Semiconductor Optoelectronics, *Vol. 41 No. 12 (2022), 1515-1526*
https://bdtgd.cn/

Semiconductor Optoelectronics ISSN: 1001-5868

PV FED CASCADED MULTILEVEL INVERTER FOR IMPROVEMENT OF POWER QUALITY BY USING ADAPTIVE NEURO FUZZY INFRENECE SYSTEM CONTROLLER

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Abstract: By employing an ANFIS controller, a PV-fed 15-level cascaded multilevel inverter for power quality enhancement will be constructed. Harmonics reduce the power quality of solar PV energy conversion equipment. This study examines a solar-powered 15-level cascaded inverter and how it may be used to filter out harmonics. A variety of controllers (PI, Fuzzy Logic and ANFIS) are utilized in this work in order to govern the PWM frequency (Proportional Integral, Fuzzy Logic, and Adaptive Neuro Fuzzy Inference System, respectively) (Proportional Integral, Fuzzy Logic, and Adaptive Neuro Fuzzy Inference System, respectively). Since the proposed ANFIS controller reduces harmonic distortion relative to standard controllers, power quality is enhanced by default. This proposed setup is developed in MATLAB/SIMULINK using PI, FL, ANN, and ANFIS controllers.

Keywords: Power Quality, Photo Voltaic (PV), Cascaded Multilevel Inverter, Fuzzy Logic (FL) (FL)

I.INTRODUCTION

Many rural communities in developing nations need access to electricity so that residents may raise their level of life. Energy efficiency, electricity supply, and sustainability are now the most important areas of study. Without a steady and stable energy supply, no nation can make strides in economic, human, or industrial growth. Due to diminishing petroleum supplies and an increasing dependence on foreign sources of fossil fuels, there is a greater need for more efficient energy usage. In the past, we relied on thermal and nuclear power to meet our energy needs. Utilizing any one of these options is not without its drawbacks. Research into renewable energy sources, as opposed to those based on fossil fuels, has increased as the importance of doing so has grown. For this reason, cleaner forms of energy are needed in all sectors of the economy, including homes, transportation, factories, and farms.

Companies involved in producing energy have been driven to new heights by the unexpected demand and the resulting threat to our environment. [5] Many chances to invest in energy-related laws and projects throughout the globe have become less complicated in recent years. The term "renewable energy" means "energy that comes from a non-depletable source." Solar power, hydroelectricity, wind energy, biomass, and even geothermal energy are all examples of clean, sustainable energy that can be replenished naturally. As an alternative to traditional energy sources such as fossil fuels, the potential for renewable energy resources in a given region is considerable. Rapid implementation of renewable energy would increase energy security and reduce environmental damage.

