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Improvement of Power Quality in Cascaded ML Inverter using FLC Based Voltage Regulation Techniques

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ABSTRACT

The power quality of a solar photovoltaic (PV) system is diminished by harmonics. This research will look at eliminating harmonics in a solar-powered, fifteen-level cascaded inverter by using Proportion Integration (PI), artificial neural network (ANN), or simulated annealing (FL) determining factors. The recommended FLC-based solution aims to enhance power quality by focusing less on the elimination of harmonic distortions than do conventional approaches. In order to increase power quality and conform to grid connection regulations, this research suggests a technique of changing the control and voltage there at inverter's output. Simulations are performed in MATLAB/Simulink for a solar-powered, 15-stage cascaded inverter using PI, ANN, and Stone fireplace controllers. To demonstrate the effectiveness of the proposed technology, a 3 kWp entire universe equipped with a layered inverter is built and shown. These three strategies are put through an experimental evaluation by employing power quality metrics and output voltage control.

Keywords- Fuzzy controller, PV Panel, Multilevel Inverter, Boost Converter, Harmonics, Power Quality

1.INTRODUCTION:

Providing rural regions with access to electrical electricity is a top priority in many developing countries because of its importance in fostering the development of sustainable living conditions [1]-[4]. Energy efficiency, electricity supply, and sustainability are the three most important fields of study in today's world. Expansion of the economy, growth of the human and industrial sectors, and the availability of low-cost, dependable, and secure energy sources are all preconditions for national prosperity. The demand for greater energy efficiency has grown in recent years in response to rising concerns about the environment, declining petroleum reserves, and increasing dependence on fossil fuels coming from politically volatile places. Sustainable existence maintained by an infinite resource base is the definition of renewable energy. Nature provides a wide variety of renewable energy options, such as solar, wind, hydroelectric, biomass, and geothermal. Renewable energy resources have a broad reach and promising future in comparison to conventional power sources such fossil fuels, which are limited to and concentrated in certain regions. Widespread adoption of sources of clean energy would improve efficiency, boost the economy, and strengthen energy security, all while reducing the impact on the environment. Healthcare improvements, lower infant mortality rates due to cleaner air, and massive budget cuts for governments are all positive outcomesExpenditures in the healthcare sector [6] - [8]. Pv systems, solar heating, concentrating solar power, and focused photovoltaics are all ways that the sun's rays may be harnessed and used, and these methods are often categorised according to their methods of collection, conversion, and distribution. Both active and passive forms exist for them. A photovoltaic (PV) system converts sunlight into electricity using photoelectric effect. The PV system uses a collection of silicon semiconductors to collect light and turn it into electricity. Converters then convert the generated DC to AC for use. With specialist MPPT tech, the quantity of solar energy collected may be maximised. Sun-tracking photovoltaics are often employed for this purpose.

It is suggested that a power electronic interface be installed between the source and the load to help stabilise the voltage. The goal of this interface is to improve power quality via the regulation of output voltage. The proposed method is novel since it takes use of a multilayer inverter to provide two advantages at once. The term "multilevel" was originally used to refer to the three-stage converters. During the commutation process of the semiconductor switch, the several Input voltages are combined to produce a high output voltage. The voltage capabilities, power quality, electromagnetic compatibility, and switch losses of multilevel inverters are all improved. There are a few distinct MLI designs, including the Compensator Screwed down or Clamped (npc Multi Level Inverter, the Flying Capacitor Multi Level Inverter, and the Cascaded Multi Level Inverter. An MLI (Multilevel Inverter) that is cascaded is used (CMLI). The primary purpose of CMLI would be to convert DC power from several independent sources (such as solar panels and batteries) into a single, consistent voltage. If all of the HBs have the same DC link voltage, then the CMLI is said to be symmetrical. As solar PV voltages might fluctuate based on the weather, asymmetrical inverters are highly recommended. With asymmetrical inverters, the DC link voltages are not the same.

CMLI uses the fewest components to give the same amount of voltage levels as other mlis. Nonetheless, the CMLI has one major drawback: it requires supplementary DC sources in order to do useful power conversions. Although this is a drawback, solar PV might be a solution.

2. CONTROLLER MODELING

Most renewable power sources, including solar photovoltaics, are connected to the grid through a distribution system (DS), which serves the same purpose as a generating or synchronous machine. As the power generated by a PV varies as a consequence of the panel's absorption of solar radiation, the rated voltage may swing by as much as 20% between morning and evening. With the use of power electronic circuits, we can ensure that the PV's DC voltage remains stable at all times. As the grid delivers electricity in AC, the steady DC voltage is inverted to AC. Keeping with this line of thinking, the suggested experiment employs an appropriate inverter with such a maximum fluctuation of 1% to emphasise objective for just a 48V, 7A solar array with a variable of 20%.

