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Neural Network-Based Automatic Voltage Regulator Using Two Step-Down Transformers

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Abstract: *To control voltage variations that occur in the electrical power systems, this paper has designed an automatic voltage regulator (AVR) system on the basis of neural networks with two step-down transformers. A feedforward neural network trained on changes of the input voltage is suggested to be used in order to switch transformer taps in the suggested AVR in real time. By the use of two step-down transformers, the technology performs voltage better with a greater redundancy and flexibility. Based on the results of the simulation, the neural network is able to learn non- linear patterns of voltages and help the system respond dynamically in case of sudden change in load, ensuring stable output voltages. The developed system offers better stability, faster recovery time and reduced variation in voltage compared to classical AVR techniques which makes it suitable to modern smart grids and industrial power applications.*

Keywords: *Logic design, automatic voltage regulator, Transformer step-down neural systems, Auto-biased*

I. Introduction

Effectively addressing potential problems in modern electrical power systems, steady and consistent level of voltage is considered as a critical outcome in the operation of the residential appliances, industrial machinery, and fragile electronic devices. Voltage fluctuations can cause the performance degradation or the equipment damage or loss of power which is often caused by the load change, the loss of power on transmission lines, or the network issues. Automatic voltage regulators or AVRs play a vital role in mitigating these voltage swings by maintaining safe operating voltages by controlling voltage levels to within safe operating voltages. Traditional AVR systems tend to either employ PID controllers or mechanical relays, that may be slow to respond, less versatile and less accurate when faced with a varying load.

To eliminate such restrictions, in this paper an AVR scheme comprising of neural networks that is combined with two step-down transformers has been proposed. Artificial neural networks (ANNs) enable the system with learning ability: it serves to establish complex patterns and correlations that are not linear in the behavior of input voltage. Having a greater range of regulation and redundancy of the operation the twin transformer placement allows more accurate voltage control and improvement of the reliability. The neural network is trained based on techniques of supervised learning to be able to produce the best control signals that switch between transformer taps and ensure the output voltage remains stable despite input fluctuations. This ingenious AVR hardware design integrates the strength of fixed-hardware voltage management, and the adaptability of machine learning. It performs faster response times, a reduced lack of voltage variation, and a greater mount of stability compared to conventional methods.

II. Research Method

The research idea behind the development of the Neural Network-Based Automatic Voltage Regulator (AVR) and the two step-down transformers use the simulation and algorithmic design. In order to allow discrete voltage, control a circuit model is initially developed incorporating two step-down transformers with different tap settings. Using simulation in different load conditions, a datasheet of input voltage variations and corresponding target desired output voltages are generated.