Reducing pollution would save governments millions of dollars in healthcare expenses [6-8].
Many rural regions now rely on renewable energy sources for their power, water heating, transportation needs, and more (off grid). This allows us to reliably predict that renewable energy assets will play a significant role in increasing rural areas' access to reliable electricity. Technologies that harness the sun's rays to create energy include concentrated solar power, solar heating, and concentrated photovoltaics. Depending on your point of view, it might be either active or passive. Photovoltaic (PV) systems use the photoelectric effect to transform the energy from sunlight into electricity. In a photovoltaic (PV) system, photons are gathered by a grid of silicon semiconductors and converted into electrons. Converters convert the DC energy into an alternating current. Therefore, MPPT systems are necessary for getting the maximum power out of solar panels. Solar photovoltaic (PV) panels that follow the sun are the most common solution. To maximize output while maintaining a steady voltage, the sun-tracking photovoltaics adapt to seasonal and annual changes in the amount of sunshine received. The efficiency of the solar array as a whole determines which panels make up the PV system.
Connecting solar PVs to the grid is simple since this renewable energy source is so stable. One drawback of solar power is that its production does not always coincide with real demand. A large part of the blame rests on PV's intermittent power output. Consequently, several issues arise, one of which is voltage regulation. Active and reactive powers may be used for a very long period to regulate the voltage during transmission and distribution. Voltage regulation refers to the process of controlling the voltage gap between the transmission and distribution points. Numerous devices, such as STATCOMs and SVCs, work together to maintain voltage across within safe limits even when the system is under load. When operating under heavy loads, impedance is often to blame for voltage regulation issues, since it may create either an overvoltage or a decrease below the normal range. The voltage disparity may be fixed by installing a power electronic interface between the power supply and the load. The main functions of this interface are to control the output voltage and enhance the power quality. Using a modern multi-inverter provides advantages in two distinct areas. The phrase "three level converters" is where the name "multilevel" originates from. This may be accomplished by the commutation of semiconductor switches and the use of several DC sources. Multilevel inverters provide several advantages over single-level inverters, including better power quality, greater electromagnetic compatibility, and lower switch losses.
In addition to Neutral Point Clamped or Diode Clamped MLI, Flying Capacitor MLI, and Cascaded MLI, there are a few more names for this kind of inverter.
The use of a Cascaded Multilevel Inverter allowed for these outcomes to be realized (CMLI). CMI is the leader in converting DC sources like batteries or solar panels into a steady state voltage (SDC). The CMLI is considered to be symmetrical if and only if the voltages on each HB DC connection are the same. Due to the frequent fluctuations in solar panel voltage caused by environmental variables, asymmetrical inverters are highly recommended. Design flaws in

the inverter lead to inconsistent DC outputs. The CMLI requires fewer components than other multilevel inverters to reach the same voltage levels. The CMLI needs separate DC sources to accomplish actual power conversions. Although it has this drawback, solar PV may still be utilized to power it. How to simplify voltage regulator administration and boost power quality in a solar power circuit is outlined.

II.PROPOSED SYSTEM

An illustration of the suggested solar PV-powered 15-level MLI system is shown in Figure 1. The 15-level cascaded H-bridge multi-level inverter for the solar PV array is shown in the diagram below. In this method, PD PWM is used with a variety of controllers, including PID, FLUZZY, ANN, and ANFIS. THD is better controlled by the ANFIS controller than by the PI, FLC, or ANN controllers.

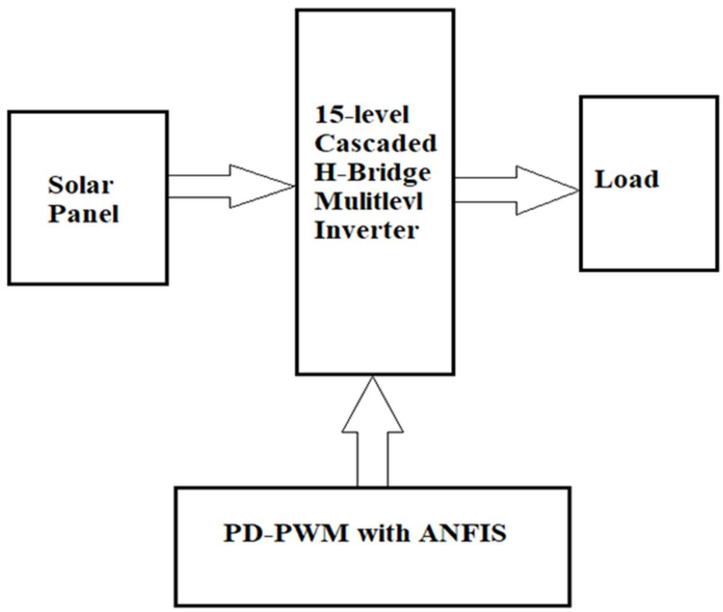

Figure. 1 A 15-level-MLI system powered by a proposed solar PV system

III.CONTROLLING MODELLING

Like a generator or synchronous machine connects to the grid, most renewable energy resources, such as solar PV, link to an inverter. The rated voltage of a photovoltaic system may swing from -20% to +20% during the day due to fluctuations in the amount of irradiance absorbed by the panel. Using power electronic circuits, the DC voltage of the PV may be stabilized. Since alternating current (AC) is the standard for grid voltage transmission, steady direct current (DC) voltage must be transformed into AC (AC). The proposed experiment uses a 48V, 7A solar panel, which has a variance of 20 percent, with an inverter that has a maximum variation of 1 percent to assure accuracy.

