulated and tested on a 2KVA power transformer under different faults. During normal operating conditions, current will flow through all phase of the power transformer within predesigned values which are appropriate to these elements rating and the faults can be classified as the flow of a massive current. the results signify suitable completion.*

***Streszczenie.** W artykule przedstawiono zabezpieczenie różnicowe, które jest używane do ochrony transformatora mocy prototypu Terco. Algorytm zabezpieczenia różnicowego mocy został zasymulowany i przetestowany na transformatorze mocy o mocy 2 kVA przy różnych uszkodzeniach. W normalnych warunkach pracy prąd przepływa przez wszystkie fazy transformatora mocy w ramach wstępnie zaprojektowanych wartości, które są odpowiednie dla tych elementów znamionowych, a zwarcia można sklasyfikować jako przepływ prądu o dużej wartości. (**Zabezpieczenie transformatora przy wykorzystaniu przekaźnika różnicowego**)*

Keywords: Power transformer, Differential protection, Fault conditions, Differential relay.
Słowa kluczowe: transformator mocy, zabezpppieczenie, przekaźniki różnicowe

Introduction

Transformer protection methods are focused on differential protection and the attempts to improve the transformer protection, were based on a comparison between no fault and interior fault [1-2]. As the fault is occurred, transformer must be out of operating zone as fast as to prevent or to reduce potential destruction and coils harm. Repairing transformer damage associated cost is very high. Also, unplanned outage of a power transformer may be costly and economically useless. Accordingly, high demands are imposed on power transformer protection system. The differential protection wards the fault that happened in the protection zone can be determined by the differential protection and gives a correct action to disconnect the zone. Due to hefty sensitivity and austerely, these types of relays are used to protect the electrical equipment [3].

Differential protection technique which is basically consisting of differential relay depends on the fact that the input power of the transformer identical to the output power. At appropriate flow of the secondary currents, under standard conditions, there is no current running the coil of the relay. At each time of fault occurs, the currents equilibrium will not happen and the relay connections must be closed to give a trip order signal to activate the circuit breakers and separating the faulty mechanism [4].

The transformer is considered among the most main parts of electrical transmission system therefore, many types of prevention varieties and detecting arrangements must be established. The nature of the transformer function can not be isolated from the other equipment of electrical power transmission system. Therefore, the other parts and equipment and their functionality behave should be considered as it is in coupled and direct communicates with each other to prevent the overall transmission system from shut down or sever damage [5].

The researcher had chosen the Department Electrical Power Engineering Technology – Technical College of Engineering – Mosul ∕Northern Technical University (NTU), to apply a differential relay application in a laboratory prototype board.

Proposed methodology.

The aim of this work is to study:

- Faults and classifications.
- Transformer protection.
- Select the protection zone.
- Discuss and compared the results for each type of faults.

Literature review

Raju and K. Ramamohan Reddy (2012), studied the reliability implement enhancement of power transformer based differential relay at internal and external fault. They applied Fourier series method for sine and cosine factors necessary for odd harmonics and fundamental. They concluded that the advanced scheme offers a good discrimination between the magnetizing and the inner fault currents [6].

The proposed method

The variance between the primary and secondary for (CTs) must be equal to zero, that means the transformer does not distinguish a fault. No lessees in the perfect power transformer, there for no operating current. Practically on eddy current and core losses appeared in the transformer [8-9].

Figure (1) illustrates single phase of a three-phase differential protection system (DPS). The protection equipment was enclosed by a couple of (CTs). Because of the (CTs) natural propensity, differential relay protection will not offer back up protection as a ratio to the rest of the system equipment, for this reason, this form of protection diagram is commonly favoring as a unit protection schedule. At no fault conditions, the current IP is similar to that get out from the protection equipment at each instant. When respecting the (CTs) A, the aviator wire of (CTs) A is lambing a current equal to:

(1) $$I_{AS} = \alpha_A\, I_p - I_{Ae}$$

Also, for (CT) B, the equation as shown below:

(2) $$I_{BS} = \alpha_B\, I_p - I_{Be}$$

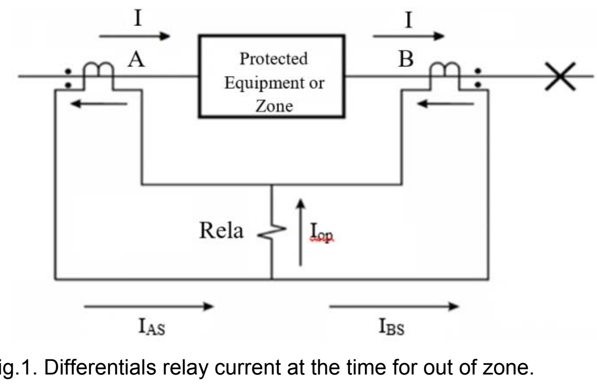

Fig.1. Differentials relay current at the time for out of zone.

