

Implementation of transformer protection Scheme with immunity against saturation of current transformer

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Abstract- In this research, we will discuss protection against current transformer saturation. A system was built to simulate the real system of the electrical power production system in the college laboratory, where experiments were conducted on the transformer during the synchronization process with the electrical grid. In these experiments, short circuit faults were intentionally created to study their effects on the transformer.

To collect data and analyze results, a IN 6009 card was used to gather readings from the system and transfer them to the computer. Then, Lab VIEW software was used to analyze and convert the readings into useful results. These results help to understand how saturation affects the performance of the transformer and to develop effective protection strategies. This research will review the results obtained from the experiments and discuss possible solutions to prevent current transformer saturation and ensure the continuity and safety of the power production system.

Keywords: Production, transformer, laboratory, software, saturation, current transformer, short circuit, inrush current.

INTRODUCTION

Electric power systems are characterized by continuous flow during generation, transmission, and distribution, and they are safe and error-free [1]. Due to the many advantages they offer, engineers strive to solve the problem of power flow interruption [2]. One of the issues facing transformers is the problem of saturation [3]. The saturation problem in transformers, in general, and in current transformers, in particular, prevents the flow of electrical power [4]. Therefore, it is necessary to study the saturation problem practically in the laboratory [5], as saturation can result from several causes such as short circuits [6]. Since a short circuit is a real fault and not a transient condition [7], it requires protecting the electrical system from saturation resulting from short circuits [8]. Studies and literature have shown that short electrical faults are among the most damaging factors to power

supply equipment [9]. However, traditional protection methods struggle to distinguish between faults [10-11-12] and also face issues with coordination between protection zones [13-14]. Protecting the electrical network or delaying fault detection can lead to interruptions in power supply [15-16]. Therefore, relying solely on traditional protection methods for the saturation problem is inadequate [17-18]. The transformer protection system needs to be adaptable, fast, and protected against saturation [18-19-20]. This paper presents an experimental investigation into a protection algorithm against saturation caused by short circuits, tested in the laboratory using an integrated power system that simulates a real system for fixed-speed wind turbines (a DC motor supplied with constant voltage and a constant current source) [21], an induction generator mechanically connected to a three-phase electrical transformer, and a three-phase-transmission-Line.

2-UsedTechnique:

2.1. In this technique, the principles of the proposed technique are illustrated as follows in a quick review. The designed algorithm relies on establishing a relationship between the current signal resulting from the low voltage I_{scv1} and the high voltage signal I_{scv2}.

2.2. Reading the three-phase relay current and the fault current at the beginning of the operation.

2.3. The algorithm verifies the existence of current in two parallel paths: the first path represents the current calculations on the high voltage side, and the second path on the low voltage side.

2.4. The program begins performing calculations on the two parallel paths.

2.5. Calculate the difference in the value of $i_1 - i_2$ the high voltage and low voltage, and the concept of differential protection.

2.6. Use the algorithm condition between and icsv1 and icsv2.

2.7. The tolerance ratio is 0.3 as a condition.

2.8. The condition of the product of the two values icsv1 × icsv2 being less than zero.

2.9. Use the concept of sin - cos in protection against saturation .

2.10. Decision

3- EXPERIMENTAL SETUP

The laboratory system used in this study consists of two aspects, the first aspect represents the wind power system and consists of a simulator of a constant-speed wind turbine (a DC motor fed from a constant voltage and constant current source), a wound rotor induction generator that is mechanically connected with a DC motor, and the excitation terminals of the generator are connected to a controlled DC source, an output of generator is connected to a transmission line, the second end of the transmission line is connected to a transformer, and the second end of the transformer is connected to a second transmission line. The second transmission line is at its end on one side of a circuit breaker responsible for connecting the system to the electrical grid when the synchronization conditions are met. The second side of the laboratory system is the electrical grid, and it is connected to the other end of the synchronization switch. The Ni6009 tool is used to transfer signals from the laboratory system to the laptop by using 6 current transformers to make the values of the electrical signals match the Ni6009.

