A Novel ANFIS Based Solar Fed Cascaded Fifteen Level Multilevel Inverter to Enhance Power Quality

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Abstract. This work presents Proportional Integral (PI) controller, the Artificial Neural Network, ANFIS and Fuzzy Logic controllers to examine the eliminations of harmonics in a Solar Fed cascaded fifteen level inverter. Contrary to other approaches, the ANFIS solution suggested helps achieve minimized harmonic disturbances aimed at improving power efficiency. In order to preserve voltage and frequency at the inverter output end consistent with grid link specifications, this paper also recommended an upgrade to the efficiency of electricity. Simulation for solar fed cascaded 15-Level inverter is done with PI, ANN, FL and ANFIS-based controllers in the MATLAB/Simulink area. The four methods are simulation and determination of the output voltage control in measuring power efficiency metrics.

Keywords: Solar PV system, Multi level inverter, Artificial neural network controller, Fuzzy logic controller, ANFIS controllers.

1. Introduction

Providing access to electricity in rural areas is an essential condition in order to improve the health standards of living that are a top priority for many developed countries [1]. The most significant subjects of study in society are energy conservation, power availability and biodiversity. Sustainable, clean, economic, stable and safe energy is a key prerequisite for a country's economic growth, human and industrial development. The importance of effective energy usage has increased by environmental considerations, the exhaustion of petroleum supplies and an increase in the dependence on fossil fuels from insecure locations [2]. Sources such as thermal nuclear energy used for some period now have their own advantages and demerits in generating electricity. The increasing focus on reducing the carbon footprint has contributed to the growing interest in research into non-fossil fuels as an energy source. This requires a more efficient supply of energy in all fields, such as domestic, transport, manufacturing and agricultural [3]. This unexpected environmental pressure and difficulty has led electricity suppliers to better improve and efficiently change the energy grid. The decreased uncertainty of various energy policies has been shown in recent times and global investment opportunities in the energy market have been increased [4]. The life of renewable energy from infinite natural resources can be termed. Natural renewable such as solar power, water, climate, biomass and geothermal heat are available for several sources. The range and opportunities of renewable energy options across a given geographical zone are immense in comparison to other types of energy such as fossil fuels, which are confined and clustered in small locations. Performance and economic gains are huge with the accelerated introduction of clean energies, leading to substantial energy stability, while reducing the environmental impacts [5]. This includes positive changes in better childcare and reducing child deaths owing to lower environmental impacts, saving millions of countries in health services [6]. Sometimes the specifications on energy generation, water heat, transport, and utilities in rural areas are shifted away from renewable energy by consensus (off grid). In this respect, clean

energy reserves are securely required to have an incentive to enhance and enhance access to energy in rural areas [7].

Over the years, the voltage was regulated by the usage of active and reactive power in transmission and distribution. Voltage control is the calculation of the voltage change in transmission and delivery between two endpoints. STATCOM and SVC are just a handful of co-operative devices the ensure that voltage is sustained under load conditions under allowable limits [8]. The cause of voltage control problems is primarily the existence of impedance that leads to overvoltage or drops under normal conditions under heavy loads. A control electronic interface between the source and charge, the purpose of which is to regulate the output voltage and improve power efficiency, is suggested to reduce the voltage imbalance. The innovation of the work suggested is to use the dual benefit multilevel converter [9]. The word multilevel is derived from 3 levels. The switching of the semiconductor switches adds more DC inputs to the high voltage. Increased energy efficiency, greater electromagnetic compatibility, decreased loss of switches and increased voltage capacity is the benefits of multi-level inverters. The three MLI systems are the multi-level inverter, the inverter, the multi-leavit inverter and the inverter in the cascade [10]. The Cascaded Multilevel Inverter (CMLI) is used in this document. The main function of CMLI is to synthesize a preferred voltage, obtainable from battery or solar cells, from different DC sources. The CMLI shall be called symmetrical if the voltages of the DC connection of the HBs are equivalent [11]. As the Solar PV voltages vary with environmental considerations, it is strongly recommended that asymmetric inverters. In comparison to DC link voltages, asymmetric inverters have a different meaning. CMLI needs the least number of modules to meet the same number of voltage standards compared with other multi-level inverters [12]. The only drawback of CMLI is that for actual power conversions it requires different DC sources. However, the use of solar PV at the input will offset this drawback. The paper offers a clarification against this background to reduce the difficulty of the voltage regulator regulation and increase the power efficiency on a solar circuit. the inexorably real ecological issues and energy emergency, several international locations all at some stage on the planet have dispatched key agencies in the subject of recent strength. As a type of sustainable power that's wealthy and smooth, wind electricity has attracted global consideration [1].Wind influence age framework grows quickly, they have an effect on age involves the first region within the new power age, and the quantity within the impact matrix is rising. In the various sorts of wind turbine frameworks, extremely durable magnet coordinated generator (PMSG) has grade by grade emerge as more appealing because of the viability, dependability and extra sizable pace range [2]. As consistent with the layout of wind power framework dependent on PMSG, PMSG is straightforwardly associated with electricity matrix via one after the alternative (BTB) converters, and the regular interest of converters is defenseless in opposition to unequal network voltage hangs. There are many factors at the back of choppy matrix voltage, like totalorganizing, inadequate establishing, abnormal organizing, curve establishing, circuit breakage, and so forth [3]. Unequal lattice voltage will spark off negative succession components in the framework. As a general rule, the real factors, as an example, feeble matrices would possibly cause yield electricity variances [4]. Be that as it could, because of the presence of terrible grouping components under uneven framework voltage, the collaboration amongst tremendous and bad arrangement voltage and contemporary is the precept justification for the second one-request consonant fluctuations on dc shipping voltage and yield power [5]. Moreover, the pressure owing into the matrix may be faded because of the network voltage lists. Nonetheless, MSC isn't always sensitive to network voltage droops and produces electric-powered pressure constantly, bringing about the yield force of MSC isn't equivalent to matrix-associated electricity. This prompts a few feasible troubles, for instance, dc-interface overvoltage or modern three-level inverter flows [6].