2.1 Control System with Quantitatively Imprecise Logic

Unlike conventional logic, in which values may be either 1 (ON) or 0 (OFF), the states of values in fuzzy logic are always somewhere in between (OFF). Unlike Boolean logic, which only allows for true or false, fuzzy logic can have three, four, or even more alternatives. It only accepts either false or true as input, unlike Boolean logic. Decisions may be made with more confidence using fuzzy logic even when data is vague, uncertain, or contradictory. It is illustrated in Figure 1 that a fuzzy controller (FLC) is used to implement the VR in a solar PV-powered cascaded h - bridge multilevel H bridge inverter.

Here, the fifteenth-level inverter's output voltage (Vo) is compared to a reference voltage (Vref) that indicates the target voltage that must be achieved in order to bring the inverter back into compliance with the grid's requirements. Both the rate of change of the error, de/dt, and the error, e = Vref -Vo, are input parameters to the FLC. The FLC is composed of five fundamental elements. A rule sets, fuzzy rule, fuzzy inference system generator, and fuzzy inference system debugger. After fuzzification, the input data may be utilised to produce membership functions with arbitrary membership degrees.

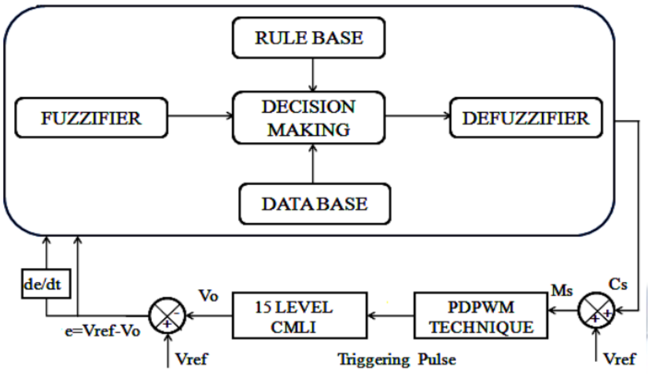


Fig 1: Fuzzy Logic Control Structure.

The inverter's power circuit requires a modulating signal M and PWM generation in order to transmit the correct gate pulses to the mosfet.

The issue is formulated by using the error and its derivative, MF. The MF for the incorrect signal is shown in Figure 2. A negative N, a positive P, and a zero Z denote the corresponding directions in this graph. The letters B, M, S, and E all have similar meanings: huge, medium, tiny, and error, respectively.

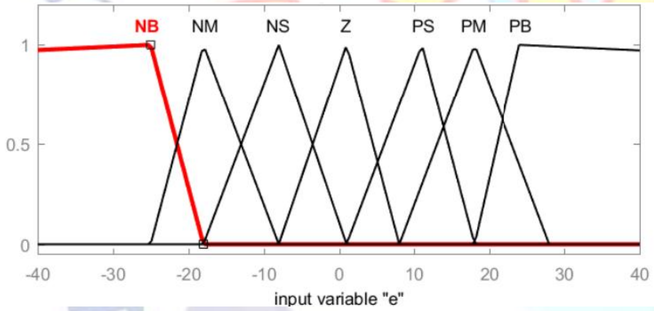


Fig 2:The Error signal membership function.

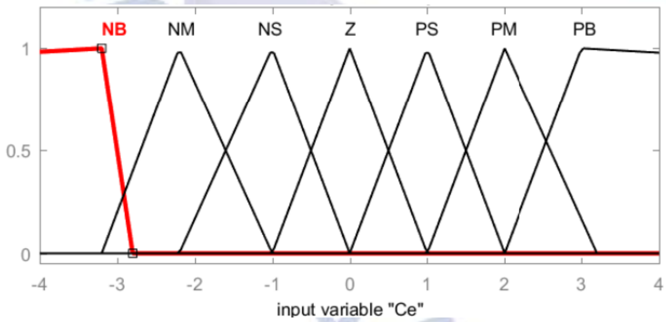


Fig 3 Modification In Error Signal Membership Function.