Component	Name
1	Constant voltage and current source
2	DC motor
3	Synchronous generator
4	electric transmission line
5	electrical transformer
6	current transformer
7	Three-phase alternating current source
8	resistors
9	synchronization switch
10	Frequency meter
11	Voltage meter
12	NI6009
13	laptop
14	Faults circuit
15	circuit breaker



Figure 2 the used laboratory model

Software Implementation

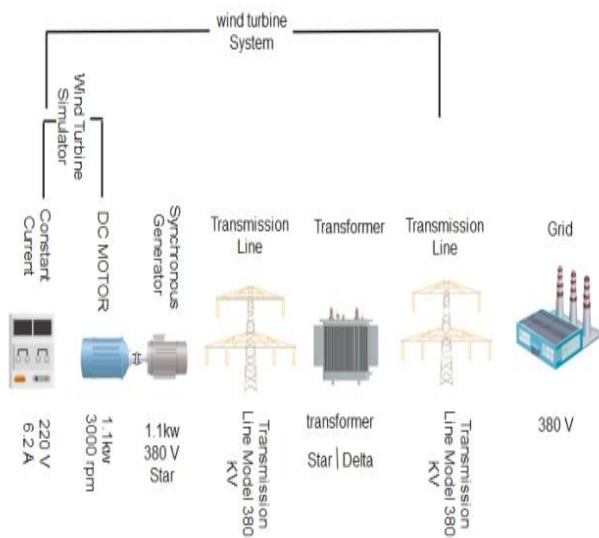


Figure 1 laboratory system

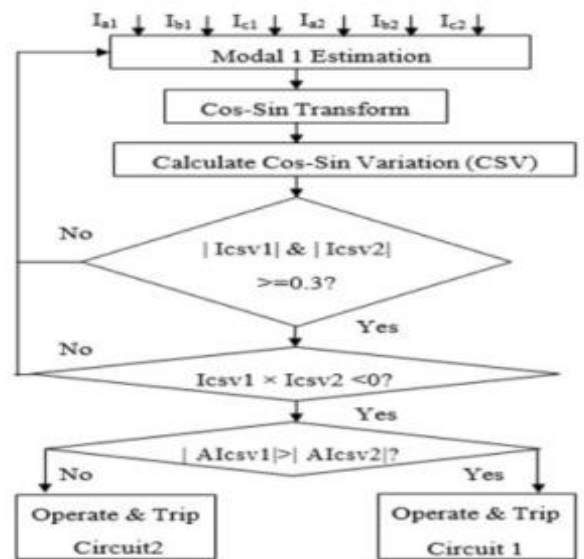


Figure 3 Algorithm

The Lab-View package is utilized to implement the proposed technique using real measurements as program inputs rather than product signals. Lab-View is a sophisticated and versatile tool used to collect measurements, control operations, and analyze stored data. As the G graphical programming language [18], Lab-View employs a graphical programming language.

The software uses a calculation process to find the relationship between the transformer-grid side current and the transformer-neutral side current. Mostly, the relationship should be equal to one. Due to the disturbances resulting from the nature of wind energy, a tolerance ratio of 0.2 was added. Suppose the product of the relationship is equal to one in addition to the tolerance ratio. In that case, the transformer is in a normal condition. If it is outside this value, there is a fault in the transformer area due to magnetic saturation caused by a short circuit. Since the transformer encounters transient states, to avoid faulty disconnections, the program ensures that there are 10 consecutive fault signals, and when the program checks that the fault is internal, it issues a trip command.

faults occur. This demonstrates the relay's ability to distinguish between normal and abnormal conditions..

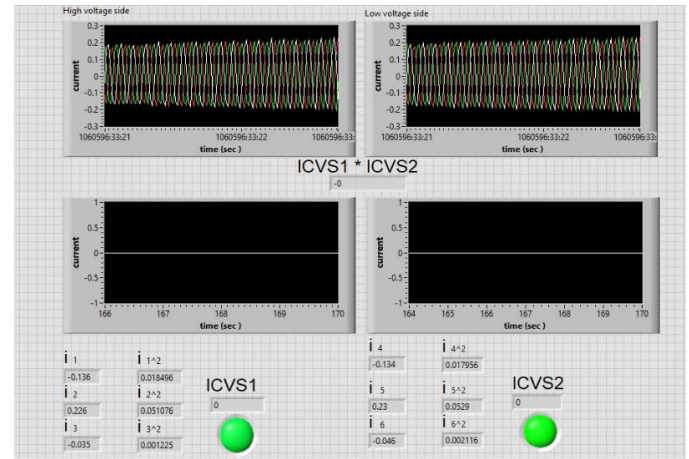


Figure 5 Normal

3.2- The performance of the relay during an internal fault

Effect of Short Circuit and Waveform Distortion Due to Magnetic Saturation, and Relay Behavior During Such Faults on the Transformer:

3.2.1. Impact of Short Circuit:

During an internal short circuit, the transformer currents increase significantly due to the low resistance in the fault path.

