Improving the Security of Power Grids using Fuzzy Logic and Hidden Markov Models

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Abstract
In the United States the use of smart grid technology allows for bi-directional flow of electricity so that users can generate and sell energy back to the electric power grid. This advancing technology presents increased security vulnerabilities and risks. Various levels of vulnerability could be identified that are related to their causes and effects on the normal functioning of the power grid. Moreover, the unsupervised machine learning approach could be integrated into an evolutionary algorithm such as a genetic algorithm, to evaluate how the control system could change its responses over time. In order to improve the security of the power grids, fuzzy logic controllers were applied to circuits with different types of power converters. Hidden Markov analysis also proved helpful in increasing security. The results were analyzed and applied to smart grid technology models.

Methodology
Low-Dropout Linear Voltage Regulator:
The original circuit, designed by Dr. Venkatesh Kumar in a PI-Controller Based Voltage Regulation of Three Phase Inverter. A signal builder was added to input a sine wave. In the circuit the error, derivative of error, and integral of error were taken of the input and the line to line output voltage. These three values were inputs for the fuzzy logic controller and the three outputs controlled the PID controller. Figure 5 shows that both inputs to the circuit with and without fuzzy logic were the same. Figure 6 shows that the fuzzy logic controller lowered the output voltage of the circuit. This means that it had an impact on the values and it is effective in altering voltage.

Results
Results from Low-Dropout Linear Voltage Regulator:

Overcurrent in Boost Converters:
The analysis of the boost converter included the testing of overcurrent within the circuit. Figure 7 shows the result of the current with voltage remaining constant. Testing the overcurrent showed where in the circuit the current was fluctuating with other parts of the circuit still intact such as voltage, resistance, amplitude, period, and capacitance.

Results from Overcurrent in Boost Converters:

Results from Buck-Boost Converter Model:

Both the fuzzy logic controller and the Markov feedback controller proved effective in stabilizing the output voltage, as shown in figure 8. In this figure, the circuit model was in boost mode, meaning it increased the input voltage of 20 V to about 23 V. A more stable output means a more secure output, which means a more secure system.

Conclusion and Recommendations
Analyzing different types of power converters allowed us to see on a smaller scale how a smart grid functions. Adding a fuzzy logic controller to a low-drop out voltage regular changes the output voltage of a circuit. This means that depending on the rules that program the fuzzy logic controller, the output voltage can be regulated based on specific needs. It can also be used to correct any faults that occur because the fuzzy logic controller can be programmed to adjust for abnormalities in voltage. The analysis of boost converters shows how the different parts of the circuit and the sensors work together to create efficient circuit flow. The overcurrent and overvoltage sensors produced different results throughout, depending on the placement in the circuit. For the buck-boost model, fuzzy logic and Markov control stabilized and secured the system, making both control systems an attractive addition to smart power grid security.

References

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