Customary management techniques can not show excellent manipulation execution underneath unequal framework deficiencies. Vector management in a twofold pivoting coordinate side is proposed in [7] at some stage in unequal situations. In those managed plans, advantageous and terrible grouping components of cutting-edge are controlled freely, which is inescapable to isolate the positive and poor succession components. In the imply time, this control plan can smother the fluctuations on yield dynamic force, however, the receptive pressure fluctuations and intense pinnacle current aren't

stifled viably. An adaptable dynamic force manage plot dependent on a short current regulator and a recognizable reference contemporary selector has been proposed in [8]. The plan incorporates five distinct present day control processes which are on-the-spot dynamic responsive pressure manipulate, normal dynamic and receptive force manage, right away managed positive-succession, adjusted high-quality grouping manipulate, fine and poor association pay manage. These systems can understand the disposal of force vacillations or the equilibrium of three-degree inverter flows, giving a hypothetical premise to the observe-up explores. Nonetheless, the proposed control plot isn't always joined with PMSG to tackle the viable issues, for instance, overvoltage and over-present day. Focusing on the issue of unreasonable top modern, a current prescribing plan is proposed in [9] where the top present-day is ensured inner a protected reach with the aid of controlling the dynamic force. By the through, the high quality and terrible grouping division of voltage and modern-day are inescapable and the level of voltage irregularity must be completely considered in the acknowledgment of the management approach. One more control technique is displayed in [10], which comes to a decision the current reference esteem with the aid of searching into the desk, to restrict the acute top present day. In any case, this method wishes to envision the statistics table offline, which is not difficult to discern.

Another strategy for running out the reference articulations of dynamic and responsive pressure is added in [11], which restricts the pinnacle current underneath choppy voltage. Notwithstanding, this approach will construct the dc delivery voltage. To lessen the hazard of dc-interface over voltage in the course of the lattice voltage lists, some plans which want to utilize greater devices were proposed [12]. These more devices essentially contain the slowing down chopper (BC), crowbar circuit and strength stockpiling kinds of tools, which increment the manage prices. A captivating manipulation method is introduced in [13], which can preserve the dc-interface voltage constant without the want for any outer gear. In any case, MSC and GSC regulators want to trade their manipulate capacities. The dc transport voltage is restricted by the MSC regulator and the most extreme force factor following (MPPT) is achieved via GSC regulator. The managed execution of this plan is suitable under the even blame, but it's miles poor beneath the lopsided flaws. Besides, it's far more important that the regulator limitations need to be re-tuned, which makes it greater hard to carry out the manipulated plot.

2. Test system Case study

The test system considered for the implementation of the proposed controllers is presented figure.1. The PV generated electricity is fed to the boost converter with incremental conductance based MPPT algorithm. The output voltage of boost converter is fed to the 15 level CHB inverter, after filtering it is sent to the load. The switching pulses are generated to the suggested topology by using the proposed PI, Fuzzy, ANN and ANFIS controllers.

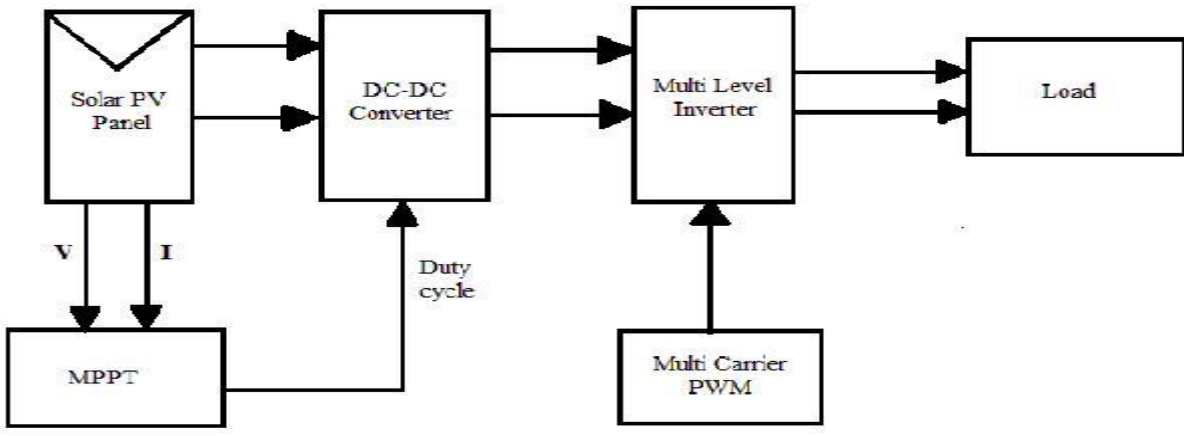
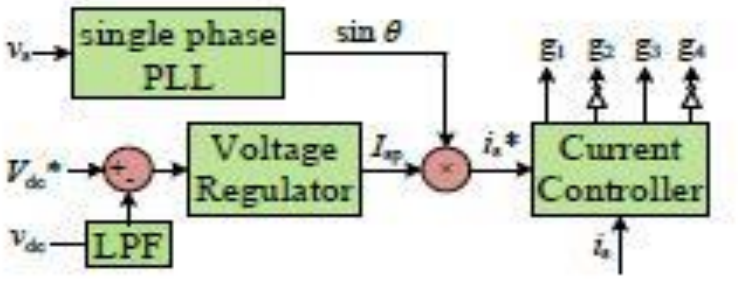