3.2.2. Waveform Distortion:

The sudden increase in current causes the transformer core to enter magnetic saturation, resulting in waveform distortion.

This distortion appears as an increase in nonlinear components (such as higher-order harmonics) or a deviation from the normal sinusoidal shape.

3.2.3. Difference in Currents on Both Sides:

Currents on the high-voltage and low-voltage sides become mismatched due to internal energy losses caused by the fault.

Relay Behavior During Such Faults:

3.2.3.1. Current Monitoring:

The relay monitors currents on both sides of the transformer using current transformers (CTs).

It measures instantaneous changes and abnormal values, such as sudden increases or waveform distortions.

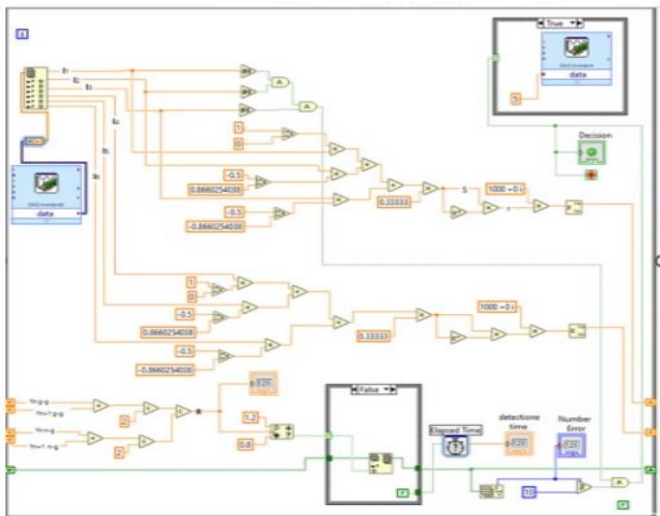


Figure 4 Technique

3.1- The performance of the relay under normal operation

Relay Performance During Normal Operation

The signals operate normally as indicated in Figure (5). When these signals are fed into the computer through a data acquisition device, it is confirmed that the system is in a normal state without any magnetic saturation. According to the proposed technique, simulated using LabVIEW, the number of consecutive errors is less than ten, ensuring no

3.2.3.2. Signal Analysis:

The relay analyzes the waveforms for indicators like magnetic saturation, higher-order harmonics, or asymmetry in the currents.

3.2.3.3. Fault Identification:

If abnormal distortions consistent with internal faults, such as significant differences between the currents on both sides, are detected, the relay classifies it as an internal fault.

3.2.3.4. Protection Activation:

The relay sends a signal to disconnect the transformer from the network, protecting it and minimizing damage caused by the fault.

Summary: A short circuit causes increased fault current and waveform distortion due to magnetic saturation. The relay detects the fault by analyzing these distortions and activates protection by isolating the transformer from the system

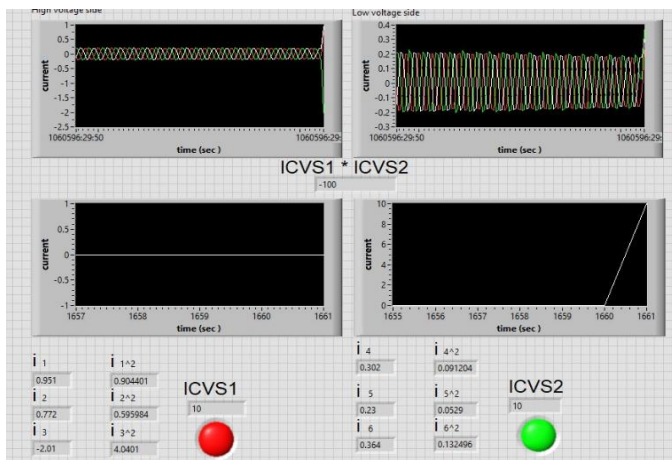


Figure 6 internal fault

3.3- The Performance of the Relay During an External Fault

When a short circuit occurs on a transformer, it causes a sudden rise in current, potentially leading to magnetic saturation in the transformer core. The relay's behavior to protect against this situation relies on various techniques for effective protection, including:

3.3.1. High Current Detection

The relay monitors the current on both sides (high voltage and low voltage). If the current exceeds a certain threshold, it is considered an indication of a short circuit.

