

# REACTIVE POWER CONTROL TECHNIQUE FOR SINGLE PHASE PV INVERTERS

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**Abstract:** The paper exhibits a receptive power control strategy for single-stage Photovoltaic (PV) inverters, particularly unfolding inverters using fuzzy controllers. The proposed framework holds the advantage of the unfolding inverters having low material cost and semiconductor misfortunes, and handles the downside of the standard unfolding inverter not having ability of responsive power infusion. It is vital to take note of that receptive power conveyance is compulsory for PV inverters as indicated by the current declared directions. The idea depends on changing the state of the matrix current waveform however keeping a similar zero intersection focuses as in the solidarity control factor condition. The present waveform is administered by genuine control and responsive power, at the cost of a worthy distortion. The working standards of the proposed strategy what's more, scientific inferences of the matrix current capacity are given in the paper. Exploratory outcomes in a lattice tie inverter model have demonstrated a decent concurrence with the inferred hypothesis; also, they affirm the plausibility of utilizing the proposed procedure in matrix tie inverters.

## Key Words:

PV, Inverter, Fuzzy controller

**I. Introduction:** Unfolding grid-tie inverters are normally utilized in Photovoltaic (PV) and Fuel Cell (FC) appliances [2]-[9]. This is for the reason that an effortless controller can be applied and it can diminish the numeral of high frequency switching semiconductors, e.g. MOSFETs. This show the way to little component cost and high effectiveness. Fig. 1 demonstrates a distinctive structure block figure of an unfolding grid-tie inverter [4]. The frontage stage is a dc-dc converter, which converts a dc current from a voltage source, such as PV Cells, to a rectified sinusoidal inductor current. The subsequent stage

is a line frequency inverter to unfold the inductor current into a bipolar sine wave current, which is harmonized with the grid voltage [10]-[12]. Characteristically, semiconductor switches in the line frequency inverter are SCR thyristors [10]. It is eminent that SCR are turned off at zero current with moderately lengthy commutation time which constructs hard for the insertion of reactive power. Thus, the unfeasibility of inserts reactive power is the major disadvantage of unfolding inverters. Conversely, a novel instruction has been newly published to necessitate that PV inverter products must have the ability to amend Power Factor (PF) up to 0.95 in either inductive or capacitive types. In significance, a bundle of previously intended commercial products are facing the troubles of not transitory such a regulation. Some superior modulation techniques have been projected lately to convince the PF bylaw but they cannot be useful to unfolding inverters in view of the fact that the zero crossing points of grid voltage and current are not the similar. Thus, producer have to remodel PV inverter structure entirely utilizing altered semiconductors or changing topology to be added difficult and costly such as Neutral Point Clamped (NPC) inverters to satisfy the regulation in their prospect products.

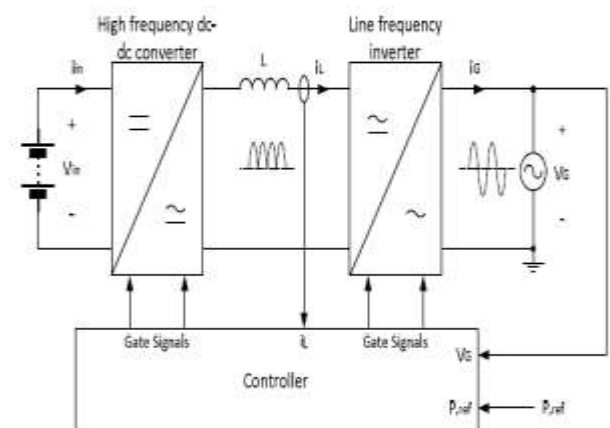


Fig. 1 A typical single-phase grid-tie unfolding inverter system.

## II. PHOTOVOLTAIC SYSTEM

Adapting solar energy interested in electrical energy by PV setting up is the mainly predictable approach to utilize solar energy. While solar photovoltaic cells are semiconductor apparatus, they have a bunch in general with processing and fabrication methods of other semiconductor gadgets such as computers and memory chips. As it is fine recognized, the needs for purity and superiority control of semiconductor gadgets are fairly big. Solar photovoltaic components, which are a product of amalgamation of photovoltaic cells to amplify their power, are extremely dependable, tough and little noise apparatus to manufacture electricity. The stimulate for the photovoltaic cell is liberated the sun is the merely supply that is requisite for the process of PV structure, and its energy is approximately infinite. In cases where it is not possible inexpensively or sensibly to supply the necessary energy from PV components other means are utilized. In most cases the PV system is utilized in combination with a Diesel generator. Such hybrid structures make sure those energy burdens are met while completely employing the PV supply. A archetypal amalgam system is exposed in Fig-ure.2.