Figure.1: Test system considered for proposed controllers implementation

3. Proposed Controller

The System reliability and maximum use of availabilities are achieved by a grid connected PV system. Figure.2(a) shows a bi-directional voltage regulation based on a space vector modulation generation. Because it doesn't need a sophisticated mathematical model or procedure, this is the simplest approach. The grid power voltage and current are synchronized using a single stage Phase Locked Loop (PLL). Supply voltage, sin sine wave, is generated at the fundamental frequency. It is also recommended to regulate the DC voltage to extract the important element of supply current. ANFIS controller is recommended to control the voltage of the system [10]. First-order low pass filters are used to reduce the amplitude of the DC voltage signal. The voltage regulator creates a positive current, when it is necessary to draw electricity from the utility. As a result, the grid receives an in phase supply current. Because of this, an out of phase accessibility of resources is created so when grid is supplied by a PV system [11]. When the flow of power is interchanged, the desired direction of flow may be achieved. THD and voltage level are also enhanced as a result of the applied control approach. The Output dc voltage is controlled if the grid is unavailable. It's still possible to run the water pump on its own, though, thanks to the PV array's ability to adapt to changing weather conditions. The layout of the ANFIS controller is depicted in Figure.2(b).



(a)

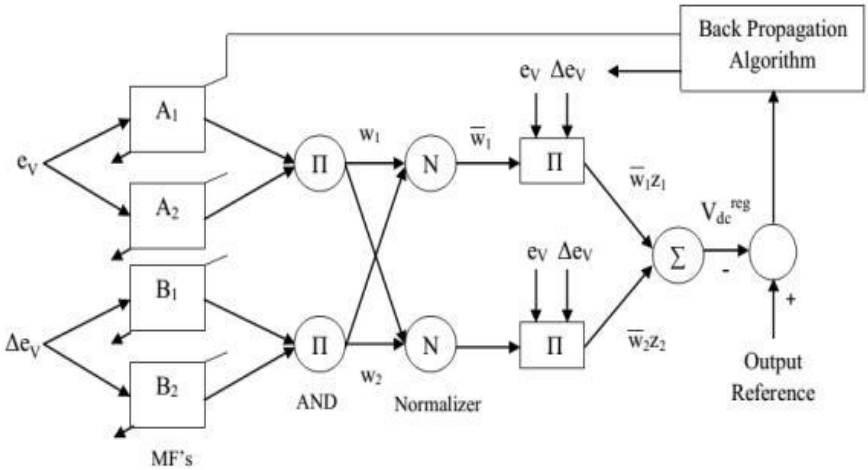


Figure. 2 (a) Controller for bidirectional power flow control of VSI (b): Type-3 ANFIS Structure

The five layers can be classified as input layer, rule layer, output members function layer, input membership function layer and output layer combindly comprises the structure of ANFIS system. To minimise the sum of squared errors (SSE), One or linear regression models are classified the data to 2^n orP^n fuzzy interference decision tree.

$SSE = \sum_i er_i^2$

No. of fuzzy divisions for each input variable=P^n
No.of input variables=n

Error between desired & actual o/p = er_{i2}

The Sugeno fuzzy inference system can be stated below,

$f_1 = p_1 e_v + q_1 \Delta e_v + r_1$

$f_2 = p_2 e_v + q_2 \Delta e_v + r_2$

$[e_v , \Delta e_v]$

Dc voltage link of filter of a given input vector can be obtained for mechanism. ANFIS structure and each layers explained below:

Layer1: Node functions are consisted with adaptive nodes in this layer. node function is as follows:

$O_i^{layer1} = \mu_{Ai}(e_v)$

$O_i^{layer1} = \mu_{Bi}(\Delta e_v)$

A_i is linguistic label which is related of node function

O_i^{layer1} is a membership function which indicate the extent that satisfies the quantifier A_i which specifies e_v.