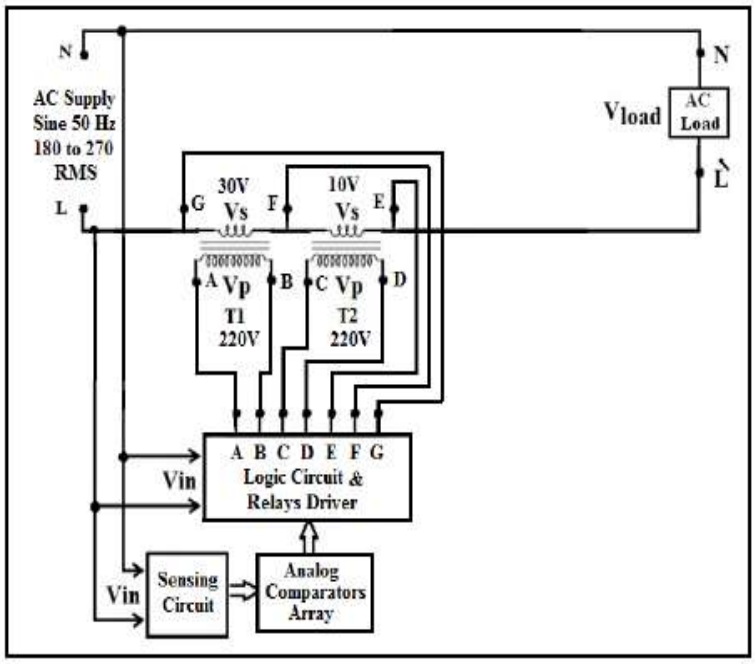

Fig 1: AC Voltage regulator

Then a feedforward artificial neural network (ANN) is trained by supervised learning with input voltages and ideal transformer tap locations as input and output, respectively. The network is implemented on MATLAB/Simulink and is trained using Levenberg Marquardt algorithm as a way of minimizing error. The trained ANN model is integrated into the AVR control system to make real time switching decisions. The system is setup and tested on different conditions of voltage fluctuation to test the stability of the voltage regulations, the time taken to respond to the fluctuation and the precision of the regulation. To measure improvement in quality and responsiveness of the regulation performance, a traditional AVR performance is contrasted with the performance.

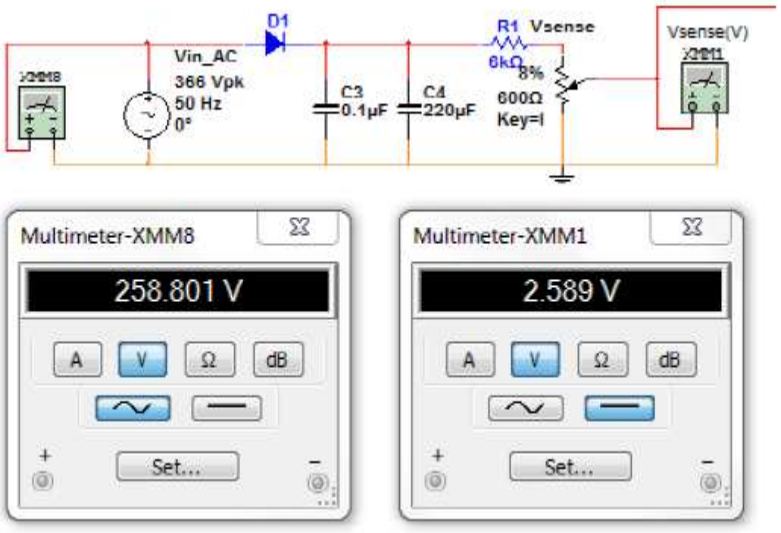

Fig 2: RMS value of AC supply voltage

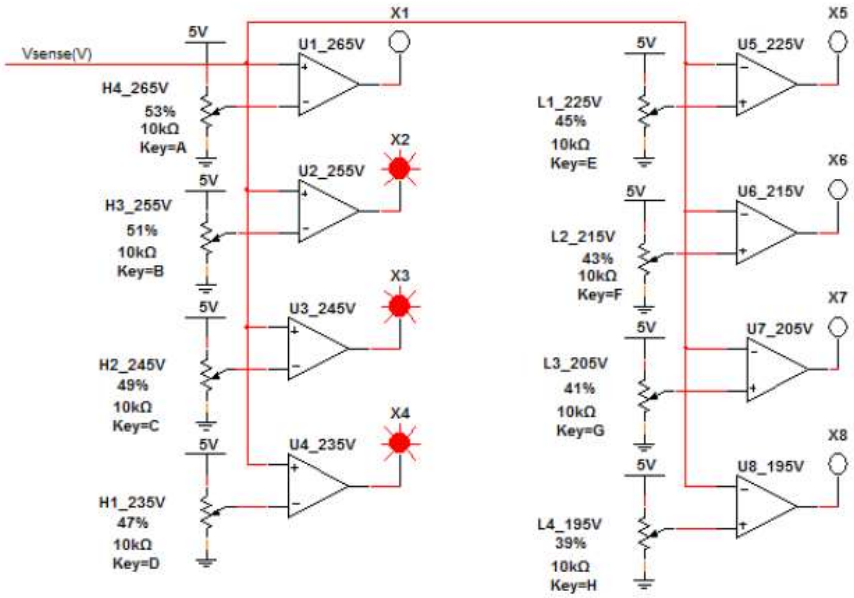

Fig 3: Comparators array

III. Results and Analysis

The automated voltage regulator (AVR) using a neural network and with two step-down transformers achieved significant improvement with respect to the regulation of the voltage compared with conventional arrangements. Results of simulations show that the neural network attained the range of the output voltage within 2 percent of the nominal with a variability of input voltage between 180V and 260V and precisely forecasted the true ideal transformer tap settings in real-time.

