

Power Quality Extension using Fuzzy Logic Controller Based PMSG and Quasi Z-Source Inverter for Grid Connected Wind Energy Conversion System

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Abstract:- This manuscript depicts the power quality extension in Wind Energy Conversion System (WECS) using permanent magnet synchronous generator (PMSG) and Quasi Z-source Inverter (qZSI). The PMSG beat the induction generator and previous generators, because of their impressive performances without take up the frame work power. In this document the qZSI is a fresh topology to conjugate from the established Z-Source Inverter. The qZSI inherits the entire compensation of the standard Z-Source Inverter. Here the qZSI executed buck-boost, inversion and power control operation of the WECS additionally, the potential qZSI the unique compensation of less component ratings. The entire supplementary control technology is built for the ZSI can be used by the qZSI. This paper present a FLC based HCC technique for the qZSI. Here, FLC method has a fantastic response time and reduced the harmonics content in lower level. Matlab Simulation results and experimental results are verified by the proposed method.

Key- Words:- Fuzzy Logic Controller (FLC), Hysteresis Current Control (HCC), Permanent Magnet Synchronous Generator (PMSG) and quasi Z-Source Inverter (qZSI), Wind Energy Conversion System (WECS).

1 INTRODUCTION

In modern years, an assortment of profession has been done in expansion of power quality using changeable generators and power electronic strategy. Small scale stand-alone wind energy conversion systems is a foremost another source of electrical force, finding applications in locations where conventional generation is not sensible. Unfortunately, most of the systems cannot communicate power at each wind speed predominantly low wind speeds which are low in power, but they are all very frequent. But spanking new PMSG technology gives high effectiveness power translation that is mechanical force into electrical power. In this investigation to realize the prototypes or in use PM generator systems are offered for that purpose. From all the other generators, that are used in wind turbines

the PMSG's have the [17] top compensation. Because they are steady and protected during usual operation and they do not need a supplementary DC supply for the excitation circuit (winding).

The predictable Voltage-Source Inverter (VSI) and Current Source Inverter (CSI) are used to convert DC power to AC power and act as a boost-buck converter. But in this converter, the DC power side cannot be boosted up [4, 5] in the predictable inverters (i.e.), their nearby output voltage collection is limited to either superior or minor input voltage. But the proposed quasi Z-source inverter (qZSI) is an option power conversion concept, while it can have mutually voltage buck and enhance capability. In accumulation to that, it has the subsequent compensation: protected to EMI noise, no in-rush

current and misfiring compared to the predictable [2, 3] converter.

The below figure (1), is the major structure of the quasi Z-source inverter. It employs an incomparable impedance network fixed between the power source and the circuit for converter. That contains a split-inductor L1 and L2 and capacitors C1 and C2 associated in parallel. The quasi Z-source network is connected from the inverter to a DC power supply. The DC power supply will be a battery or diode rectifier output power. The qZSI can boost up the input voltage by introducing an extraordinary shoot through switching state. In this state, the qZSI is an immediate conductor of the identical inverter phase leg. This type of switching state is banned for the conventional [4, 5] voltage source inverter, because it causes short circuit in the DC link capacitor.

In the qZSI, the shoot through state is used to boost up the magnetic power stored in the DC side inductors L1 and L2 without any short circuit in the DC capacitor C1 and C2. The input power is satisfactory; the shoot through state is eliminated. Moreover the qZSI begins to manage as a usual voltage source inverter. The mandatory DC voltage is applied to the inverter section, this section convert DC power to necessary AC grid power. This excellence grid power should be circulated in the valued clients. This unique impedance network allows the quasi Z-source inverter to buck or boost up the output voltage, and also contribute in the unique features. This function cannot be obtained in the established [1] power inverters.

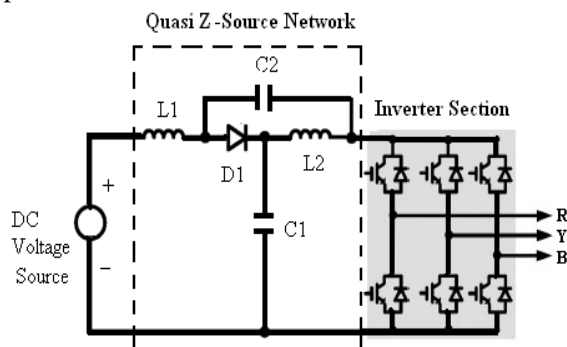


Fig. 1. Circuit Diagram of Quasi Z-Source Inverter.

2 MATERIALS AND METHODS

At present, the permanent magnet synchronous

generator is used for wind energy conversion system to progress the instant of power, and also to reduce the losses of power system. Two main objectives of PMSG is extracting uppermost power from wind and feeding the grid with high-quality electrical energy. Additionally it has some facial appearance such as little influence with capacity, tall presentation, compact the gear box mass, and no need of peripheral power supply for permanent magnet excitation. Here an innovative changeable velocity WECS with a PMSG and FLC based HCC technique is proposed in the quasi Z-source inverter system. Personality of quasi Z-source inverter is used for position to track greatest energy, control and distribute the quality power to the grid, concomitantly.

