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Designing Of a Tap Changing Mechanism With Solid State Devices

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Abstract:
This paper introduces atap changing mechanism for power transformers employing a solid-state device, Gate Turn-Off Thyristor (GTO), under the control of a fuzzy logic controller.The proposed system aims to optimize voltage regulation of power transformers by dynamically adjusting tap positions in response to changing load and supply conditions. The new tap changing mechanism's implementation, and performance evaluation are presented in this paper, along with its advantages over conventional techniques.

Keywords **—**Solid-state device, Gate Turn-Off Thyristor (GTO),Fuzzy logic controller, Voltage regulation.

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I. INTRODUCTION

On-Load Tap Changers (OLTCs) have been essential part of power transformers for many years. These devices allow adjustments to the transformer's output voltage while it remains operational, ensuring continuous electricity flow to consumers[1,2]. In conventional methods, OLTC utilize mechanical elements like selector switches and gears for tap adjustment.

This study explores the replacement of On-Load Tap Changers (OLTCs) in transformers with a tap-changing mechanism that integrates Gate Turn-Off Thyristors (GTOs).By incorporating GTOs into the tap-changing mechanism of transformers, significant improvements in switching speed and efficiency can be achieved [3]. The control of GTOs is facilitated by a Fuzzy Logic Controller (FLC), which intelligently responds to variations in load conditions. Through fuzzy logic algorithms, the FLC accurately senses load fluctuations and generates control pulses to regulate the operation of GTOs. These pulses enable precise switching of GTOs, thereby optimizing transformer performance under varying load scenarios.

In this paper, we explore the integration of GTOs and Fuzzy Logic Control into the tap-changing mechanism of power transformers. By leveraging these technologies, we aim to improve switching speed, responsiveness, and overall efficiency, thus contributing to the advancement of modern power distribution systems.

II. METHODOLOGY

Effective voltage regulation is essential for maintaining the stability and efficiency of electrical power systems. Traditional methods involve manual adjustments to reference voltages, as well as the activation or deactivation of capacitor banks and compensating reactors. However, these approaches lack the ability to make real-time decisions based on system monitoring and alarm management[4]. In our investigation, we propose an innovative strategy for voltage regulation utilizing a Fuzzy Logic Controller (FLC) to oversee the operation of On-Load Tap Changers (OLTCs). This approach enables dynamic decision-making in response to system conditions, thereby enhancing the overall stability and efficiency of power systems.

Automatic Voltage Control (AVC) systems play a pivotal role in preserving voltage stability within electrical networks[5]. Historically, OLTCs equipped with mechanical tap changers were employed for AVC purposes. Nonetheless, their sluggish response times, tendency for arcing, and mechanical losses presented significant drawbacks. To address these limitations, contemporary AVC systems integrate power electronics devices such as TRIAC, MOSFET, IGBT, and GTO, resulting in improved response times and efficiency[6].

The incorporation of an FLC into AVC systems offers notable advantages over conventional micro controller-based approaches. Fuzzy logic proves more adept in managing complex systems, where micro controller logic may fall short, owing to its basis in approximation and human-like reasoning. FLCs also exhibit tolerance towards imprecise data, capability in modeling nonlinear functions of varying complexity, and seamless integration with conventional control techniques[7].

In our study, we propose a system architecture that combines the utilization of solid-state devices like GTOs with a Fuzzy Logic Controller for AVC in OLTC systems. By employing GTOs for tap adjustment and FLC for decision-making processes, the system achieves rapid response times to fluctuations in load, ensuring swift voltage control. The system's automatic operation, driven by real-time voltage sensing, enhances efficiency and reduces operational time compared to traditional mechanical tap changers. Overall, the integration of solid-state devices and FLCs presents a promising avenue for bolstering voltage stability and load management within electrical networks.

III. PRINCIPLE OF OPERATION

The proposed tap-changing mechanism for transformers incorporates Gate Turn On Off Thyristors (GTOs) and a fuzzy logic controller to ensure a consistent and uninterrupted voltage supply to the load.Unlike traditional transformers with tap changers that use OLTCs as their only moving part, this system introduces a new tapping mechanism.GTOs are integrated into each tap of the transformer, functioning as switches that can be activated by pulses generated from a fuzzy logic controller. This controller receives voltage data from two sensing devices-one monitoring the source voltage and the other measuring the voltage across the load. Through analysis of these inputs, the fuzzy logic controller determines whether the load-side voltage deviates from a predefined reference voltage by a specified threshold.

Upon detecting a deviation beyond the acceptable range, the fuzzy logic controller generates a pulse targeted at the specific GTO corresponding to the tap requiring adjustment to uphold the desired voltage level on the load side. This capability of the fuzzy logic controller to analyze voltage data and determine the appropriate GTO to trigger ensures a precise and tailored response to voltage fluctuations.