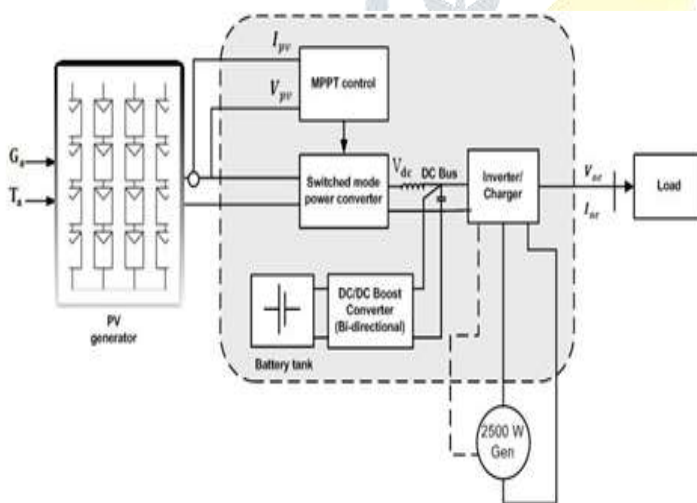


Figure 2: Hybrid stand-alone PV system

## III. FUZZY LOGIC CONTROLLER

Fuzzy logic is a novel expertise that improves predictable structure intend with engineering proficiency. Utilizing fuzzy logic, we can avoid the requires for exact mathematical modeling A being operator is distant additional victorious in controlling a procedure than a regulator intended by contemporary logical method. So it is worth

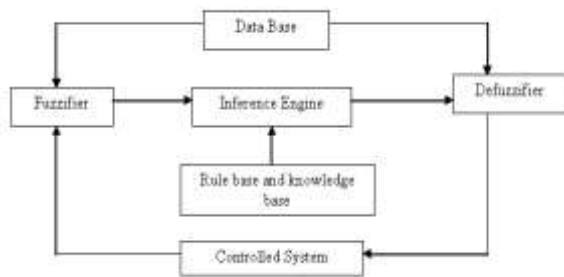
reproduce the control approach based upon instinct and familiarity and can be considered as heuristic choice or rule of thumb choice. In academic and technical arena, Fuzzy is a scientific expression that treaty with vagueness or vagueness based on human intuitions. Professor Lotfi A Zadeh launches the notion of fuzzy sets, according to him. Fuzzy logic is a mathematical indefinite explanation.

During the precedent numerous years, FLC has materialized as one of the mainly energetic regions of investigates for the functions of fuzzy set hypothesis. A fuzzy set is a simplification of the notion of a regular set in which the membership function (MF) standards can be only single of the two values, 0 and 1. A fuzzy set can be distinct as under.

Fuzzy set A in a universe of discourse U is characterized by a MF  $\mu_A: U \rightarrow [0] [1]$  and associates with each element x of U a number  $\mu_A(x)$  in the interval [0 1] representing the degree of membership of x in A.

### Fuzzy Controller Model

Fuzzy modeling is the technique of describing the traits of a device the usage of fuzzy inference guidelines. The approach has a distinguishing feature in that it may express linguistically complex non-linear system. It is however, very hand to discover the guidelines and track the club functions of the reasoning. Fuzzy Controllers are usually built with fuzzy rules. These fuzzy guidelines are acquired both from domain specialists and by means of observing the who are currently doing the manage. The clubs functions for the bushy sets could be derive from the statistics available from the domain experts and/or determined manage actions. The building of such guidelines and membership functions require tuning. That is, overall performance of the controller should be measured and the club functions and rules adjusted based totally upon the overall performance. This system will be time ingesting. The fundamental configuration of Fuzzy logic control based as proven in Fig. 4.1 consists of four foremost components i.e. (i) Fuzzification, (ii) knowledge base, (iii) Inference Engine and (iv) Defuzzification.



