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Design and Implementation of Differential Relay Based on Graphical User Interface

***Abstract**. This paper demonstrates a differential relay (DR) which can be used to protect a power transformer based on the Graphical User Interface (GUI) Matlab program. The GUI may aid end users in running simulations without changing the input and parameters, allowing them to see the model's performance without having to understand the model's intricacies. This model was used to detect balanced and unbalanced faults, and it was noted that in the case of using GUI, the fault response speed was faster. The model has been put through its paces under a range of operating situations. The results show that the model was successful in recognizing internal faults while avoiding running into external faults. The results indicate that everything was done correctly.*

Streszczenie.** W tym artykule przedstawiono przekaźnik różnicowy (DR), który można wykorzystać do ochrony transformatora mocy w oparciu o program Matlab z graficznym interfejsem użytkownika (GUI). GUI może pomóc użytkownikom końcowym w przeprowadzaniu symulacji bez zmiany danych wejściowych i parametrów, pozwalając im zobaczyć wydajność modelu bez konieczności rozumienia jego zawiłości. Model ten był używany do wykrywania zwarć zrównoważonych i niezrównoważonych i zauważono, że w przypadku korzystania z GUI szybkość reakcji na zwarcie była szybsza. Model został przetestowany w różnych sytuacjach operacyjnych. Wyniki pokazują, że model skutecznie rozpoznawał błędy wewnętrzne, unikając jednocześnie błędów zewnętrznych. Wyniki wskazują, że wszystko zostało zrobione poprawnie.* (Projektowanie i implementacja przekaźnika różnicowego w oparciu o graficzny interfejs użytkownika***)

Keywords: Differential relay, Power transformer, Protection, GUI.
Słowa kluczowe: przekaźnik różnicowy, graficzny interfejs użytkownika.

Introduction

In electric power systems, the power transformer is one of the most important components, and its protection is critical. As a result, researchers are paying close attention to the protection of electrical transformers. The differential protection algorithm is among the most effective transformer protection strategies [1]. Differential protection (DP) is the most extensively utilized technique for performing the protection function in transformer protection methods that involve terminal behaviour. The (DP) technique can also be used to protect the primary winding and secondary windings of a three-phase power transformer against failures. The system's primary goal is to distinguish between faults and other operational conditions [2]. As soon as the problem occurs, the transformer must be removed from the operational zone to avoid or reduce the probability of destruction and coil damage. Repairing transformer damage and the accompanying costs are exorbitant. Furthermore, an unforeseen outage of a power transformer can be costly and economically ineffective. As a result, enormous demands are placed on power transformer protection systems. The differential protection detects and disconnects the zone when a fault happens in the protection zone. These sorts of relays are employed to protect electrical equipment due to their high sensitivity and reliability [3]. The primary requirements for power system protection are speed, sensitivity, selectivity, dependability, security, and reliability. Selectivity requires the protection system to be reliable in detecting problems within its protection zones [4]. In contrast to text-based interfaces, typed command labels, or text navigation, A Graphical User Interface (GUI) is a kind of software that allows users to communicate with digital equipment via graphical icons and visual signals such as secondary notation [5]. This work focuses on the stages involved in creating a graphical user interface (GUI) model for differential relays using MATLAB software, as well as validating this model under various operating situations. In this GUI Relay model, the K ratio was used to select the appropriate pick up value for the protected device.

Case Study Objective

The purpose of this project is to study the classification of the faults to protect the power transformer and discuss and compare the results for each type of fault.

Literature review

Adel Aktaibi, M. A. Rahman (2011) employed MATLAB / SIMULINK, to model and tested, a digital (DR), with a dual slope, dedicated a three-phase transformers protection [6].
Omar Mrehel, Hassan Elfetori, Abdallah Hawal (2013) implemented a SIMULINK model of a distance relay in MATLAB [7].
Mandeep Singh, Harjit Singh Kainth (2017) modeled a (DR), with a dual slope characteristic, for a single-phase transformer protection used MATLAB/ SIMULINK [8].

Proposed Method

The difference among primary (CTs) and secondary (CTs) has to be equal to zero. This indicates that the transformer is unable to identify a fault. There are no lessees and no operating current in the perfect power transformer. In practice, eddy current and core losses can be found in transformers [9], [10].