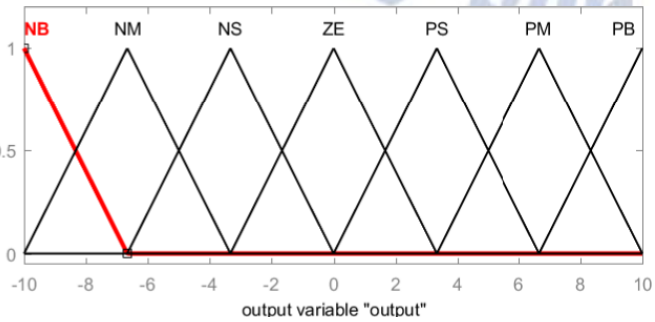
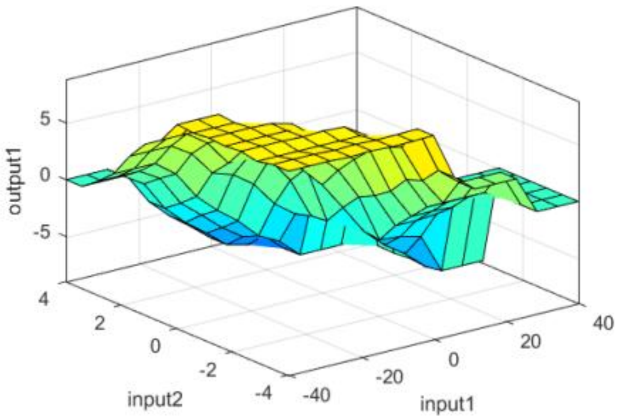


Fig 4:Output Membership Function For References.

Table 1: FLC Rule Matric.

Ce \ e	NB	NS	NM	ZE	PB	PS	PM
NB	PB	PB	PB	PB	ZE	PM	PS
NS	PB	PM	PB	PS	NM	ZE	NS
NM	PB	PB	PB	PM	NS	PS	ZE
ZE	PB	PS	PM	ZE	NB	NS	NM
PB	ZE	NM	NS	NB	NB	NB	NB
PS	PM	ZE	PS	NS	NB	NM	NB
PM	PS	NS	ZE	NM	NB	NB	NB

Fig 3:Fuzzy rule visualisation.



2.2 Automation managed by an artificial neural network

When it comes to neural networks, there is no clear division of subtasks that are given to different units; rather, the network as a whole performs functions and the units do them in parallel. In terms of the input-output data set, the controller based on neural networks supplies the necessary voltage regulation. Verror = Vref Vactual is the formula for determining the voltage discrepancy. The ANN is taught using these error values as inputs. To keep the output voltage stable, an inverter circuit has to switch at just the right angles, and an ANN can calculate those angles given the values of the error signals. The following are the stages of the ANN training process: First, please will provide input-output data set; second, please compute the weights; and third, please update the weights in light of any changes to the input. In order to handle the error signal, the neural network has to be trained using a variety of samples taken at different times.

3.Simulation and Results

To allow for voltage and MPP monitoring at each string to be independently controlled, multilevel converters use several DC connections. It is an excellent platform since there is no VR in a solar-powered, 15-level inverter. Each CMLI stage has its own unique panel configuration and connection to the corresponding irradiance level. Seven H-bridges are cascaded in succession to power the elevators on all fifteen floors. There is a comparison between a reference signal and a carrier signal that is used to generate pulses. While creating a pulse signal, a comparison is made between a reference sinusoidal carrier and a triangular carrier.

Pulses are generated using a bipolar version of the pulse-width modulation approach. Each leg's pulse sequence is compared with that of a positive and negative sinusoidal signal. In this case, the inverter output voltage is modelled as a function of irradiance levels, just as the PV panel's model is. Voltage output waveform measured from solar PV modules under varying irradiance and partly shadowed situations. This leads to a voltage imbalance since the output voltage is not being distributed consistently. These inequalities may be levelled by using virtual reality technology.

CASE(I):The Fifteen-Level Inverter Control Based on Artificial Neural Networks

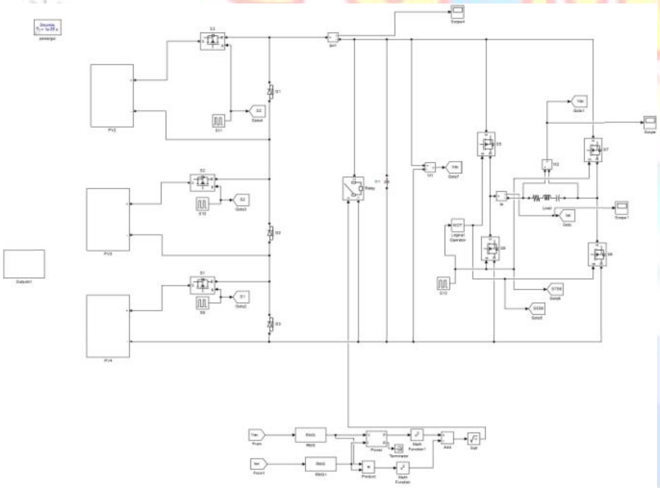


Fig 5: Simulation circuit of ANN.