**Fig.1 Structure of Fuzzy Logic controller**

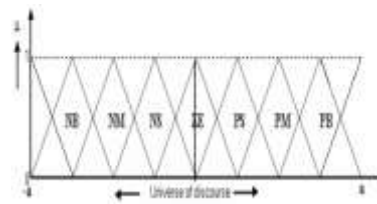
### 1 Fuzzification:

Fuzzification maps from the crisp input space to fuzzy sets in certain, input universe of discourse. So for a specific input value  $x$ , it is mapped to the degree of membership  $\mu_A(x)$ . The fuzzification involves the following functions. Measures the value of input variables.

1. Performs a scale mapping that transfers the range of values of input variables into corresponding universe of discourse.
2. Performs the function of fuzzification that converts input data into suitable linguistic variables, which may be viewed as labels of fuzzy sets.

The input variables to fuzzifier are the crisp controlled variables. Selection of the manage variables is based on the character of the device and its preferred output. It is greater not unusual inside the literature to use the output errors and the by-product of output. Each of the bushy good judgment control (FLC) input and output sign is interpreted into a number of linguistic variables. The number of linguistic variables specifies the excellent of control which can be completed the usage of the bushy controller. As the range of linguistic variables increases, the computational time and required reminiscence will increase. Therefore a compromise among the first-rate of control and computational time is needed to pick the number is seven. Each linguistic variables NB, NM, NS, ZE, PS, PM, PB which stands for poor large, terrible medium, terrible small, zero high quality small, fantastic medium, tremendous big respectively. For simplicity it is assumed that the club features are symmetrical and every one overlaps the adjoining features by using 50% i.e., triangle formed feature, the other form of features used are trapezoidal-formed and Bell-fashioned. Figure three.2 indicates the seven linguistic variable and the triangular membership

characteristic with 50% overlap and the universe of discourse from  $-a$  to  $a$ .



**Fig 2 Triangular membership functions**

### 2 Knowledge Base (KB):

Knowledge base incorporates of the definitions of fuzzy MFs for the enter and output variables and the vital manipulate policies, which specify the manipulate movement via the use of linguistic phrases.

It consists of a database and linguistic control rule base.

1. The database presents vital definitions that are used to define linguistic manage policies and fuzzy records, manipulation in a FLC.
2. The rule base characterizes the control dreams and manage policy of the area experts through a set of a fixed of linguistic control rules.

### 3 Inference Mechanisms:

The Decision – Making Logic Which plays an essential role and contains a set of fuzzy if-then rules such as

IF  $x$  is  $A$  and  $y$  is  $B$  then  $z$  is  $C$

Where  $x$ ,  $y$  and  $z$  are linguistic variables representing two input variables and one control output:  $A$ ,  $B$  and  $C$  are linguistic values.

It is kernel of an FLC; it has the capability of simulating human decision making based on fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic.

In widespread, fuzzy systems map enter fuzzy sets to output fuzzy sets, fuzzy regulations are the relation among enter/output fuzzy units. They are commonly in the form if  $A$ . (Set of conditions are satisfied) then  $B$ , (set of effects may be inferred). Each rule defines a fuzzy course in the Cartesian product  $A \times B$  (system state space). The antecedents of each fuzzy rule describe a fuzzy input region in the kingdom area. For a device of -manage variable with seven linguistic variables in every variety, this results in a  $7 \times 7$  selection table. The know-how required to generate the bushy policies may be derived from an off – line simulation, an professional operator



and/or a design engineer. Some know-how can be used on the expertise of the dynamic gadget underneath manipulate. A lot of effort has been dedicated to the creation of the fuzzy guidelines. Normally rule definition is based totally at the operator’s experience and the engineer understands. However, it’s been noticed in practice that for monotonic structures a symmetrical rule desk is very suitable, even though now and again it may want mild adjustment primarily based on conduct of the specific gadget. If the gadget dynamics aren’t known or if the device is exceptionally non – linear, trial and mistakes method and enjoy play an essential function in defining the policies.

**4 Defuzzification:**

Defuzzification converts the linguistic variables to decide numerical values. Centroid approach of defuzzification is used on this observe.