Considering equal ratio of (CT) A and B, αA= αB=α, the Iop is:

(3) $$I_{AS} = \alpha_A\, I_p\text{-}I_{Ae}$$

For out-of-zone, the operating current of the relay is extremely small, but doesn't equal zero. When internally fault occurs (inside zone), the input current is differed from the output current and the differential relay send a trip to the circuit breaker as shown in figure (2) [10-12].

(4) $$I_{op} = \alpha(I_{F1} + I_{F2}) - I_{Ae} - I_{Be}$$

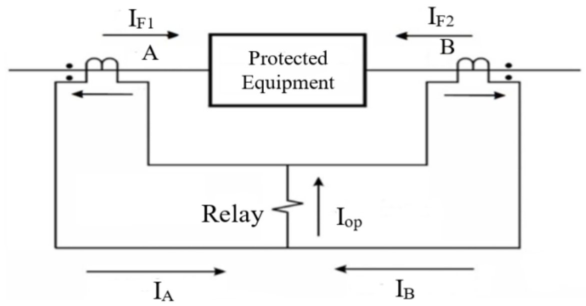

Fig.2. Equivalent circuit of differential relay for single phase.

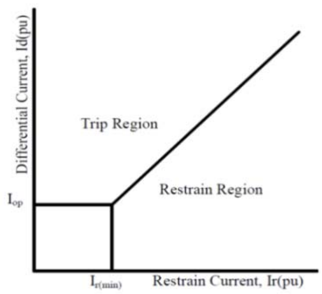

Fig.3. Differential relay characteristics.

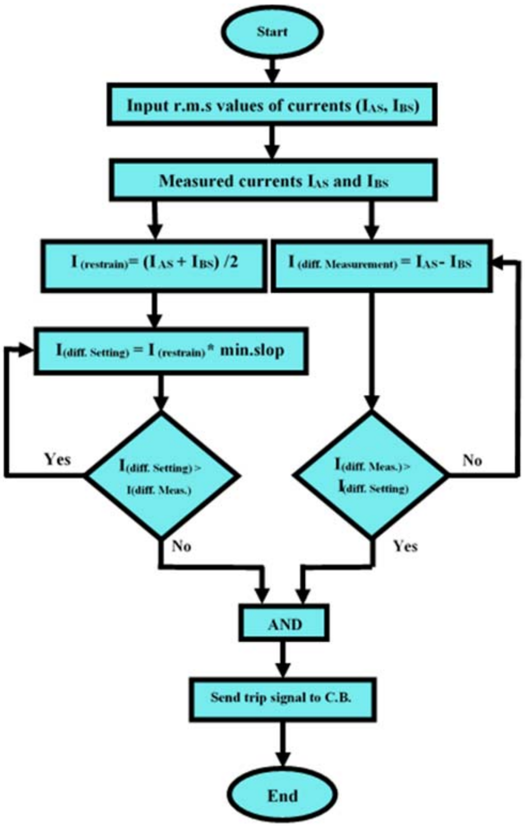

Fig.4. Flowchart of the differential relay for single line.

In terms of operation relay characteristics, its bias is used for power transformer protection. Figure (3) illustrates relationship between the differential current and the restring current (operation relay characteristics) [13].

When the ratio of the pickup is bigger than the bias setting therefor, this ratio value will fall in the tripping region (positive region), otherwise if this ratio is smaller than the bias setting then this ratio value located fall in the blocking region (negative reign) [14-15].

In the types of relay, the operation coil connected in parallel with restarting coils conflicting torque is obtained by the effect of restraining coils to the operating coils, when the faults occur out of zone, in this case the restraining torque so that the relay is not going to operate point. When fault occurs within the zone (internal fault), the operating torque will become higher than the bias torque and the relay will operate. The bias torque is adapted by conversion the number of turns on the restraining coils [16-17]. Figure (4) represents an algorithm of deferential relay protection for power transformer.