Figure (2) is simulation block diagram of wind energy conversion system. When the velocity wind is exploding in the blade, the blade should be rotated. The rotating blade is straightly attached through the shaft of the PMSG. So whenever the blade is twisted, the rotor of the PMSG is also found twisted. That time, the AC power should be generated in the PMSG. Generated AC power is directly fed to the uncontrolled bridge diode Rectifier. The major function of rectifier is changing the AC power to DC power. Then after the performance of DC conversion, the DC power is given to the quasi Z-source network. The qZSI can enhance the input voltage by introducing an extraordinary shoot through switching state. A set of boosted DC power is applied to the inverter section, this segment convert DC power to necessary AC grid power. Here the quasi Z-source inverter is controlled through Fuzzy Logic based HCC.

The fundamental purpose of this Fuzzy Logic based HCC technique to manage the quasi Z-source inverter; additionally real and reactive power maintain constant wind power source. In between the current measurement unit is measured the actual three phase grid current (I RYB act). In that case the error comparator,

compare the reference three phase set current ($I_{RYB \text{ ref}}$) and actual three phase grid current ($I_{RYB \text{ act}}$). At this point current measurement unit is produced by the three phase error current ($I_{RYB \text{ error}}$). Subsequently the three phase error current should be applied the Fuzzy Logic based HCC. Now, Fuzzy Logic based HCC depends upon the error current signal should be produced in the triggering pulses. Based on this firing pulses inverter should convert the DC power to AC Power. The superiority AC power supply from the quasi Z-source inverter is directly attached to grid. At that moment the grid should be supplied for several respective single and three phase customer applications.

In between any harmonics present in the transmission line, by using second order low pass filter, filtering the harmonics content and expansion of power quality in the power system. On the other hand similar level power generating station (Source I) is connected to the grid. So we must merge our recently produced quality power supply to that grid, during the quasi Z- source inverter. Using PMSG and quasi Z-source inverter, the recently produced power supply has been merged to the grid effectively is shown in under figure (2). Exceptional power is in spinning

reserve, whenever power demand occurring in grid, at that time utilized power.

2.1 HYSTERESIS CURRENT CONTROLLER

In the hysteresis current control method participate in the important utility in power electronic circuits, mostly in ac motor drives and uninterrupted ac power supplies where the machine is to generate a pure sinusoidal ac output voltage as well as current. Among the altered current control technique, the HCC is used very recurrently, due to cleanness the implementation. Also, moreover immediate response current loop, the technique does not need any knowledge of saddle parameters. The major responsibility of the control systems in current regulated inverters is to compel the current vector in the three phase load according to a reference curve. In this paper, FLC based HCC technique is to be implemented in the quasi Z-source inverter. Compare to conventional control methods [6, 7]; the projected control technique retains the advantage of the HCC having especially quick energetic response. The impression is based on predicting the current reference, system dynamic performance, and standard time to formulate the switching role for dictating the switching times of the switches in the inverter within a predefined Switching period.

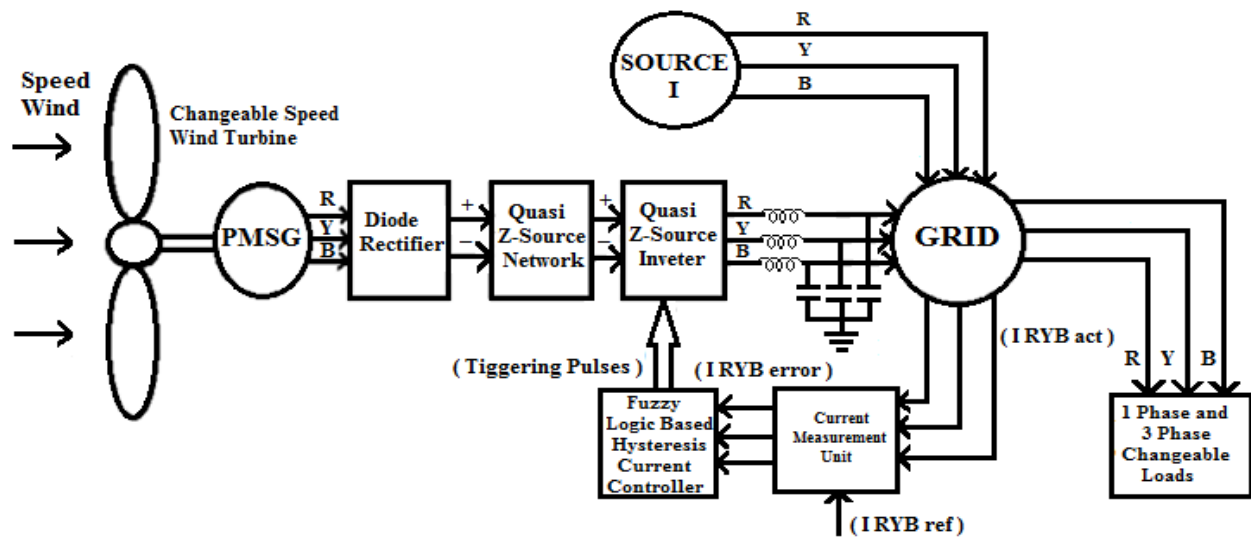


Fig. 2. Simulation Block diagram of Proposed Wind Energy Conversion System.