- (1) A scale mapping, this converts the variety of values of input variables into corresponding universe of discourse.
- (2) Defuzzification, which yields a non-fuzzy manage movement from an inferred fuzzy manage motion.

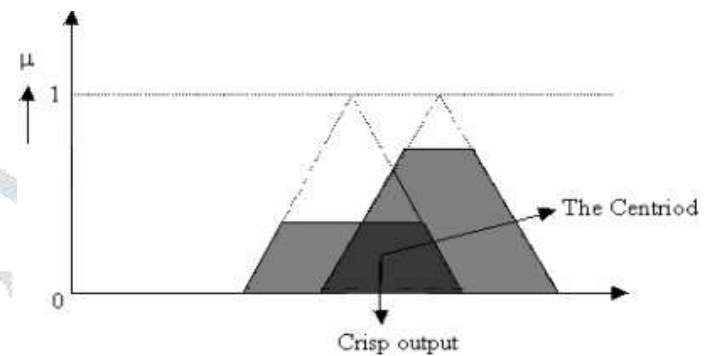
We defuzzify the output distribution B to produce a single numerical output, a single fee within the output universe of discourse  $Y = y_1, y_2...y_p$ . The data in the output waveform B resides in large part inside the relative values of club ranges. The only deuzzification scheme chooses that, element  $Y_{max}$ . That has maximal membership put in the output fuzzy ser B.  $M_B(y_{max}) = \max m_B(y_j); 1 \leq j \leq k$

The most membership defuzzification scheme has two essential issues. First, the mode of the B distribution isn’t particular. In practice B is often fantastically uneven; even if it’s miles unimodal infinitely many output distributions can percentage the equal mode. The most club scheme ignores the facts in a whole lot of the waveform B. The herbal opportunity is the bushy centroid defuzzification scheme. The areas in which the control movements are overlapped depending upon their club function. The area consequently acquired is divided into narrow strips of identical width of each vertical line, the membership characteristic and the corresponding factor at the universe of discourse is evaluated.

The centroid is calculated the usage of the method given underneath. The graphical illustration of centriod is proven in Fig. Beneath.

$$B = \frac{\sum_{j=1}^p Y_j m_B(y_j)}{\sum_{j=1}^p m_B(y_j)} \tag{5.5}$$

Where  $m_B(y_j)$  = membership function of the  $j^{th}$  strip.  $y_j$  = Corresponding Crisp value of  $j^{th}$  strip.  $p$  = number of strips.



**Fig 3 a graphical representation of Centriod**

This value is genuinely the deterministic enter required to adjust the procedure. The whole universe of discourse is then divided into seven triangles, identical in place, each representing the area of the linguistic variables as in fuzzification. The fuzzy centroid is specific and uses all the records within the output distribution B. Computing the centroid is best step within the defuzzification process, which requires easy department.

**IV Controller Design:**

Concept of proposed control is to keep the zero crossing points of grid current and voltage to be the same, but shift the first order component of grid current to carry reactive power. The ideal grid current waveform was shown in Fig. 1. Since the zero crossing points are the same as those of grid voltage, this same allusion can be functional to a variety of types of inverter to inject reactive power into the grid. Fig. 3 (a) and (b) show two typical grid-tie inverters, an unfolding inverter and a unipolar switching full-bridge inverter, respectively. The typical gate signals of two converters are identical, SA and SB switch with the line frequency, e.g. 60 Hz, and S1and S2 switch at a high frequency, e.g. 20 kHz, to shape the inductor current. It is well known that these inverters cannot delivery reactive power or

generating considerably large switching losses under standard controllers. By using the proposed technique, these topologies do not require to change any hardware components. In fact, it is only required to add a current reference generator in the control loop to produce the QSW current reference. Fig. 4 (a) is a typical control diagram for inverters in Fig. 10 with no reactive power control. The current reference is given by a sinusoidal waveform which is generated by a Phase-Locked-Loop (PLL) with a synchronization of grid voltage, and sometimes the current reference is from sensed grid voltage directly. Fig. 4 (b) shows the proposed controller block diagram, where QSW current reference generator has been introduced. The dash-line blocks illustrate the modifications of the original control loop. Firstly, a QSW reference generator replaces the simple sinusoidal wave generator. There are two parts in the generator, a sinusoidal wave generator and a controller to transform sinusoidal wave into the QSW. The sinusoidal wave generator gives a sinusoidal wave which is synchronized with the grid voltage through a PLL. Therefore, based on this synchronized signal, doing some transformation to generate QSW current reference can promise the output QSW current well synchronized with the grid voltage. Secondly, as shown in blue block, for the feed-forward control, original grid voltage should also be processed to QSW shape.