A) FLC

Instead of using Boolean algebra, the novel notion of fuzzy logic was presented by Lofti A. Zadeh. Setting values to 1 or 0 is required for usage of fuzzy logic (OFF). The ability to accept several values between true and false sets fuzzy logic apart from Boolean logic. This logic, unlike Boolean logic, only accepts the truth or falsehood. With the use of fuzzy logic, it is possible to derive certain conclusions from information that is ambiguous, vague, or lacking in precision. The implementation of VR in the solar PV feed is shown in Figure.1 utilizing a cascaded H bridge multilevel inverter with a fuzzy logic controller (FLC). To ensure compliance with grid standards, the inverter's actual output voltage (Vo) is compared to the inverter's target output voltage (Vref). Both the error rate de/dt and the error e = Vref - Vo are used as inputs in FLC. There are five primary building blocks in the FLC. In addition to defuzzifiers, inference systems, rule bases, and databases, the word "fuzzifier" covers a broad variety of other technologies. The incoming data is transformed into membership levels through a fuzzy membership function. Pulse width modulation (Ms) signals are created using it, and then utilized to gate the semiconductor switches in inverter power circuits. This signal is produced by comparing Cs to Vef.

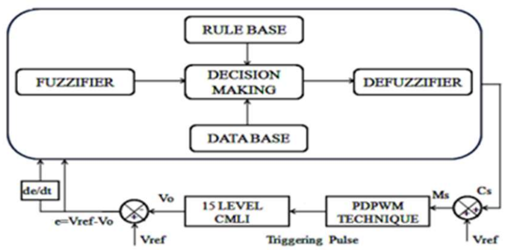

Figure. Controllers based on Fuzzy Logic 2: Layout

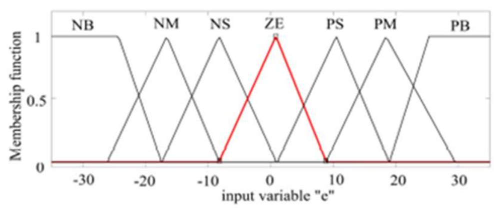

Figure. 3. A membership function for the error signal

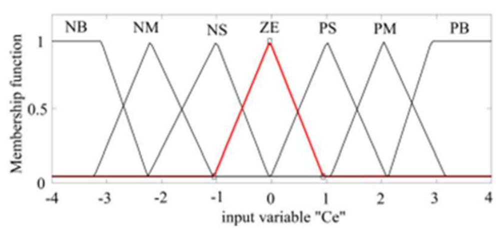

Figure. 4. Changes in the MF Error Signal

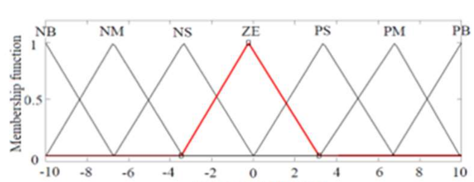

Figure.5. We'll use MF as a benchmark for the final product.

Table-I: A FLC Rule Matrix

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

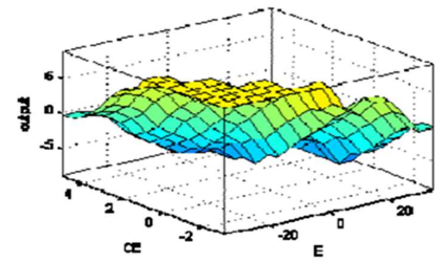

Figure. 6. Fuzzy rule sets in three dimensions

B)PI-BASED CONTROLLER

A PI (Proportional-Integral) controller, such as the FLC, regulates the voltage at the inverter's output (Flat-Line Controller). The PID controller is seen in its many applications in Figure 6. Due to the intricacy of the rules and MF parameterization, PI based controllers need more careful consideration of controller gains than FLCs. To fine-tune the PI controller's gain, an error signal from the changing irradiance is considered. When input solar PV error signals vary, PI controllers provide a reference signal.