Figure (1) illustrates the single-line diagram of the differential protection relay system (DPS). The protective equipment was encased by a pair of (CTs). Due to the (CTs) normal proclivity, (DR) protection will not offer backup protection in comparison to the rest the equipment of the system. As a consequence, this sort of protection diagram is frequently utilised as part of a unit protection schedule. The present IP is the same as what is going out of the protective equipment at any given time under no fault conditions. When the (CTs) A is respected, 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) $$I_{BS} = \alpha_B\, I_p - I_{Be}$$

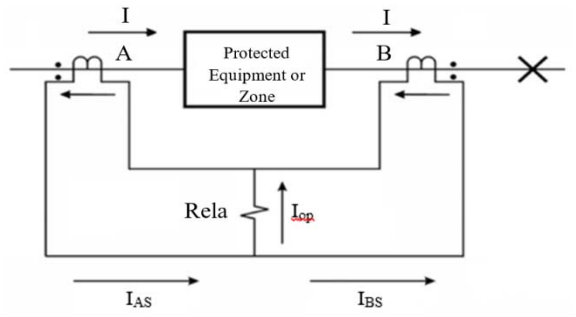

Fig.1. A single-line diagram of a differential relay fault that is out of zone.

Taking into account an equal ratio of (CT) A and B, αA= αB=α, the Iop is:

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

Figure (2) illustrates the single-line diagram of the differential protection relay system (DPS) when fault occurred in zone.

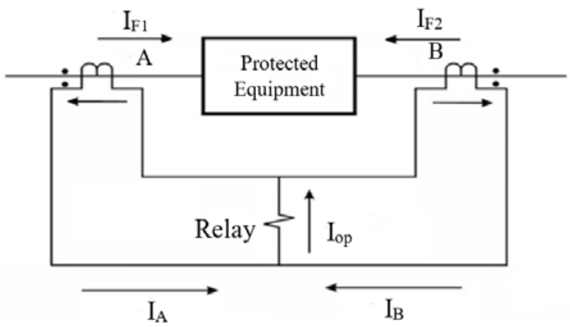

Fig.2. A single-line diagram of a differential relay fault that is zone.

Its bias employed for power transformer protection in terms of operation relay characteristics. The relationship between the restring current and the differential current is depicted in Figure (3). (Characteristics of operation relay) [14].

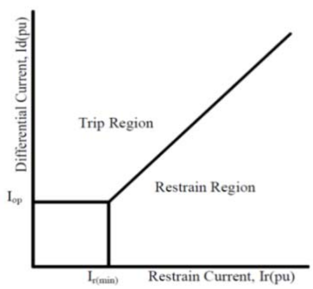

Fig.3. Differential relay characteristics.

When the pickup ratio exceeds the bias setting, the value of ratio falls into the tripping area (positive region), and when the pickup ratio will be less than the bias setting, the ratio value falls into the blocking region (negative reign) [15-16]. The operating coil is connected in parallel with the restarting coils of the relay kind. When faults occur beyond the zone, the restraining torque is determined by the influence of constraining coils on the operating coils. In this instance, the restraining torque is obtained so that the relay does not operate. The operating torque is greater than the bias torque when a fault happens inside of the zone (internal fault), causing the relay to activate. By varying the number of turns on the restraint coils, the bias torque is modified. [17-18]. Figure (4) depicts a Flowchart for the (DR) for single line protection of power transformers.