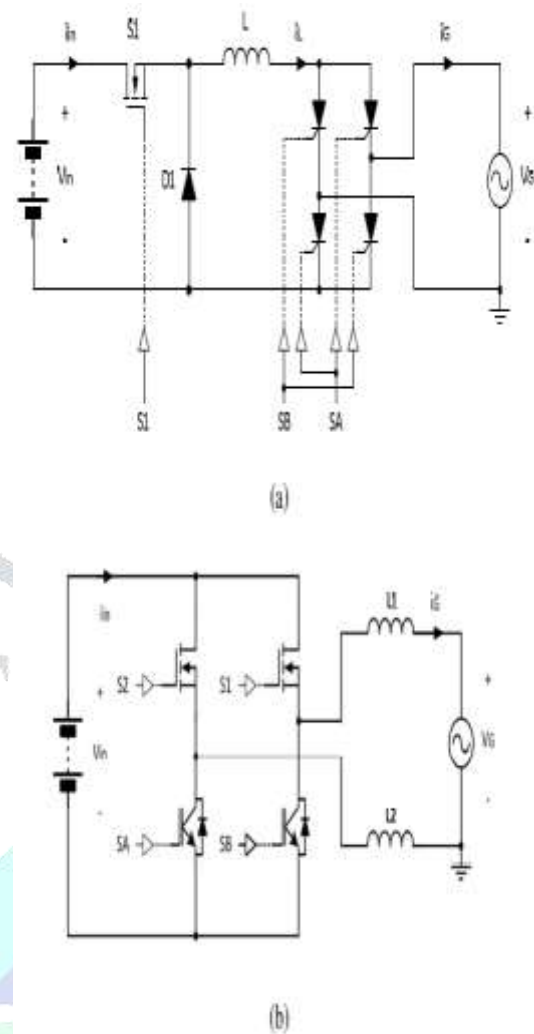


Fig. 3 Typical grid-tie inverter topologies: (a) unfolding inverter, and (b) unipolar switching full-bridge inverter.