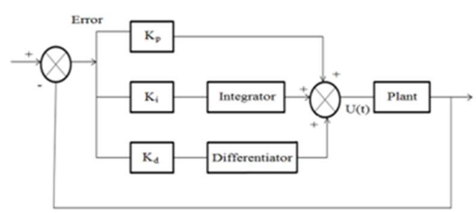

Figure.7 Design of a PID Control System

Variations in irradiance are sensed by a number of error signals, and the PI controller's gain is adjusted accordingly. For each error signal that is sent to the PI controller from the solar PV, a reference signal is produced.

(C)ARTIFICIAL-NETWORK-BASED CONTROLLER

In a neural network, each unit executes its activities concurrently with no discernible difference between the subtasks given to each unit. The neural network controller controls the voltage in the input-output dataset. One way to determine the voltage error is by using the formula Verror = Vref - Vactual. The ANN is taught using these error values as inputs. Using the ANN's recommended switching angles, a steady voltage may be produced at the inverter circuit's output. The following procedures are required to train an ANN: Information on both inputs and outputs is required, as is the computation of weights. When the input changes, the weights have to be adjusted accordingly. A neural network, pre-trained on data from a large dataset collected over time, is then used to analyze the error signal.

(D) ANFIS CONTROLLER

The ANFIS uses neural networks, fuzzy logic, and other low-level computing techniques. ANFIS just needs a few straightforward input and output parameters to successfully simulate complicated and nonlinear systems. A neural network may be used to fine-tune the fuzzy interference system. The hybrid learning approach used by ANFIS utilizes both human experience and data on input and output to construct connections between the two. In online control, ANFIS may be used to analyze non-linear functions and discover non-linear parameters, and time series models can be used to predict parameters in non-linear functions. As may be seen in Figure 10, the ANFIS often has a multi-tiered structure. This network has input, product, normalization, and defuzzification nodes in addition to fuzzification and normalizing nodes. Adaptive nodes are represented by squares, whereas fixed nodes are shown by circles. ANFIS takes in PG (t 1) and P (t) L, and we want to generate a reference power for HRES (P) from PG (t 1). (t). As a result of its reliance on relative parameters, the new ANFIS method can rapidly generate and modify rules.

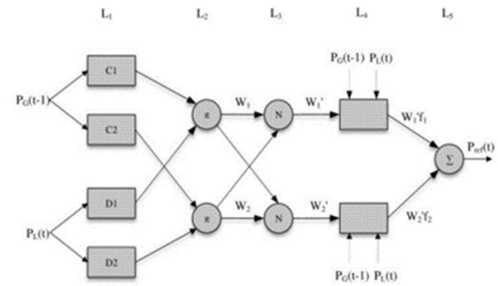

Figure..8(a) The Architecture of the ANFIS

Fig.8 depicts the ANFIS layer structure beautifully, and the equivalent illustration is provided below.

The term "Layer 1:Fuzzification" describes the function of this layer.