Materials and methods

Data for this work was taken from Sweden transformer company (terco company). A 2KVA power transformer as shown in figure (5) was depended in this work and its data are illustrated in table (1).

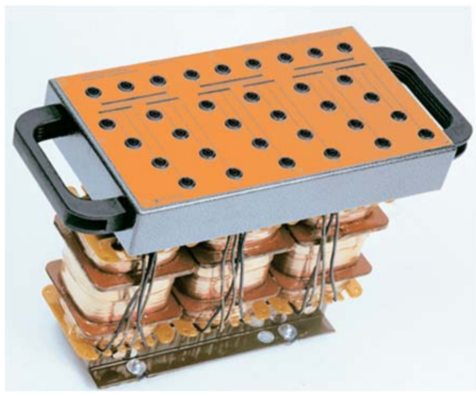

Fig.5. Terco-prototype 2KVA power transformer

Table 1. Terco power transformer (MV1915) specifications

Manufacture	terco company
Ratings	2 kVA, 50-60 Hz, 230/2 x 66.5 V / phase
Primary of transformer	0-133-230 V ± 5 % /phase
Secondary of transformer	Two 66.5 V windings / phase
Secondary tapings	0-38.4-44-66.5 V (± 5 %)

The protection method that used for power transformer depends on the transformer ratings. Mechanical relays are widely used to protect the transformer. Differential protection provides the best overall protection. Biased current differential protection provides the best overall protection [18-19]. Matlab/Simulink environment is used to model the transformer protection system. The following components are the fault simulation model are given as:

- Three-phase source.
- Three-phase C.B.
- Three-phase transformer.
- Three-phase V-I measurement.
- Subsystem.
- RLC series branch.
- Scope
- Current measurement.
- Three-phase fault.

To design a relay protective scheme, a power transformer model is essential to produce the fault records that required adjusting the fault detection system [20-21]. The implementation is completed by using Matalb/Simulink environment.

Research method

Figure (6) shows the simulated conventional relay system. In which a 3-phase, 2KVA, 50 to 60 Hz, 230/2 * 66.5 V/phase transformer were used. The designated differential relay consists of two input signals Ip and Is, where, Ip and Is are the output currents of the measurements respectively. These two input signals would be distributed into three parallel paths in order to be analyzed. The second three signals of the secondary current will subtract from the first three signals at the primary current and the results obtained will be compared with the reference current by using comparator block [22-23].

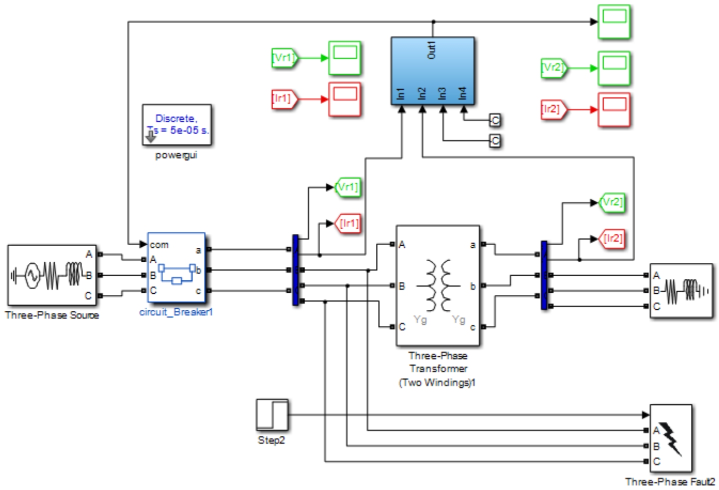

Fig.6. Modeling circuit of differential relay protection

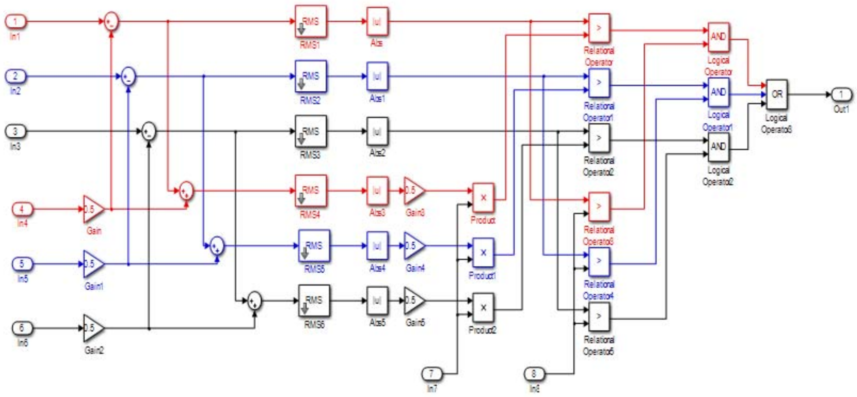

Fig.7. Scheme of differential relay subsystem

After the comparator output signals go to the flip-flop latch, the output signals of the flip-flop will multiply by AND gate and the final signal send to circuit breaker. Figure (7) illustrates the contents of differential relay subsystem block [24-26].