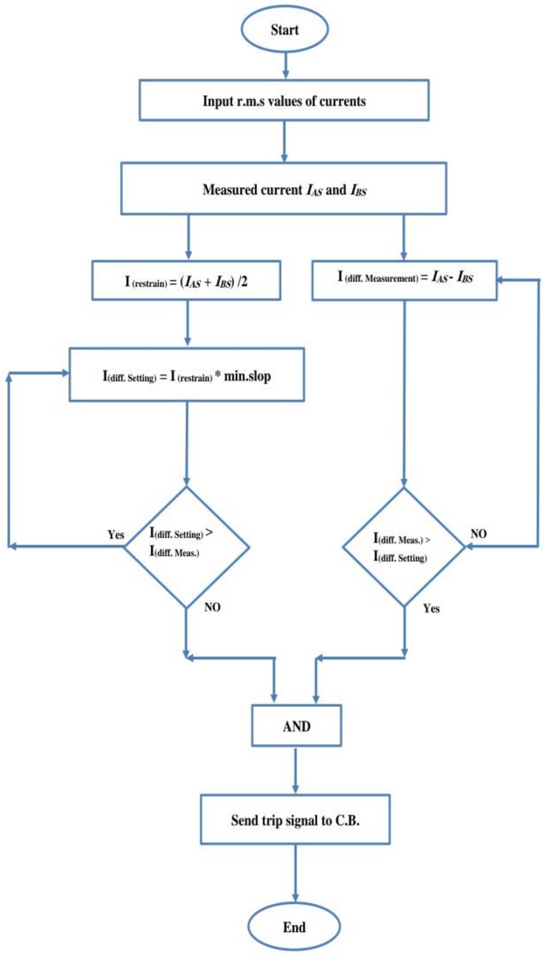

Fig. 4. Flowchart of the (DR) for single line.

Implementation of (DR) in Matlab

The implementation of a Simulink model and the GUI model for the Relay were demonstrated in this section as follows.

1. **Implementation of a relay Simulink model**

The MATLAB/Simulink environment is used for this implementation, each designed block's contents are illustrated in its own figure, and figure (5) illustrate the DR model.

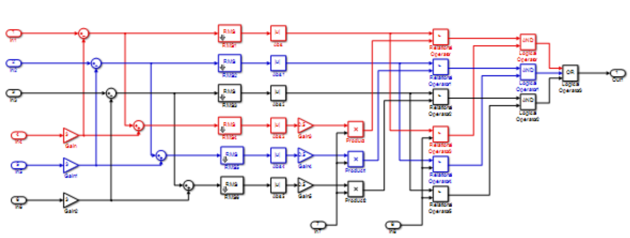

Fig.5. DR model.

2. Graphical User Interface (GUI) Model

A (GUI) it can be defined as a graphic presentation in one window or more that contains controls, also known as components, that allow users to execute reactive tasks. To fulfil the tasks, the GUI user don't need to write a script. As opposed to coding applications, the user of a GUI don't need to grasp the specifics of how activities are carried out. Menus, push buttons, toolbars, list boxes, radio buttons, and other GUI components are examples. MATLAB GUIs can additionally execute any kind of computation, interface with other GUIs, read and write data files, and show data as tables or plots. The GUI model is used to run the simulation with different inputs and parameters to examine how the model responds without having to comprehend the model's complexity [1]. The GUI model consists of:

- Operation condition selection bar, to select different operating cases for the system.
- The 'K' value which identifies the borders between the operating and restraining relay regions.
- Four axes to show the simulation results.
- Run Simulation' push button.

This design demonstrates how to create a GUIDE GUI that configures a runs the simulation, Simulink model, and displays the results in a figure window. GUI can built by:

- Creating the GUI using GUIDE GUI:

This design starts by filling it with components from the editor's graphic layout within the GUIDE application. First, in the MATLAB prompt window, type (guide) words to enter into the GUI. It will be possible to plot a result by using a blank (default) GUI template and adding a figure window (axes), inserting a push button into the GUI form component tool callback, writing program code in the programming editor, and arranging the components as shown in the figure (6).

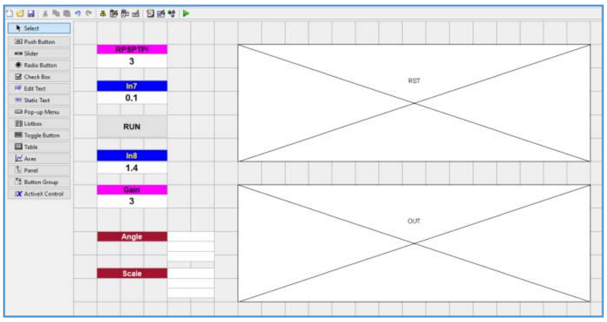

Fig.6. Design of GUI model

Creating the GUI program to write code from editor, open from the Layout Editor by selecting View > Editor, Or by right-click the Surf push button, and then select View Callbacks > Callback.