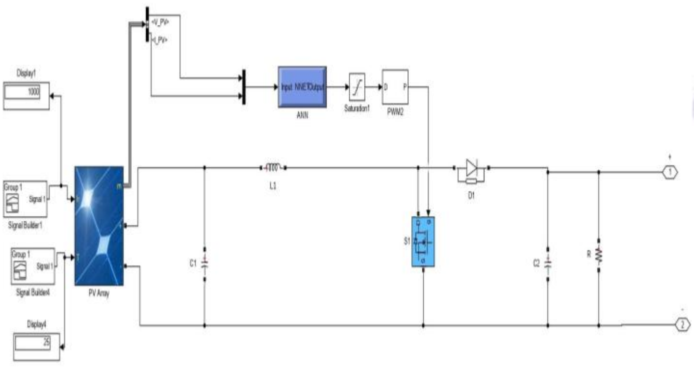


Fig 6: PV sub system in ANN

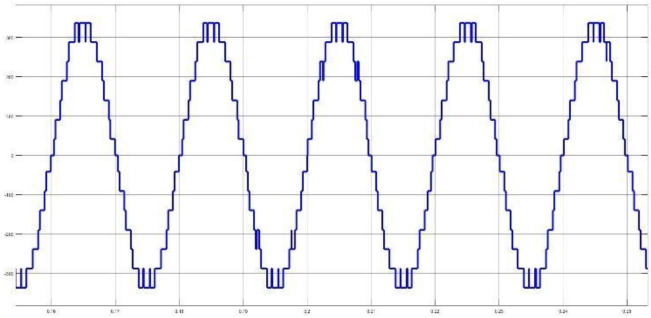


Fig 7: With the help of an ANN-based controller, the output may be adjusted over fifteen discrete levels.

Table2 Technical requirements for a computer-generated brain.

Parameters	Functions
Input layer numbers	2
Hidden layer numbers	10
Output layer numbers	1
Network	Back Propagation
Algorithm	Gradient Descent
Learning rate	0.05
Goal	1e^{-5}
Iteration count	3000
Training function	Purelin
Activation function	Sigmoid & Tangential

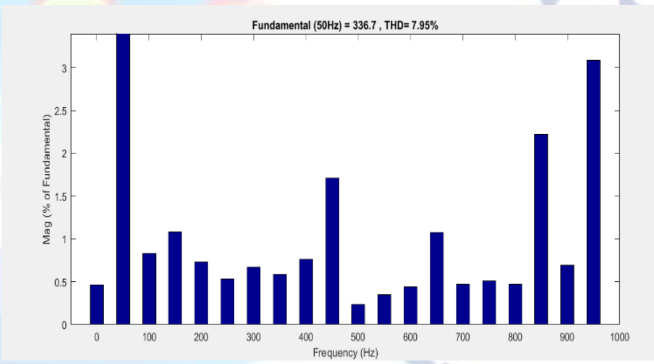


Fig 8: Voltage control using an ANN and FFT analysis.

CASE(II): FLC BASED CONTROLLER FOR FIFTEEN LEVEL INVERTER

Fuzzy inference is used for the decision making and pattern recognition. Signals of error and its derivative, presented as a membership function, make up the two inputs. In the controller, we use a function based on the triangle's membership.The membership function sends a modulating signal to the PWM generator. The derivative of the mistake also has 7 members, just like the error itself. Forty-nine rules have been developed and put into place to better regulate voltage. Figure 10 shows a Ff analysis of the data, while Figure 9 shows the regulated output voltage.

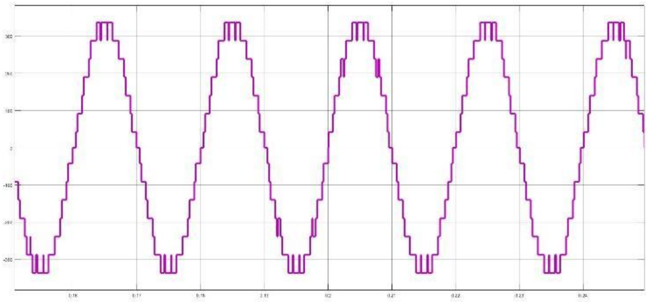


Fig 9: Using an FLC-based controller, the output is regulated over fifteen levels.