The current is compared between the two sides to detect imbalances (Differential Protection), which indicate an internal fault.

3.3.2. Harmonic Filters

Modern relays use harmonic analysis to detect magnetic saturation.

If the current waveform contains high levels of odd harmonics (such as the third or fifth harmonics), it indicates saturation.

The relay disregards these currents if they are caused by natural inrush currents during transformer startup.

3.3.3. Intelligent Time-Delay Relays

Time delay is used to avoid unnecessary tripping.

In the case of inrush currents or temporary saturation, tripping is delayed to allow the situation to stabilize.

If the high current persists, the transformer is disconnected immediately.

3.3.4. Digital Analysis

Digital relays utilize signal processing techniques to analyze the current waveform.

Sudden changes in current caused by short circuits are detected.

Digital analysis enables differentiation between true short-circuit faults and magnetic saturation or normal conditions.

SO Technology plays a critical role in protecting transformers from faults caused by magnetic saturation by improving relay response with precision and speed, minimizing potential damage, and ensuring operational continuity

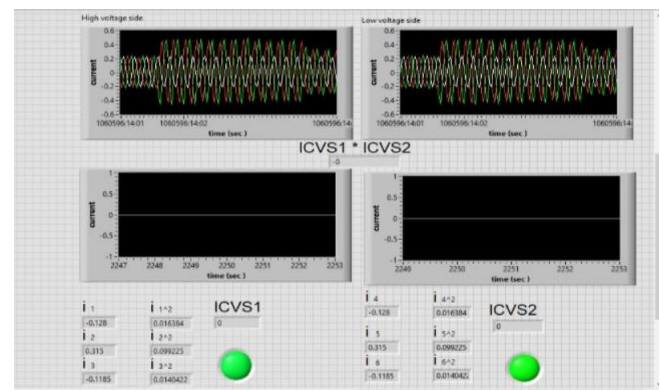


Figure 7 External Fault

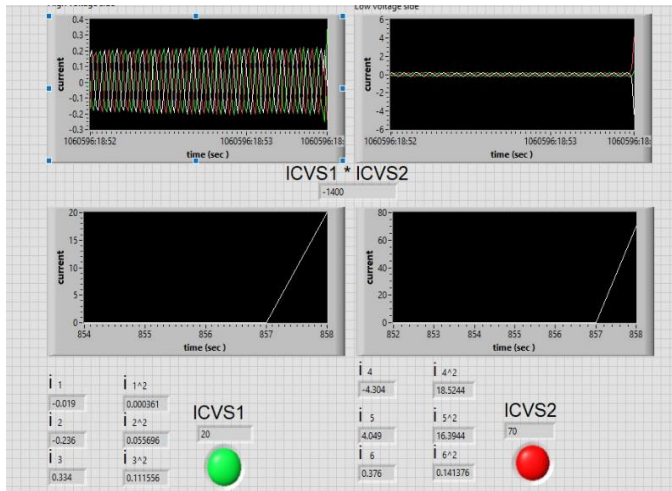


Figure 8 External Fault

4 Conclusion

the proposed algorithmic investigation conducted in the theoretical section ensured safe and scalable performance in cases of magnetic saturation caused by short circuits in power transformers. to explore the performance of the proposed model in real fault scenarios, it was employed in investigations tested under conditions similar to those of magnetic saturation caused by short circuits. the experimental results showed consistency with the simulated outcomes. because the proposed model is based on a unique coupling approach, it is sensitive to changes in magnetic saturation, stable, and reliable, and can be used in real-time applications because the proposed methodology, which is based on a unique coupling method, is stable, reliable, and rapid during the discrimination of internal and exterior faults, magnetizing inrush currents, and switching on internal faults, it can be employed in real-time applications.

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