Results and Discussion

The designated (DR) is made up of two input signals, primary current (Ip) and secondary current (Is), where (Ip) and (Is) are the measured output currents. In order to be analyzed, these two input signals will be spread into three parallel paths. The secondary current's second three signals will be subtracted from the primary current's first three signals, Using the comparator block, the results of the currents will be compared with the reference current [19-26].

The relay was tested under various fault conditions in order to validate and compare the designed models of differential relay. The first with a Simulink model, and the second with a GUI model. Figure (7) illustrates the complete circuit of the power system. We can divide this study into three cases.

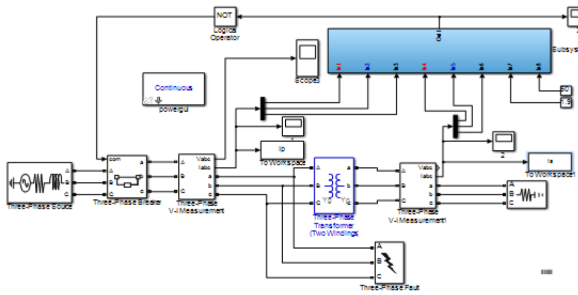

Fig.7. Complete circuit of power system.

There are three cases in this study:

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

In this case, the system operates without any faults. Figure (8) illustrate the results.

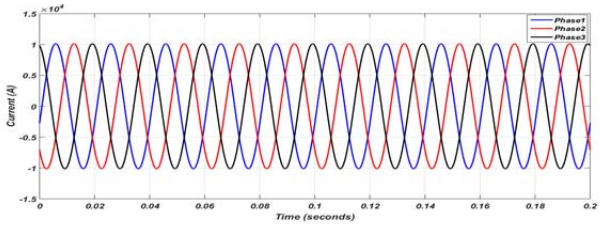

Fig. 8. Primary current without fault.

Case No. 2: External fault (out of zone):

When an external fault occurs, the fault current flows in the transformer windings, Figure (9) shows the primary current when the faults occur external.

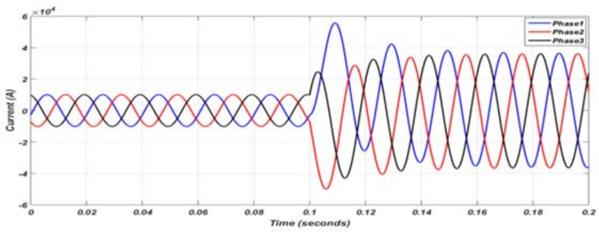

Fig. 9. Primary current external fault

Case No.3: Internal faults (inside zone):

In this case, the system operates internal faults, figure (10) illustrate the line to ground (L-G) fault.

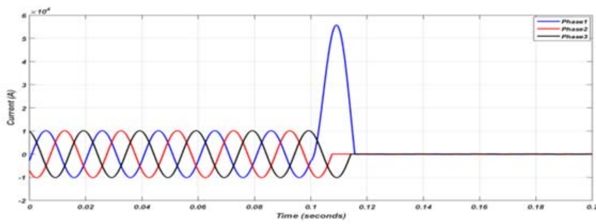

Fig. 10. Line to ground (L-G) fault

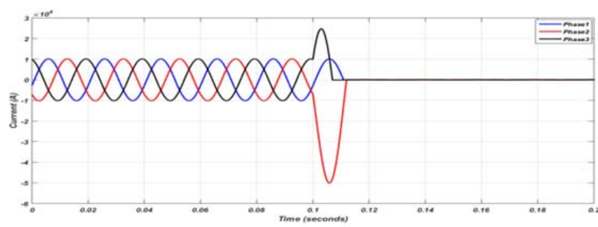

Fig.11. Line-Line to ground (L-L-G) fault

In this simulation, the system operates internal faults, figure (11) illustrate the line-line to ground (L-L-G) fault.

In this simulation, the system operates internal faults, figure (12) illustrate the three-line to ground fault.