This layer computes the variety of membership functions for each input variable. Error (e) and its derivative, error change, are used as inputs to the ANFIS (e). Utilizing trapezoidal and triangular enrolling capacity with the following node conditions yields a significant reduction in error:

$$O_i^1 = \mu_{Ai}(x) = \frac{1}{1+\left[\left(\frac{x-c_i}{a_i}\right)^2\right]^{bi}} \qquad (1)$$

With the input of I Ai to the node function and the membership function of _Ai, the premise pa The following parameter set is assumed, where the input to the node function is I Ai, and the membership function is _Ai. This is the raeameter set:

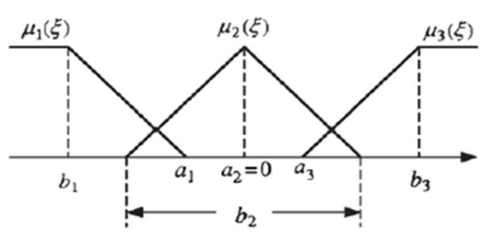

Figure. 8 (b) Membership operates with some fuzzyness.

The second layer is responsible for rule inference. Due to the permanence of the nodes in this layer, multiplication and subsequent transmission of nodes occurs. The effectiveness of a fuzzy rule may be evaluated in two ways.

$$O_i^2 = \mu_i = \mu(x)\mu(y) \quad i = 1, 2, 3 \; (2)$$

Layer 3: This might be thought of as the first level of protection. Each circular node in this layer is denoted by the letter N. The rule's shooting power is multiplied by the firing powers of all other rules to get the total firepower.

$$O_i^3 = \overline{\mu_i} = \frac{\mu_i}{\mu_1+\mu_2+\mu_3} \qquad i = 1, 2, 3 \qquad (3)$$

Layer 4: This is the next tier above. Every single node has access to an adaptable mode.

$$O_i^4 = \overline{\mu_i}.f_i = \overline{\mu_1}(a_0^i + a_1^i\epsilon)i = 1, 2, 3 \qquad (4)$$

where wi represents the Layer 3 output and (a0, a1) represents the next set of parameters.
Fifth Layer: The output layer now sits above the existing set of layers. In this layer, just one node is responsible for aggregating the results of the other nodes' calculations of individual input signals.

$$O_i^5 = \mu_i = \sum_i \overline{\mu_i} f_i \quad i = 1, 2, 3 \qquad (5)$$

The back propagation error term is used to update all ANFIS parameters

$$\frac{\partial E}{\partial O^5} = k_1.e + k_2.\Delta e \qquad (6)$$

Multiplication of the input signals' error (e) and its rate of change (e) by the coefficients k1 and k2.

$$\alpha_{k+1} = \alpha_k - n\frac{\partial E}{\partial \alpha_k} \qquad (7)$$

where is the rate of learning and is an ANFIS parameter. The following training cycle will result in a smaller margin of error.

IV.MATHEMETICAL MODELLING

A)Solar cell modelling

This diagram shows a circuit that is analogous to a PV (Photovoltaic) cell. In order to process the solar cell, a current source and diode are linked in series.

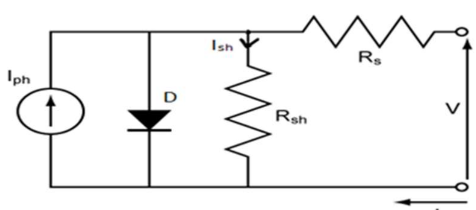

Figure.9 Modular photovoltaic solar array equivalent circuit

As shown in Fig. 9: Know the possible outcomes by using KCL.

$$I_{ph} = I_d + I_{sh} + I \quad (1)$$

$$I = I_{ph} - (I_{sh} + I_d) \quad (2)$$

We have the following equation for the current in a solar cell:

$$I = I_{ph} - I_o[e^{q(V+IRs)/nkT} - 1] - (V+IR_s)/R_{sh} \quad (3)$$

Where V_T signifies Voltage at the terminal
I_{ph} signifies the isolation current
V signifies voltage of the cell
I signify current of the cell
I_o signifies opposite saturation current
R_{sh} is Parallel Resistance
R_s signifies Series Resistance

q signifies basic charge
n signifies ideality factor of diode
T signifies complete Temperature
K signifies the Boltzmann's constant

B) CASCADED H BRIDGE MLI MODELLING

The cascaded multilevel inverter can create 5 levels with 8 switches, 7 levels with 12 switches, 9 levels with 16 switches, and 11 levels with 20 switches. There are thirteen floors with twenty-four buttons, fifteen floors with thirty-two buttons, and so on.