Figure 1 illustrates the block diagram of the proposed system, demonstrating the integration of GTOs, sensing devices, and the fuzzy logic controller.

Fig.1: BLOCK DIAGRAM OF PROPOSED METHOD

Figure 2 shows the simulation of the proposed system, where the load is linked to the secondary side of a transformer. The signal processing unit oversees the voltage on the secondary side. Should the voltage deviate from a predetermined reference value, the fuzzy logic controller instigates pulse generation. The transformer in this configuration operates at a rating of 220/11 kV. These pulses are then directed to the Gate Turn Off (GTO) device for subsequent control action.

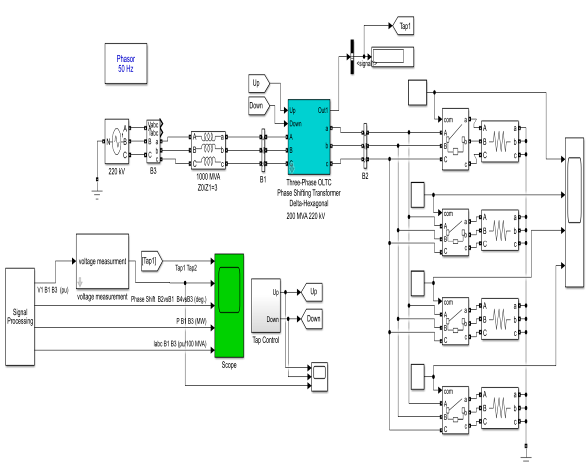

Fig. 2:SIMULATION OF PROPOSED METHOD

In this mechanism,tap changes are determined by voltage variations: when voltage increases, tap decreases, and conversely, when voltage decreases, tap increases. If the voltage remains constant, there is no adjustment to the tap positions. GTOs are connected to each tapping, with the 10th switch serving as a reference. Operating the tapings at position 10 ensures they receive 11 kV voltage, indicating no requirement for tap adjustment.

IV. RESULTS

Figure 3 illustrates the dynamic behaviour of load variations within the system, as described in the table 1[8,9].

TABLE I
LOAD VARIATIONS

TIME (sec)	LOAD STATUS
0-5	No load connected
5-10	Load 1 switched on
10-15	Load 1 switched off, Load 2 connected
15-20	Load 2 switched off, Load 3 connected
20-25	Load 4 connected in parallel with Load 3
25-35	Load 3 switched off, Load 4 still operating
35-45	Load 4 switched off

The stability of voltage levels during these load variations is shown in Figure 4. The voltage stays constant in spite of variations in the load configuration, demonstrating the efficiency of the voltage regulation mechanisms in the system.

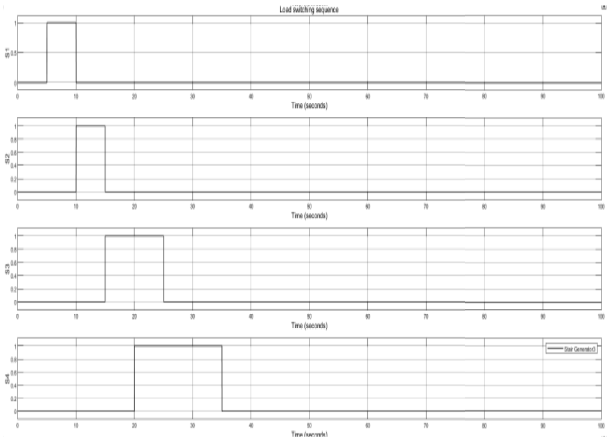

Fig 3: DYNAMIC BEHAVIOUR OF LOAD VARIATIONS

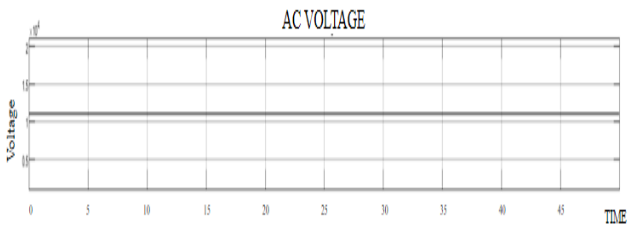

Fig. 4:THE STABILITY OF VOLTAGE LEVELS DURING LOAD VARIATIONS

V. CONCLUSIONS

In this study, we have suggested a novel approach to tap changing in place of the conventional OLTC method. Through the application of fuzzy logic controller in conjunction with GTO switches, we managed the voltage regulation process of the system effectively. Our empirical findings, backed up by matching charts, show that this unique method maintains constant voltage levels even in the face of varying load conditions. Enhancing voltage stability is crucial to improving the durability and stability of the power grid. However, it is imperative to acknowledge that this modification could result in a reduced switching response within the system. While our discoveries showcase encouraging progress in voltage regulation methodologies, additional investigation is necessary to enhance this process, striking a harmonious equilibrium between voltage steadiness and system responsiveness for an exhaustive system operation.

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