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High-Speed Real-Time Power Factor Correction Using Fuzzy Logic Controller

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Abstract— This paper examines the analysis and real-time implementation of a fuzzy logic-based unity power factor correction converter (PFC). The conventional diode bridge rectifier is replaced by a single-phase AC-DC buck-boost converter. Fuzzy logic and Hysteresis control techniques are used to enhance the performance of the buck-boost converter. The fuzzy controller is applied to the DC voltage loop circuit to improve performance. PI and hysteresis controllers are used to control the current loop. The results demonstrate that the fuzzy controller performs well when the robustness of the controller is verified using DSPACE. The experimental findings demonstrate that the proposed controller improved the converter's performance.

Keywords— Power factor correction (PFC), Fuzzy logic controller (FLC), Hysteresis Current controller, Power factor improvement

I. INTRODUCTION

An essential component of power system operation is a utility's capacity to deliver a constant flow of power within predetermined voltage and frequency ranges. A power factor that is close to one is a reliable sign of overall power quality in power systems with high reactive loads. Power companies must deal with high peak demand and increased power losses due to a poor power factor, which also raises utility costs. Therefore, one of the best ways to maintain power quality while gaining some extra advantages is to increase the power factor. In order to improve the power factor and fully implement the technical and financial advantages of power factor correction.

In order to create a dc voltage link, simple diode rectifier bridges are used because they are reliable, affordable, and easy to use. But as the demand for dc voltage has increased dramatically in many applications, the widespread use of diode rectifiers has made issues with harmonic pollution in electrical distribution systems worse. Input current waveform distortion and power factor are both high in a straightforward diode rectifier.

Despite being more expensive than straightforward diode rectifiers, single-phase buck-boost converters offer an effective solution against power quality deterioration for single-phase applications.

The buck-boost converter's voltage loop has typically been controlled by a conventional regulator PID. The PID works well with constant parameters, but when the system has some variations, it produces poor results. This control is based on system modeling around a nominal point with constant parameters and disturbance. To get robustness control and performance under parameter variations, intelligent controllers have been introduced as a solution to this issue. Fuzzy logic and artificial neural networks are used as some of these controllers.

II. FUZZY LOGIC CONTROLLER

The complex process can now be successfully controlled with the help of fuzzy logic controllers. The robustness, tolerance of imprecise inputs, and ability to handle the nonlinearity of the fuzzy logic controller are the main benefits. It also doesn't require a mathematical model in the conception of the controller. The output dc voltage of the buck-boost converter is controlled by this paper's use of a fuzzy logic controller in place of the traditional proportional-integral controller.

The main elements of an FLC system are,

- A fuzzifier
- a fuzzy rule base
- a fuzzy knowledge base
- an inference engine
- a defuzzifier

It also has normalization-related parameters. When a plant control action is not the output of the defuzzifier, the system is a fuzzy logic decision system. The fuzzifier in place transforms sharp values into fuzzy ones. Knowledge of the functioning of the domain expertise process is stored in the fuzzy rule base. The knowledge about all fuzzy input-output relationships is kept in the fuzzy knowledge base. It also comprises the membership functions that provide the output variables for the controlled plant and the input variables for the fuzzy rule base.

The core of an FLC system is the inference engine, which can replicate human decisions by applying approximation reasoning to arrive at the appropriate control strategy. An inferred fuzzy control action by the inference engine is transformed into crisp quantities by the defuzzifier.

By regulating the charge and discharge of the capacitor, the DC voltage loop controller seeks to keep this voltage at or near a fixed reference value. The switching losses in the converter and the variation in load between the converter's outputs are the main contributors to the fluctuation in capacitor voltage.

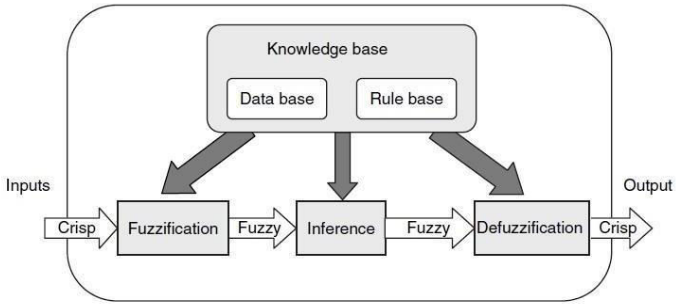

Fig.1. Fuzzy Logic Controller

TABLE I. CONTROL RULE TABLE OF THE FLC

	NG	ZE	PG
NG	NG	NG	ZE
ZE	NG	ZE	PG
PG	ZE	PG	PG

III. Hysteresis Current Controller

To keep the current flowing through a band, use a fixed band hysteresis current controller (HCC). A switching command is issued by the controller when the difference between the measured and reference currents is too great.

The hysteresis bandwidth is the only control parameter for this command. The current in the PFC circuit oscillates around a fixed band hysteresis.

This HCC control method is a nonlinear control. The current error serves as the HCC's input, and the switch's control command serves as its output.