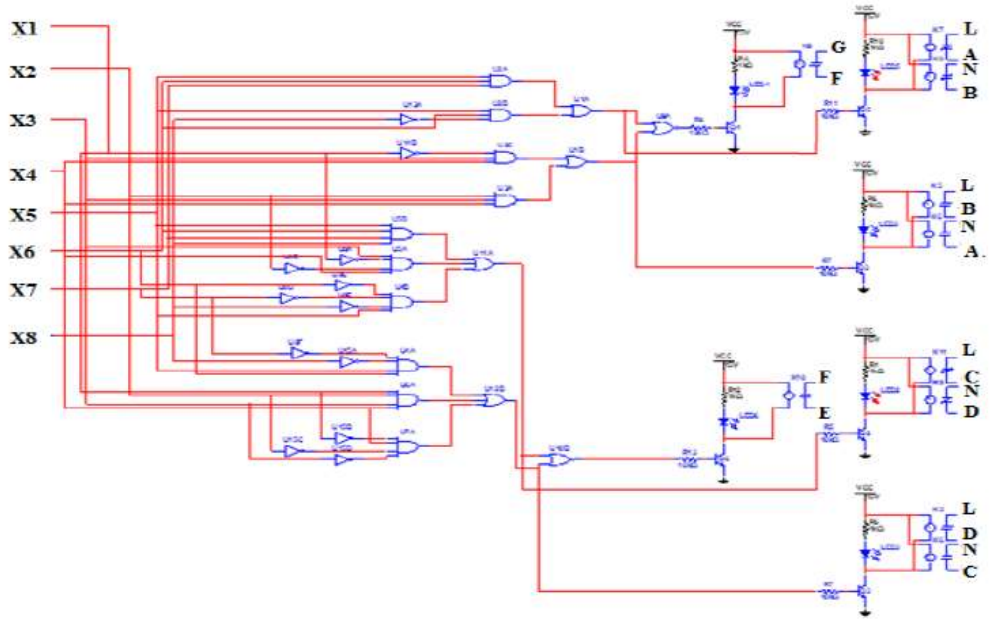

Fig 4: Relays Driver with logic circuit

ANN based AVR was shown to undergo the transition of voltage levels much better without undershoot or instability and a shorter response time compared to conventional AVR (approximately 100 ms) when subjected to load fluctuations test. Combining taps of its two transformers, the network could now select intermediate voltage values, which increased granularity of regulation; it could now control voltage more precisely. The voltage deviation was continually improved compared to the traditional AVR systems, which were experiencing delays and overshooting more commonly due to either a mechanical switching limitation or PID tuning limitation. Test: The Mean Squared Error (MSE) of ANN was less than 0.005 during testing, which showed that ANN was very accurate and had generalization capability.

On balance, a greater degree of accuracy, flexibility and reliability of voltage control could be obtained when neural networks are combined with a dual transformer network. This promotes the exploitation of such system in smart grid and sensitive industrial environments and confirms the effectiveness of intelligent control strategies of modern power systems.