Maximum and Minimum are considered as 1 and 0 for a bell shaped $\mu_{Ai}(e_v)$.

$$\mu_{Ai}(e_v) = \frac{1}{1+\left|\frac{e_v - c_i}{a_i}\right|^{2b_i}} = \exp\left\{-\left(\frac{e_v - c_i}{a_i}\right)^{2b_i}\right\}$$

Premise parameter is the linguistic label A_i, which modified the parameter set $\{a_i, b_i, c_i\}$ of the membership function. Same way $\mu_{Bi}(\Delta e_v)$ value is selected.

Layer2: Inorder to measure the firing strength of the rule, multiply the input signal and send out the product by each layer's node.

$O_i^{layer2} = w_i = \mu_{Ai}(e_v)\mu_{Bi}(\Delta e_v)$, i=1,2

Layer3: This l_{th} is the node determine the ratio between l_{th} rule's dismissal power and sum of every one rules firing strength

$O_i^{layer3} = \overline{w}_i = \frac{w_i}{w_1 + w_2}$, i=1,2

Normalised firing strengths are used as the output of this layer

Layer4: The involvement of i_{th} rules in the overall output is determined by the i_{th} number of nodes in this particular level.

$O_i^{layer4} = \overline{w}_i f_i = \overline{w}_i (p_i e_v) + q_i \Delta e_v + r_i$

Consequtive parameters refers to the parameters of this layer

Layer5: When we take the summation Σ of all the inputs from all the individual node in this network, the overall result is calculated.

$O_i^{layer5} = \Sigma \overline{w}_i f_i = \frac{\Sigma_i w_i f_i}{\Sigma w_i}$

Overall output= $V_{dc\ reg} = \overline{w}_1 f_1 + \overline{w}_2 f_2$

$$V_{dc}^{reg} = \overline{(w_1 e_v)}\, p_1 + \overline{(w_1 \ \Delta e_v)} q_1 + \overline{(w_1)} r_1 + \overline{(w_2 e_v)}\, p_2 + \overline{(w_2 \ \Delta e_v)} q_2 + \overline{(w_2 \ )} r_2$$

After training process has completed, ANFIS can be used to determine the dc voltage regulation for the specified error and change of error voltage. Then the SAF voltage is applied to the source line of the nonlinear loads and the power quality issue is compensated.

4. Simulation results

The simulations are done on the proposed system using Matlab environment. The PV output voltage for PI and ANFIS controllers are depicted in figure .3 and figure.10 respectively with 48 volts and 49 volts improved output. Figure.4, figure.6, figure.8 and figure.11 represent the CHB MLI output voltage with PI, fuzzy, ANN and ANFIS controllers respectively. The figure.5, figure.7, figure.9 and figure.12 represent the THD of output voltage with 9.67%, 7.81%, 6.33 and 4.98 % respectively for PI, fuzzy, ANN and ANFIS controllers. The results there is a considerable improvement in the THD of output while using the advanced controllers.