Hysteresis current control has several benefits, but its key benefits are,

- Straightforward implementation
- Quick time response
- Robustness
- Better dynamic response

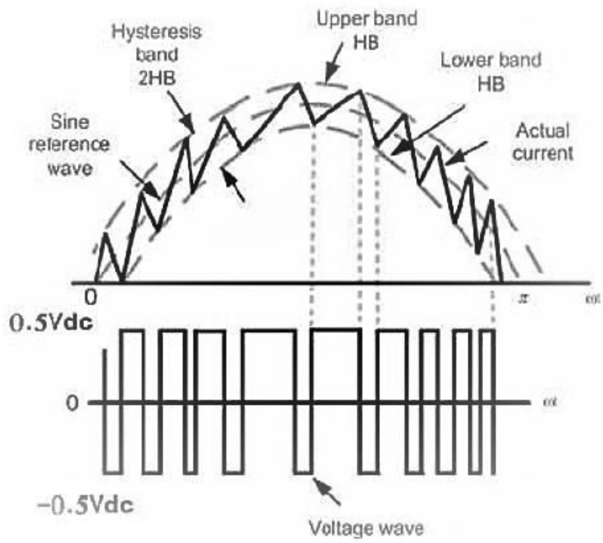

Fig.2. Hysteresis Current Controller

The main flaw in the HCC controller is the switching frequency, which is unpredictable and unmanageable, and switching losses are unknown.

V. SIMULATION AND EXPERIMENTAL RESULTS

In the case of a rectifier without PFC, no controller was used; the line current is displayed in Figure 3; it is more distorted, has a low power factor, and does not have a sinusoidal waveform as input current. These findings support PFC's critical role in power converter energy conservation. 100V is used as the reference output voltage.

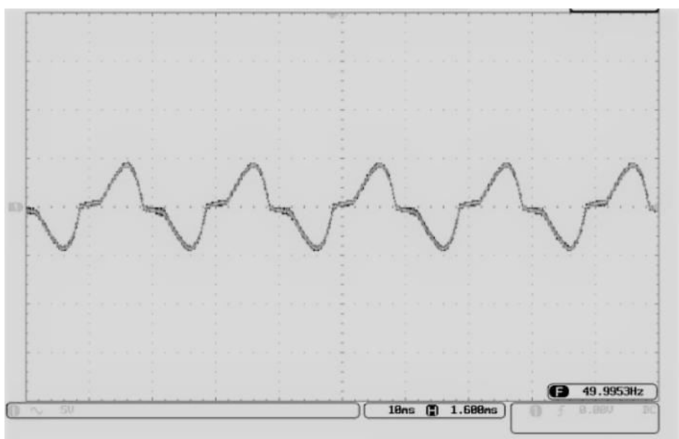

Fig.3. Diode Bridge input current

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Figure 5 exhibits the experimental line voltage and line current for the Fuzzy controlled PFC with fixed band hysteresis current controller. Figure 4 shows the simulation of the line current and its harmonic spectrum as well as the dc-bus voltage. These numbers show that the suggested FLC controller produced results that are effective and superior to those required by international standards. The THD is less than 3%, the line current is practically sinusoidal, and it is in phase with the grid voltage.

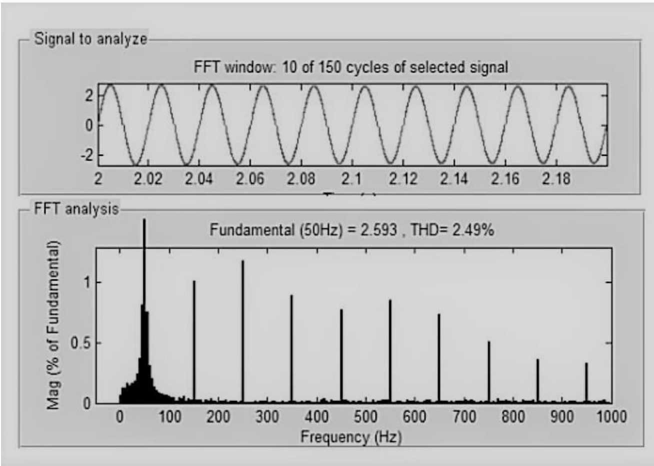

Fig.4. Line Current and its harmonic spectrum using the fuzzy controller for DC bus

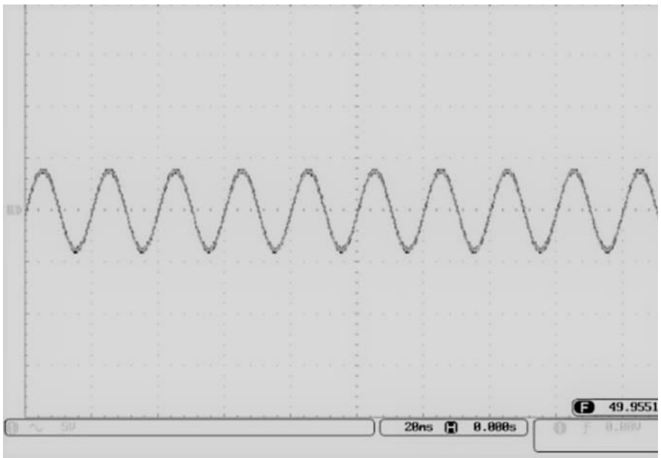

Fig.5. PFC input current

VI. CONCLUSIONS

This research analyses the DC voltage loop of a single-phase PFC converter. The fuzzy logic controller method is used to enhance the PFC converter's performance.

It is reliable and effective. With successful results, the proposed methodologies were tested using DSPACE. The fuzzy controller was then implemented in real-time. Real-time tests have verified the simulation results that have been reported, and great efficiency has been attained at the same time. Better outcomes, a lower level of harmonic distortion, and robustness management during parameter variations are all provided by the suggested controller when applied to the unity power factor.

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