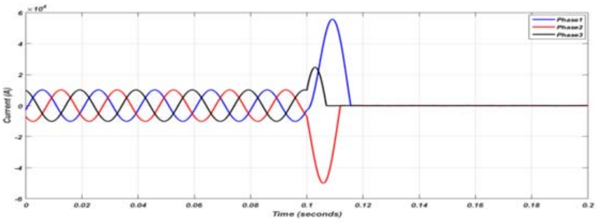

Fig. 12. Three phase to ground fault

The simulation results of GUI model can be divided into three cases:

Case No.1: At normal operation (no fault):
In this section of the GUI, the system operates normally without any faults. Figure (13) illustrates the primary and secondary current of power transformer at their normal operating values.

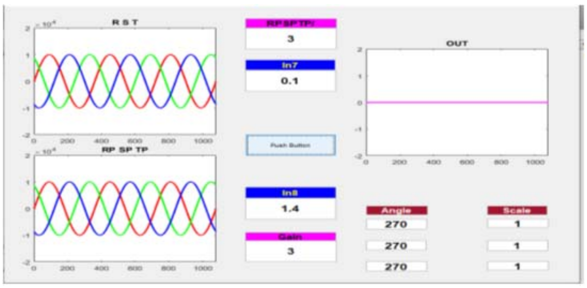

Fig. 13. Primary and secondary currents at no fault

Case No. 2: External fault (out of zone):
The GUI results in (DR) output signal. When a fault occurs externally, figure (14) illustrates the primary current and secondary currents.

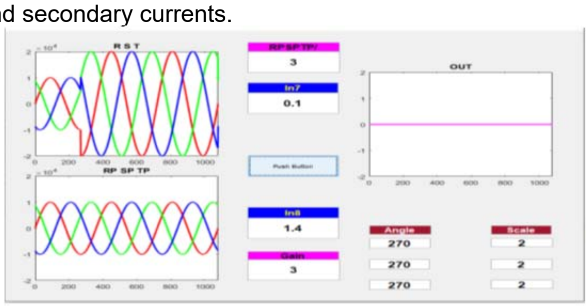

Fig. 14. Primary currents at external fault

When external fault occur, no trip signal sent from the (DR) to the (CB) because the fault occurred externa (outside) of the transformer-protected zone, as the turn ratio is the same.

Case No.3: Internal faults (inside zone):
At an internal fault, when a fault occurs as shown in figures (15-17), a trip signal is delivered from the DR to operate (CB). As (CB) will open, the current will be zero after the fault time occurs.

Line-to-line fault:

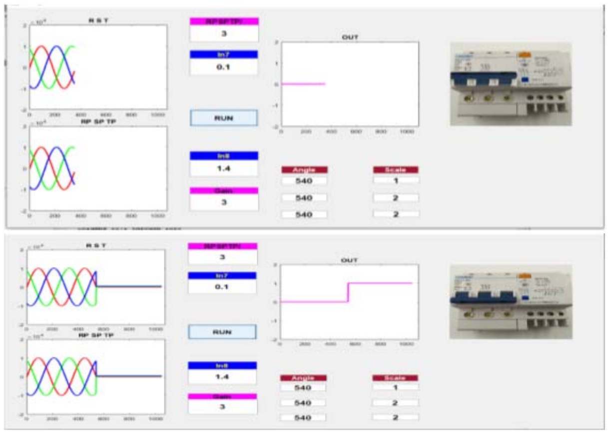

Fig. 15. Currents at line to line fault

Line to line to ground (L-L-G) fault:
Figure (16) illustrates the current signals of relay line to line to ground fault.

Fig. 16. Current at line to line to ground (L-L-G) fault

Line-to-ground (L-G) fault:
Figure (17) illustrates the current signals of relay line to ground fault.

Fig. 17. Current at line to ground (L-G) fault

Conclusion
The DR characteristics are simulated in this paper using Matlab/Simulink. The DR's performance characteristics were examined in a location with three phase faults and numerous faults that occur in the power transformer, such as the L-L fault, the L-L-G fault, and the L-L-L-G fault. The study and results show that the proposed (DR) is an appropriate solution. The proposed relay may discriminate between no-fault and fault conditions. We conclude from the results that in the case of using GUI, the transient response was faster for all types measured at the same time and the peak impulse, which led to a faster separation of the circuit breaker in a shorter time.

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