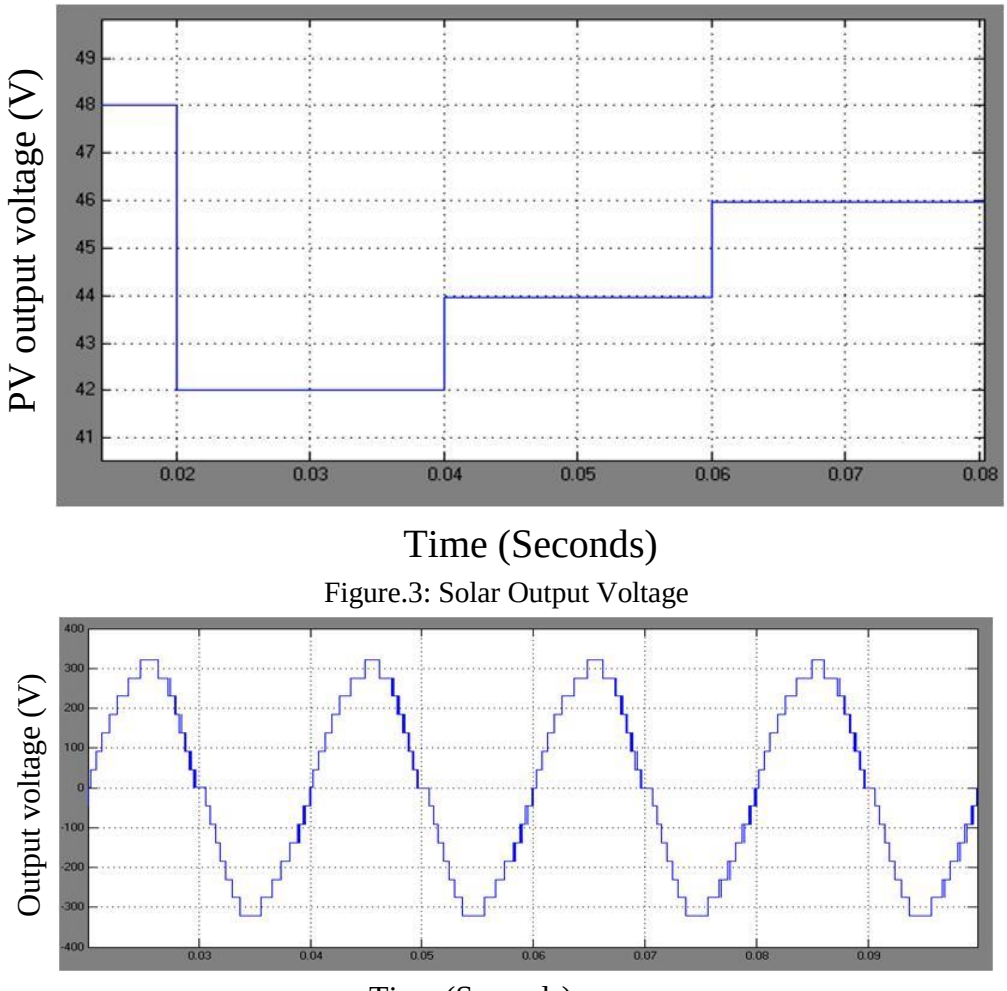


Figure.3: Solar Output Voltage

Figure.4: CHB inverter 15 level output voltage with PI controller

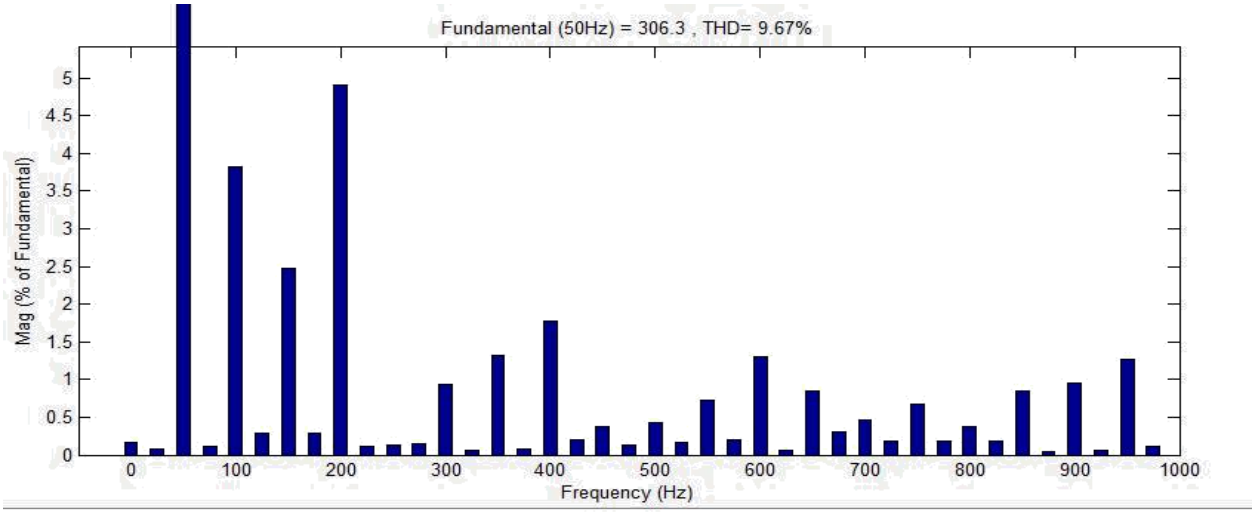


Figure. 5: CHB inverter 15 level output voltage THD with PI controller

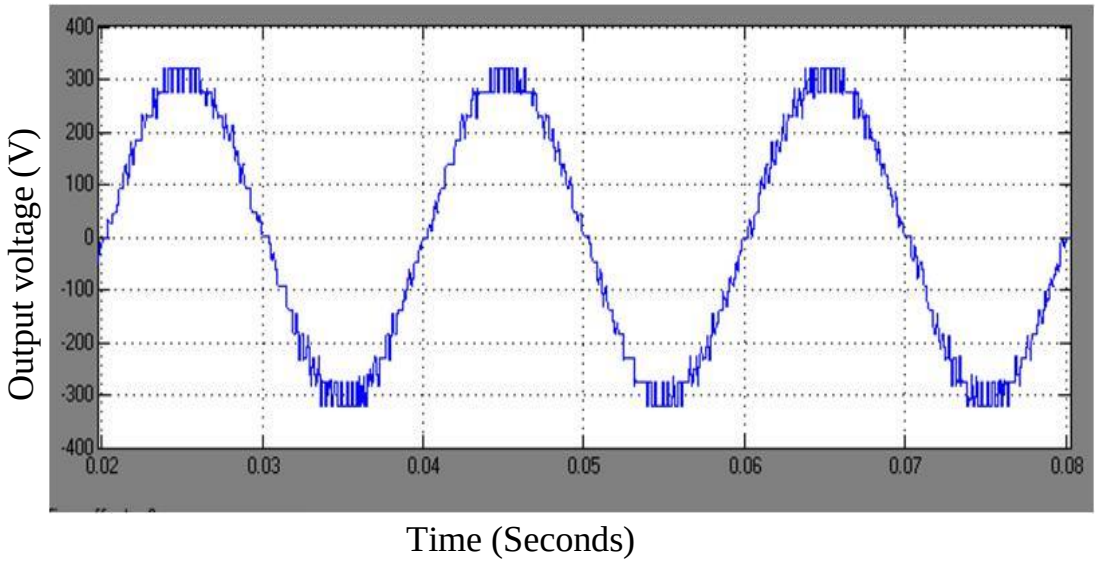


Figure. 6: CHB inverter 15 level output voltage with fuzzy controller

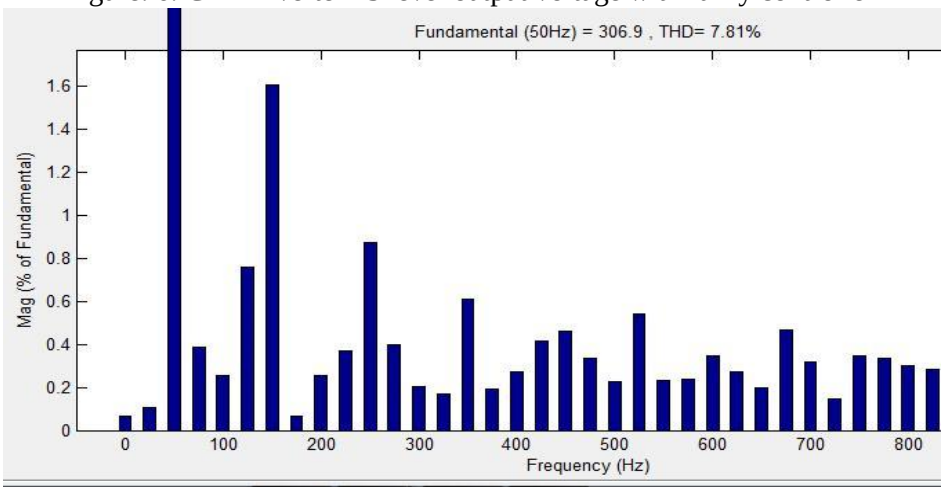


Figure. 7: CHB inverter 15 level output voltage THD with fuzzy controller

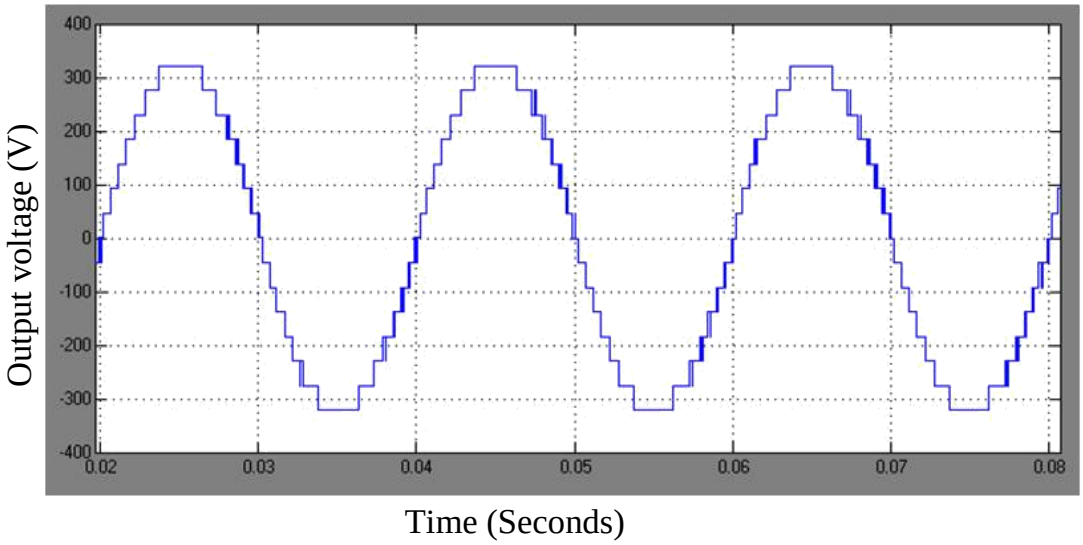