Results and discussion

Case No.1: At no fault (normal operation):

The simulation results of voltages and currents for primary and secondary are shown in figures (8 – 11).

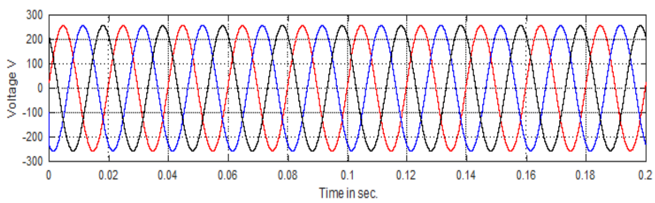

Fig.8. Primary voltage at no fault

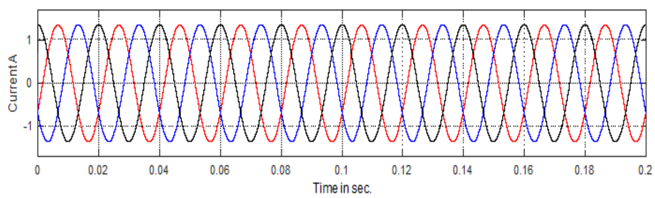

Fig.9. Primary current at no fault

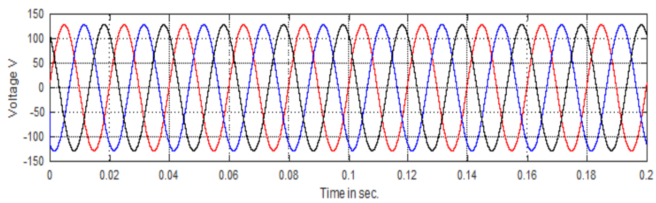

Fig.10. Secondary voltage at no fault

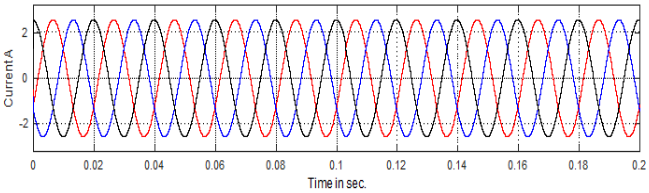

Fig.11. Secondary current at no fault

At normal cases, no fault occurred, the secondary voltage and current are at the designated operating values according to the transformer turn ration (2:1).

Case No. 2: External fault (out of zone):
The simulation results for differential relay output signal. At external fault occurs the primary and secondary currents are given in figures (12-14). A unit step function is applied to the three-phase fault icon.

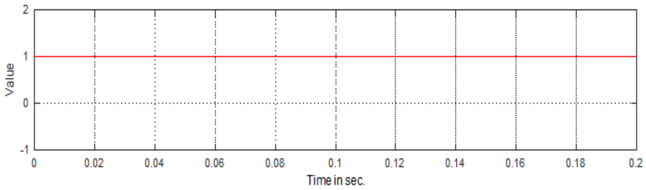

Fig.12. Differential relay output signal

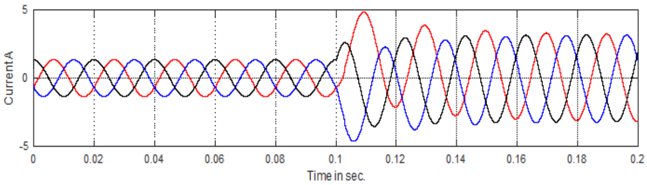

Fig.13. Primary current at external fault

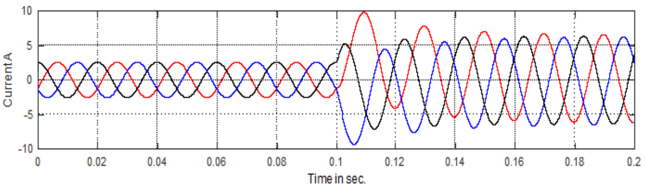

Fig.14. Secondary current at external fault

At external fault, no trip signal sent from the differential relay to the circuit breaker because the fault occurred out of the transformer protected zone as the turn ratio is the same. This can be shown in figures (12-14).