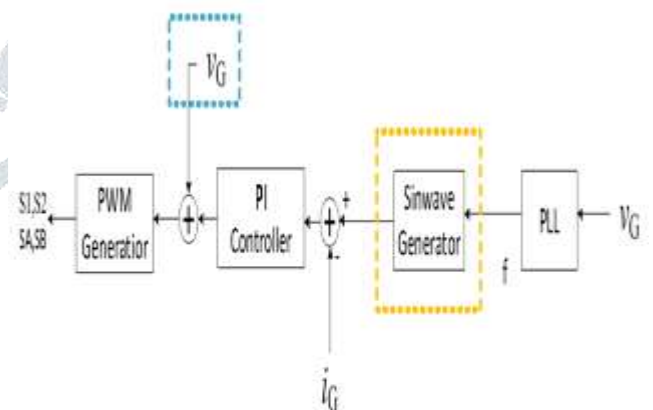


Figure.4.a Control block diagrams A typical inverter controller

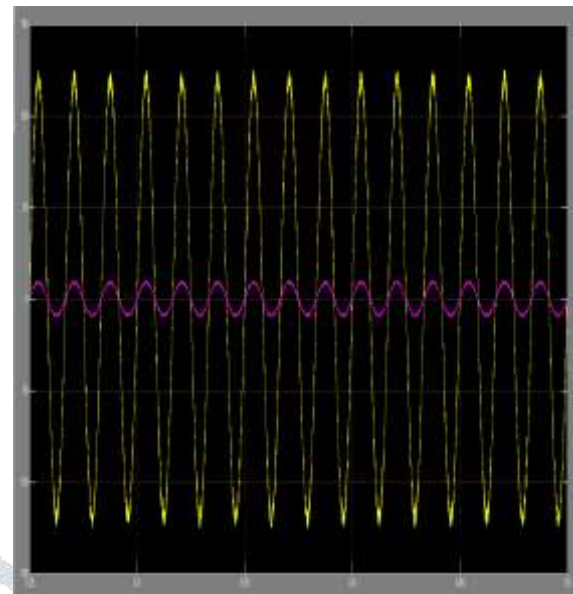
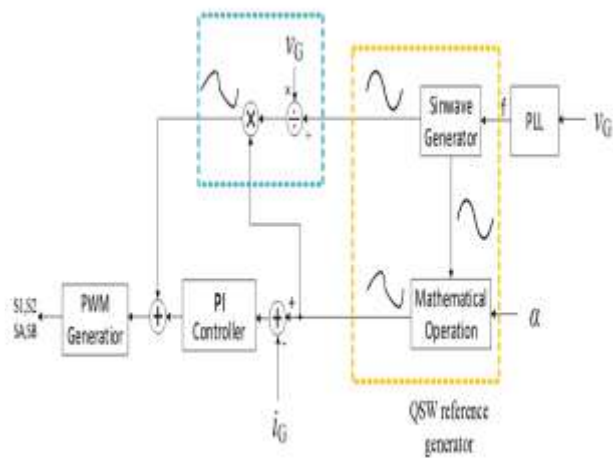
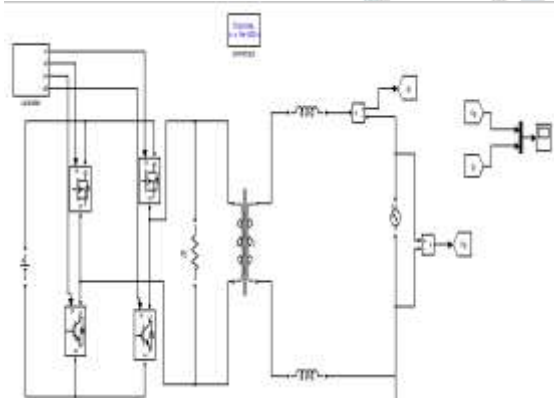


Figure 4.b. controller implementation to guarantee a QSW grid current.

These controller blocks PI values are designed by using Fuzzy logic Controllers.

Figure.6 Steady state responses of delivered grid current and grid voltage for different values of  $\alpha$ : 0.5

**V. Simulation Results:**



**Proposed circuit**

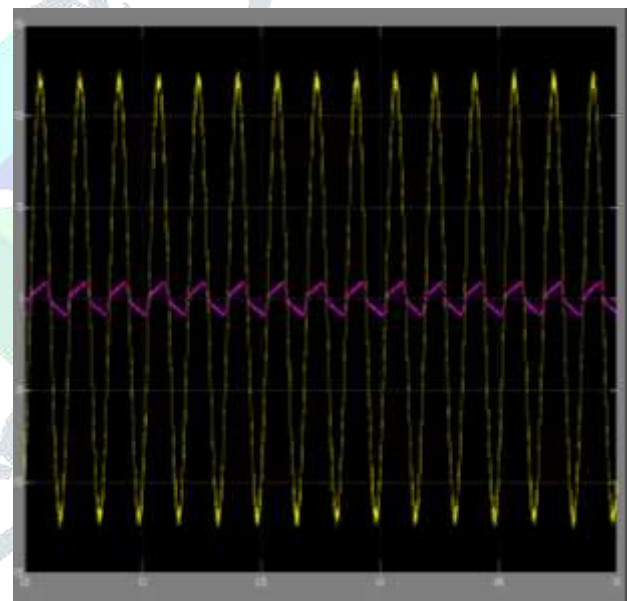


Figure.7 Steady state responses of delivered grid current and grid voltage for different values of  $\alpha$ : 0.78