Figure. 8: CHB inverter 15 level output voltage with ANN controller

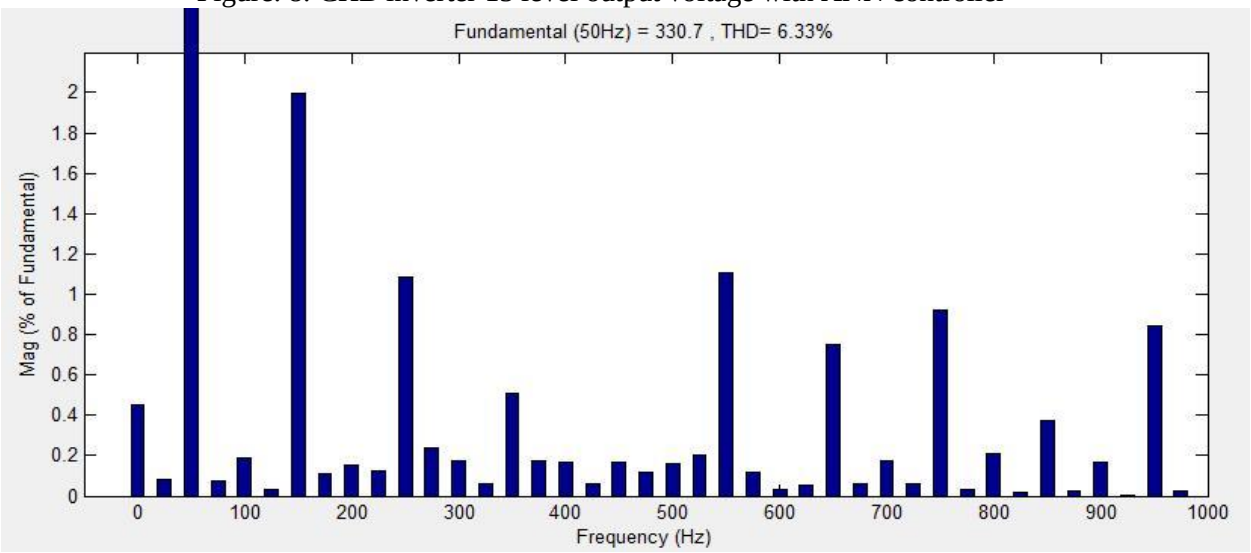


Figure. 9: CHB inverter 15 level output voltage THD with ANN controller

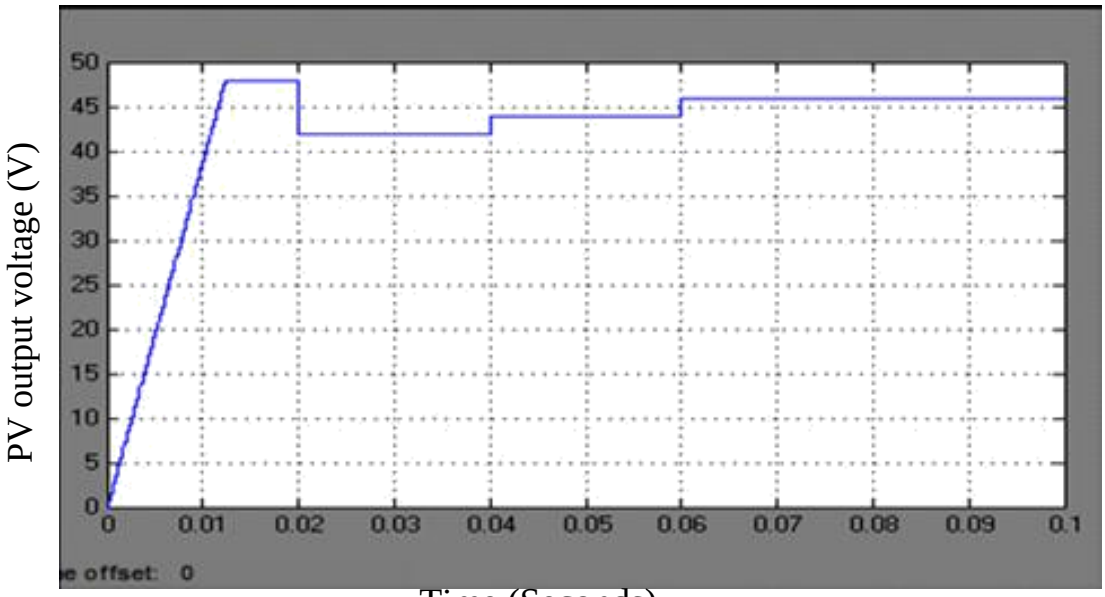


Figure.10: Solar Output Voltage with ANFIS controller

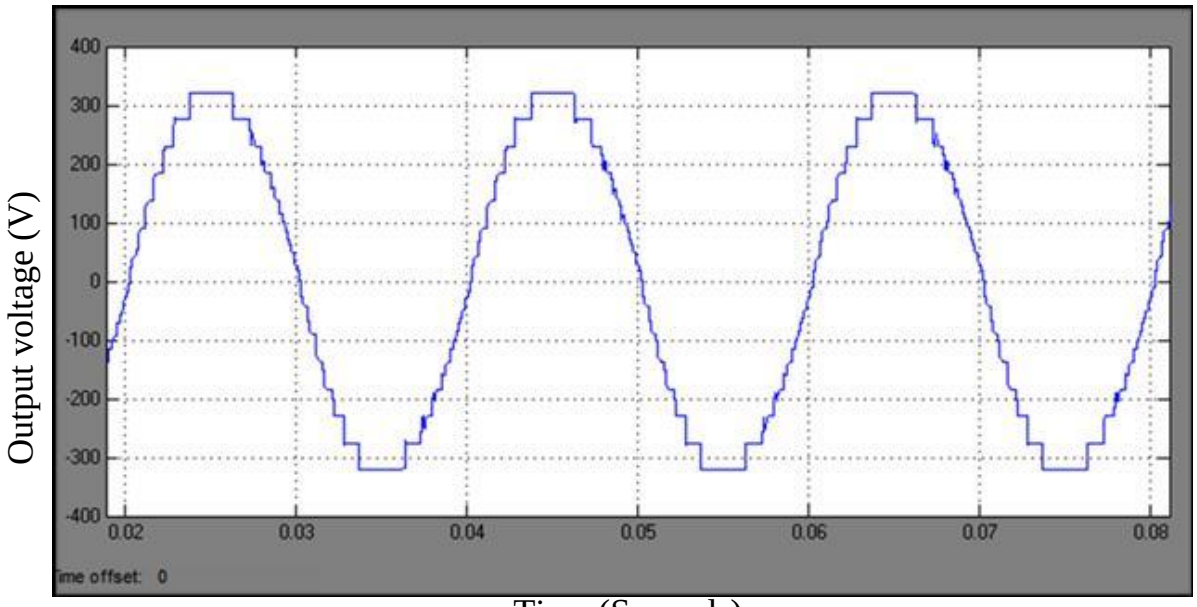


Figure. 11: CHB inverter 15 level output voltage with ANFIS controller

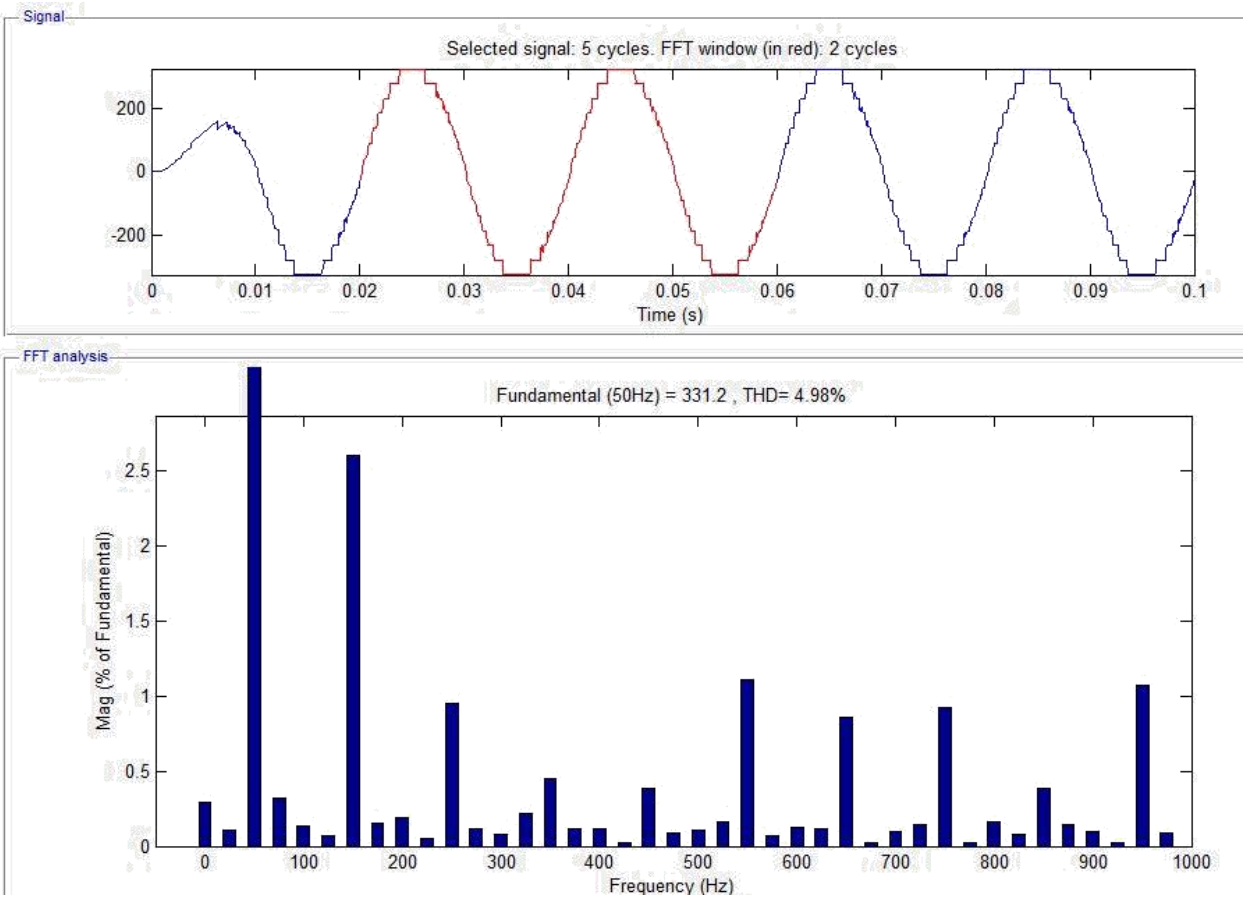


Figure. 12: CHB inverter 15 level output voltage THD with ANFIS controller

Conclusion

In this work Propose ANFIS based solar fed cascaded multilevel inverter for enhancing power quality. Conventionally PI, FLC, ANN controllers are examined for eliminating harmonic content in inverter output voltage. The voltage regulation topology as well as the enhancement of energy efficiency was selected and analyzed in simulations and in a sensory evaluation for a 15-level solar power supply inverter. If the findings are taken into account, ANFIS is seen to yield stronger VR results if differences in solar PV input are taken into consideration. However, for the nine levels, FLC is considered, but DC power supplies and not solar panels are used to enforce this. The other methods are used for low power and lower forms of MLI topology. The commercial usage of MLI is explored through the provision of constant output voltage, and the simulation results indicate that the device proposed is efficient. Users who really need grid interaction and better power quality will use this tool.

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