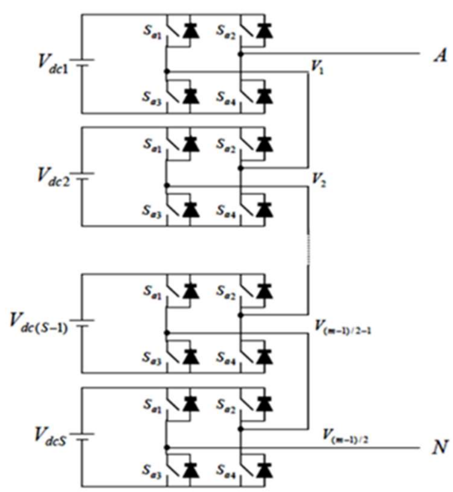

Figure.10: Inverter with n-level cascading

Fig.10 is a schematic representation of an n-level H-Bridge cascaded inverter. Each phase has its own dedicated dc power source. Each of the H-Bridge inverter's branches receives its own dc supply. The number of phase voltages at the output is defined by the given equation.

IV.SIMULATION RESULTS

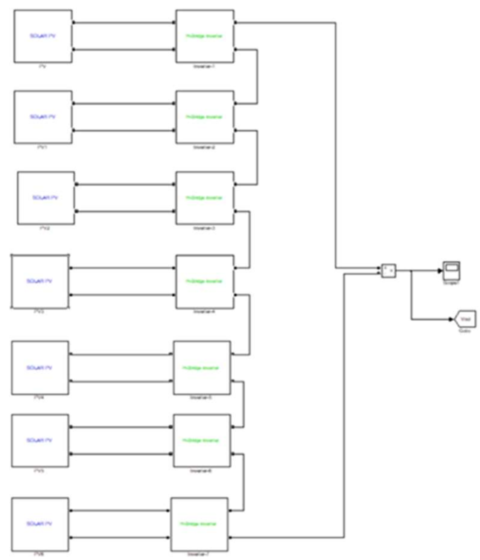

Figure.11 The suggested solar-powered 15-level Multi-Level-Information Processing (MLI) system's schematic in MATLAB/SIMULINK

CASE-1 WITH PI CONTROLLER

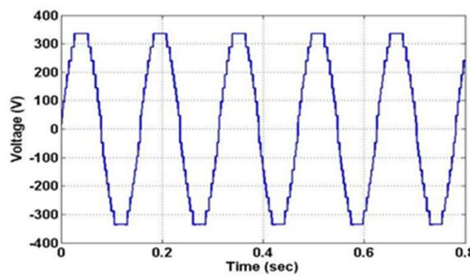

Figure.12 Standard PI-controlled 15-level voltage output.

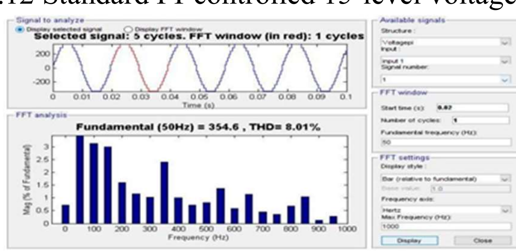

Figure.13 Total Harmonic Distortion (THD) at the Output: 8.01

CASE-2 WITH FLC CONTROLLER

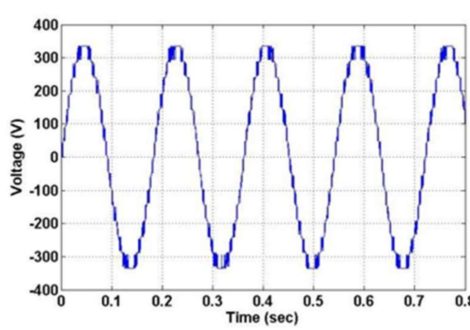

Figure. The FLC controller's output voltage is at the 14th level.