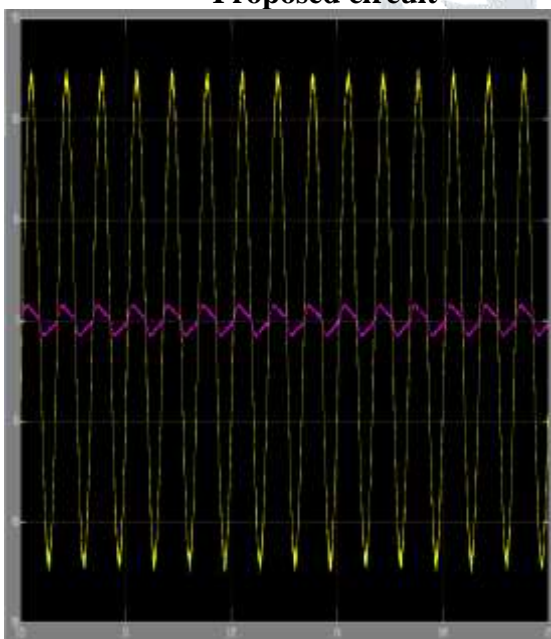


Fig.5 Steady state responses of delivered grid current and grid voltage for different values of  $\alpha$ : 0.22



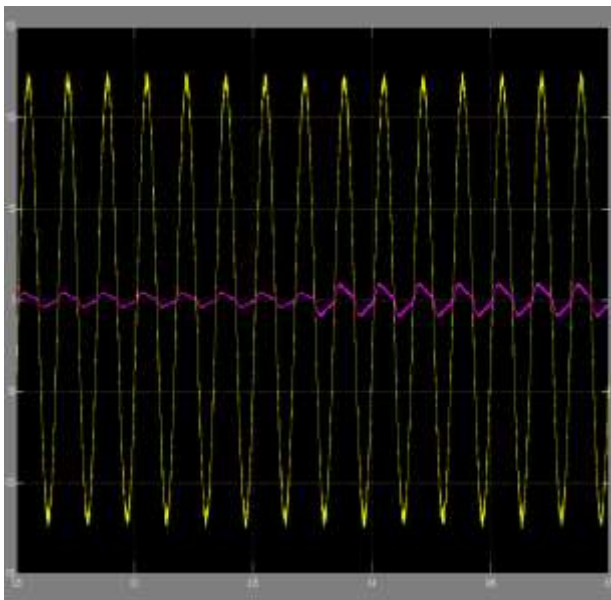
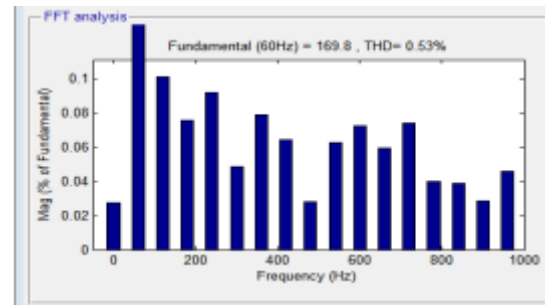


Figure.8 Transient characteristic when  $\alpha = 0.78$  and current magnitude changes from 4A to 9A.

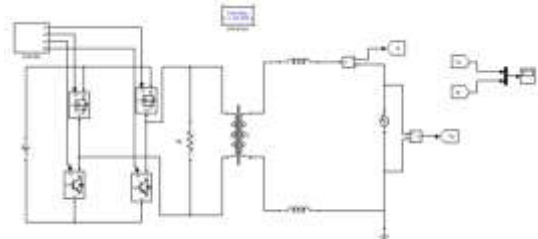


**PRAPOSED METHOD THD**

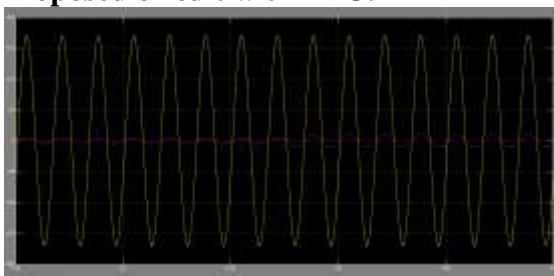
**VI. Conclusion:**

The presentation of the projected fuzzy controller has been done in simulation demonstrated in a prototype of a full-bridge inverter. For the inverter system, a 800W/120V inverter was built, which is a full-bridge inverter with unipolar SPWM, controlled by a TI F28377s DSP. The inverter has the same topology as shown in Fig. 3(b). Table I shows the specification of this inverter. In the tested, DC source voltage is set to be 380V as input voltage of the inverter, AC voltage source which represents grid to be 120V and the peak value of QSW current reference is set to be 9A.

**Case 2: extension by fuzzy logic controller:**



**Proposed circuit with FLC:**



**VOLTAGE AND CURRENT WAVEFORMS**

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