Case No.3: Internal faults (inside zone):
The differential relay output signal when fault occurred at time 0.1 (sec) is given in figure (15).

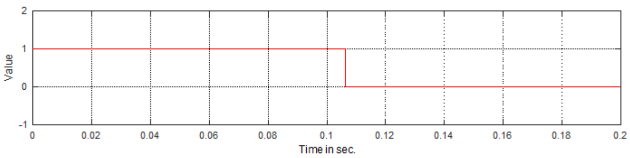

Fig.15. Differential relay output signal

Line-to-ground fault:
The current signals of relay line-to-ground fault is shown in figure (16).

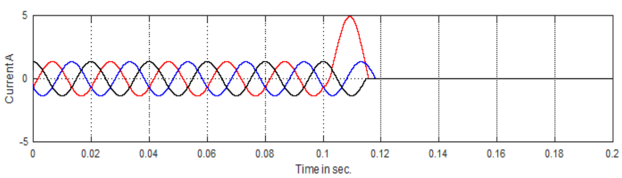

Fig.16. Current at line-to-ground fault

Line-to-line-to-ground fault:
The current signals of relay line-to-line-to-ground fault is shown in figure (17)

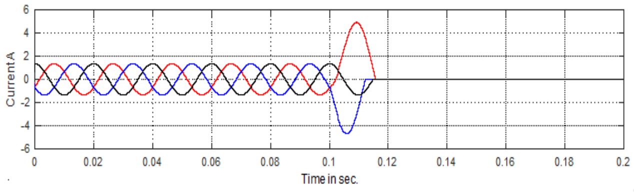

Fig.17. Current at line-to-line-to-ground fault

Triple-to-ground fault:
The current signals of relay triple-to-ground fault are shown in figure (18).

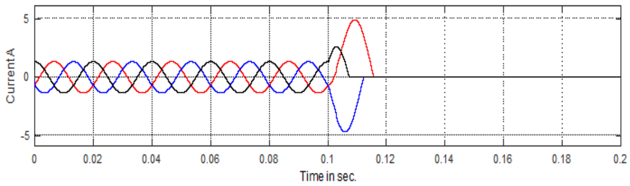

Fig.18. Current at three phase-to-ground fault

Line-to-line fault:
The current signals of relay line-to-line fault is displayed in figure (19).

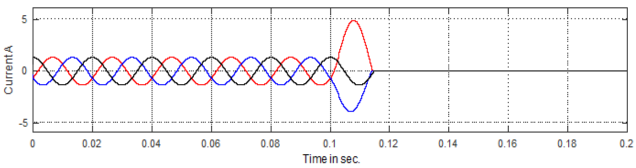

Fig.19. Current at line-to- line fault

At internal fault, when fault occurred at 0.1sec as shown in figure (15), a trip signal delivered from the differential relay to operate the circuit breaker. As the circuit breaker be opened, the current will be zero after the fault time occurred. This can be shown in figures (16-19).

Conclusions
In this paper, the differential relay characteristics are simulated using Matlab/Simulink. The performance characteristics of differential relay were evaluated at a location with three phase faults, and also study the various faults that occur in the power transformer, such as L-G fault, L-L-G fault, L-L-L-G faults, L-L fault and L-L-L fault. MV1915 2KVA power transformer Sweden transformer company (terco company). The analysis and results demonstrate that the projected differential relay denotes a suitable solution. The proposed relay was capable to distinguish the no-fault and fault situations. From the results we conclude that the transient response for all type taken within same time and peak impulse value.

As shown from figures (13 and 14), when external (out of zone) fault occurred, the current wave form signals for the primary current are similar to that obtained from secondary current that due to no operation of relay and the crest value of the current in one phase reached approximately to 10A.

As shown from figures (18 and 19), the currents value in two phases after fault occurred in line-to-line-to-ground were equally (5A), but these values different in line-to-line case.

List of Symbols

CT: Current Transformer
αA: Ratio of (CT) A
IAe: Excitation current of secondary (CT) A
αB: Ratio of (CT) B
IBe: Excitation current of secondary (CT) B
Iop: Relay operating current
Id: Differential current
Ir: Restrain current
IF_1: Primary fault current
IF_2: Secondary fault current

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