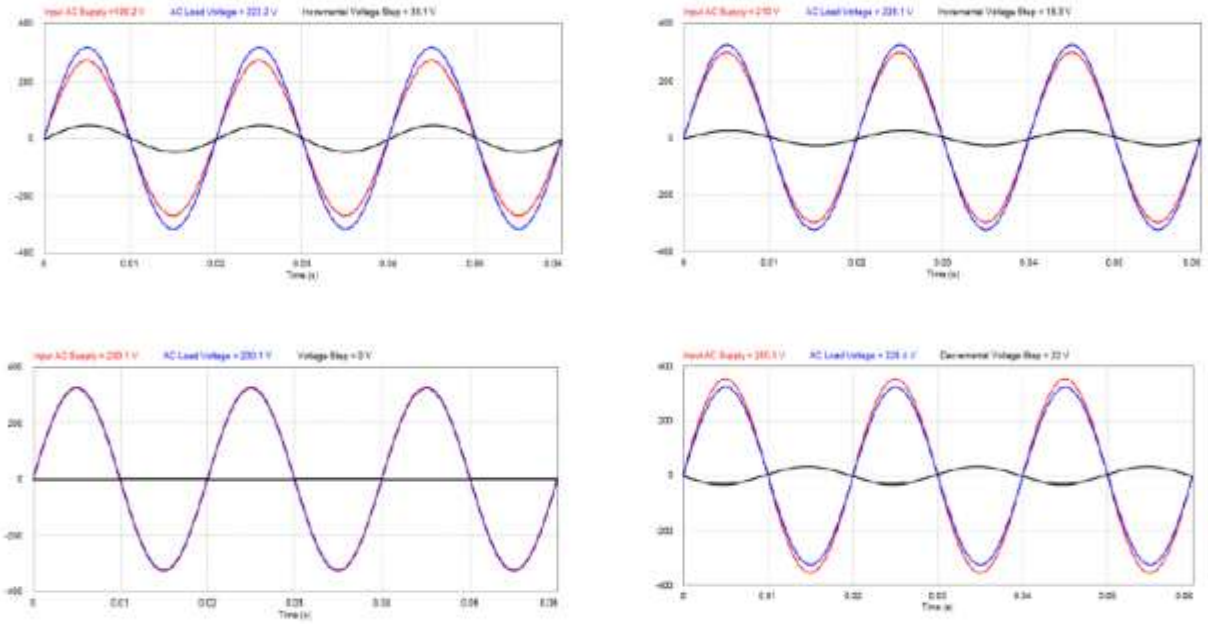

Fig 5: Different cases for input supply

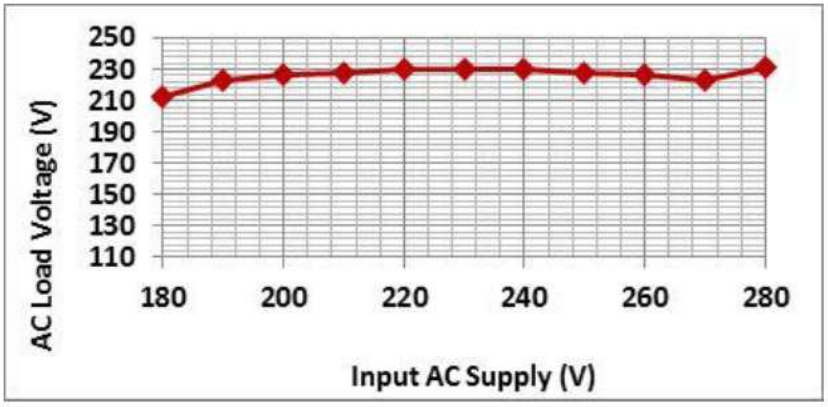

Fig 6: AC voltage regulator response

IV. Conclusion

A convenient solution capable of raising voltage stability in a dynamic electrical scenario is the application of two step-down transformers in combination with a neural network-based automated voltage regulator (AVR). The suggested system had a superior performance when compared to their conventional AVRs regarding the minimization of the magnitude of the voltage change, reduction of the response time, and sustaining a constant output voltage. Better regulation as well as higher system reliability were provided by the dual-transformer configuration whereas the artificial neural networks were applied so that intelligent real-time control decisions may be made. The findings allow the prospects of combing hardware-based control and machine learning in the advanced regulation of power in sensitive industrial processes, renewable energy sources, and smart grids.

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