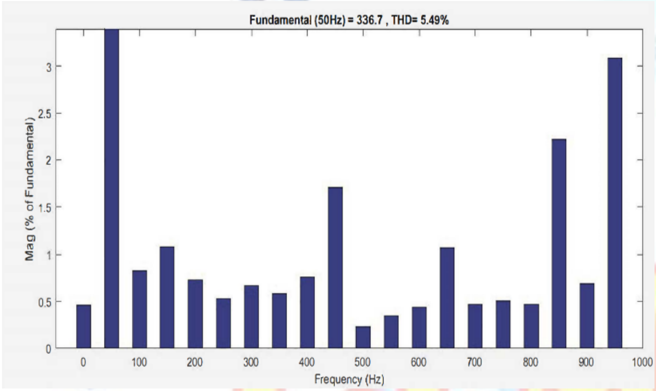


Fig 10 Voltage control using a field-programmable-latch (FLC)—an FFT study.

The examination of the voltage magnitude at the output is shown in figures, together with all other necessary parameters.

The research does not simulate a fully linked to the grid operation, but the converter's goal is to deliver the necessary voltage and current.

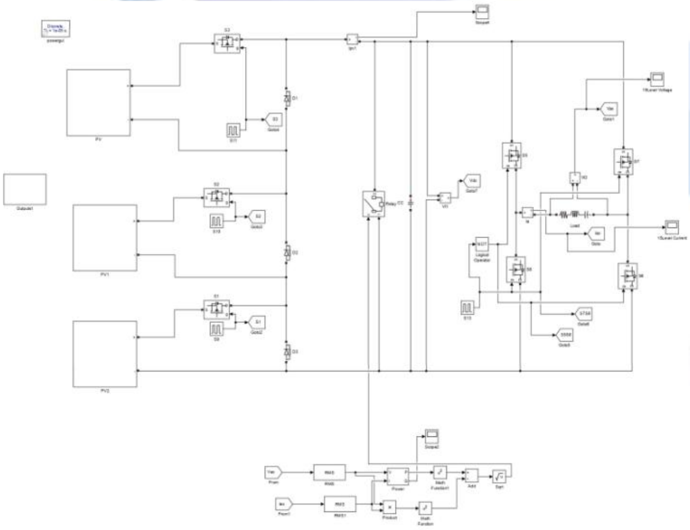


Fig 11: Simulation circuit of ANN.

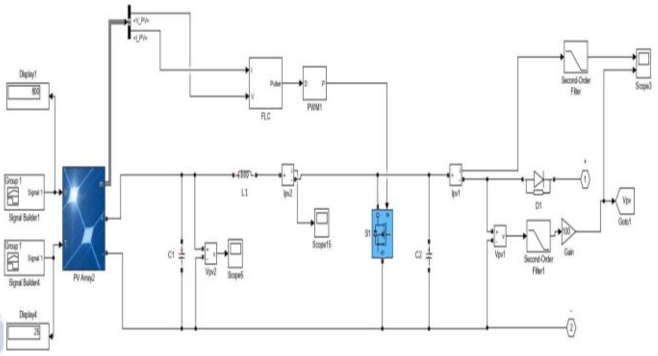


Fig 6: PV sub system in FLC

Table 3 Comparison of results.

S. No.	Method	Level	THD	VR Deviation
1.	FLC	15	5.49%	4.6
2.	ANN	15	7.94%	9.7

Table 4 Comparison of results with other mythologies.

S. No.	Authors	Level	THD	Methodology
1.	Jeyraj & Rahim (2009)	5	6.8%	PI
2.	Ghazanfari et al (2012)	5	6.13%	Voltage balancing
3.	Cecati et al (2010)	9	-	Fuzzy
4.	Corzine et al (2004)	7	9%	PI
5.	Propsed	15	5.9%	Fuzzy

In which FLC outperforms PI or ANN-based controllers in terms of voltage regulation.

Results are compared to different approaches and shown in a table. Due to the scarcity of published works on virtual reality, we compared how different projects approached the medium and how many stages they included in their analysis.

Closed-loop systems have a delay in stability because of the time it takes to compare the current and target signals, causing an error, and then correcting that mistake using the controller's block-set of logic. A dead time of 1 s is added in the controller to guarantee that the decrease in delay achieved in the feedback loop is carried out without any mismatch.

4. CONCLUSION

Simulation is used to test and implement the voltage control architecture and power quality improvement for a solar-fed, 15-level inverter system. VR is best achieved with FLC if input solar PV fluctuation is taken into account. Nonetheless, research towards nine-level FLC continues, it will be implemented using DC power supply instead of solar panels. With reduced power and lower levels of MLI topology, all other approaches are implemented. Experimental findings demonstrate the efficacy of the proposed system, and commercial applications of MLI with a constant output voltage are explored. In order to increase electricity quality, consumers must engage with the grid, and this strategy works for them.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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