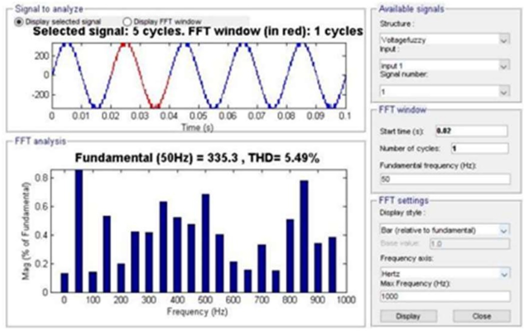

Figure. Total Harmonic Distortion (THD) at 15 volts (5.49%)

CASE-3 WITH ANN CONTROLLER

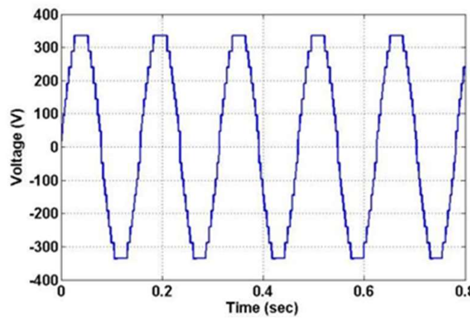

Figure. An ANN-controlled 16-level output voltage

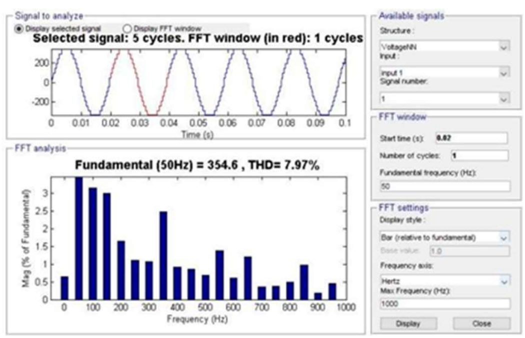

Figure. Total Harmonic Distortion (THD) at the Output Voltage (7.3%) 17

CASE-4 WITH ANFIS CONTROLLER

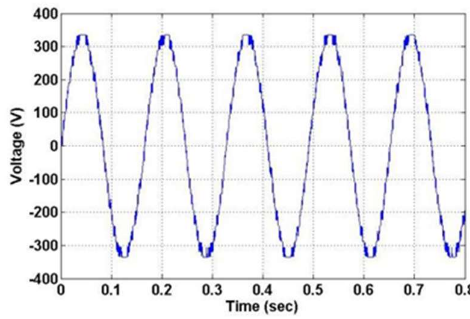

Figure. Using an ANFIS controller, the output voltage may be set to 18V at a 15V level

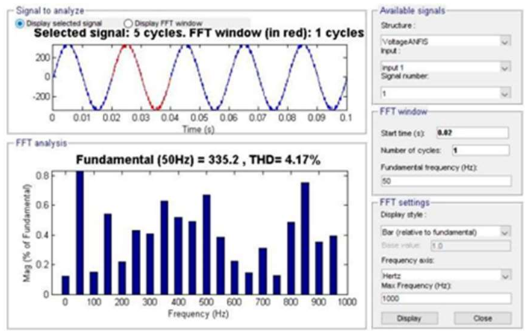

Figure. (19) Total harmonic distortion (THD)% (4.17%) of the output voltage

CONCLUSION

Both voltage control and power quality enhancement are taken into account during the simulation of a 15-level solar-powered inverter. Outcomes demonstrate that ANFIS improves VR results when input solar PV variation is included. The nine-tiered ANFIS system runs only on a DC power source, not solar panels. Many low-power and low-level MLI topologies are built using the other methods. The suggested system's ability to provide a stable output voltage for commercial usage of MLI has been experimentally verified. Users interested in improving their electricity quality and grid participation may use this method.

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