The fundamental implementation of FLC based HCC technique is depends on deriving the signals from the current error with a programmed patience band. This control technique is depends on the relationship of the actual phase current (I RYB act) with the tolerance band roughly the reference current (I RYB ref) linked with that phase. On other words, this kind of control is critically affected by the phase Current interaction which is typical in three phase systems. This is essentially causes by the interruption between the commutations of the three phases, since each and every phase current not only based on the resulting phase voltage, but this also synthetic by the voltage of the other two phases. Based on trouble position switching frequency may vary during the important period, resulting in asymmetrical inverter function. HCC is that the leg voltage switches to maintain the phase current inside the hysteresis band. The phase currents are, therefore, around sinusoidal in steady state. The smaller the hysteresis band, the further closely do the phase currents stand for sine wave.

2.2 Fuzzy Logic Controller

Fuzzy logic has quickly become one of the major successful of today's technologies for developing refined control systems. Fuzzy logic is a form of many-valued logic. It deals with interpretation that is inexact rather than fixed and accurate. Compared to conventional [9] binary sets (somewhere variables may take on true or false values) fuzzy logic variables may contain a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of fractional truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions. While variables in mathematics usually take numerical values, in fuzzy logic applications, the non-numeric linguistic variables are frequently used to make possible the expression of rules and information. The linguistic hedges can be linked with assured functions.

Generally, a fuzzy rule system has four modules; they are Fuzzification, Fuzzy Inference,

Rule base and Defuzzification. Fuzzification way to technique is to be convert classical data or crisp data to fuzzy data or Membership Functions (MFs). Fuzzy inference, capital combine membership functions with the control rules to derive the fuzzy output. Rule base means under rule base, rules are constructed for outputs. The rules are in "If Then" format and properly the If side is called the conditions and the Then side is called the conclusion. Defuzzification way to use different methods to calculate each associated output and put them into a table. Pick up the output from the lookup table based on the error current input during an application.

Fuzzy Logic has two inputs which are the error (Err) and change of error (ΔCE) at sampled times T defined by:

$$Err(T) = \frac{[P(T)-P(T-1)]}{[V(T)-V(T-1)]} \tag{01}$$

$$\Delta CE = Err(T) - Err(T-1) \tag{02}$$

Where P (T) and V (T) is the instant power and voltage of the Grid respectively. The proposed membership functions for both inputs and outputs are NB (Negative Big), NM (Negative Medium), NS (Negative Small), NZ (Negative Zero), ZE (Zero), PZ (Positive Zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Big). The proposed fuzzy rules which are carried out by using the method are shown in below Table I.

Table I: Fuzzy logic controller Rules base

| Err(T) VS ΔCE | NB | NM | NS | NZ | ZE | PZ | PS | PM | PB |
|-----------------------------|----|----|----|----|----|----|----|----|----|
| NB | ZE | ZE | ZE | PB | PB | PB | PB | PB | PB |
| NM | ZE | ZE | ZE | PM | PM | PM | PM | PM | PM |
| NS | ZE | ZE | ZE | PS | PS | PS | PS | PS | PS |
| NZ | PM | PS | ZE | ZE | ZE | ZE | ZE | NM | NS |
| ZE | PS | PM | ZE | ZE | ZE | ZE | ZE | NM | NS |
| PZ | NS | NM | ZE | ZE | ZE | ZE | ZE | PM | PS |
| PS | NS | NS | NS | NS | NS | NS | ZE | ZE | ZE |
| PM | NM | NM | NM | NM | NM | NM | ZE | ZE | ZE |
| PB | NB | NB | NB | NB | NB | NB | ZE | ZE | ZE |

3 RESULTS AND DECUSSION

3.1 SIMULATION RESULTS

The exceeding figure (2), is 580v AC input voltage is exposed in the below figure (3), given to the diode rectifier by means of WECS that is permanent magnet synchronous generator. Then the diode rectifier converts the 580v AC supply input into 520v DC supply output as shown in below figure (4). The DC output voltage is straightforwardly fed to the quasi Z-source network. Earlier convert DC power to AC power, the shoot through state is carried out through quasi Z-source inverter. As a product the voltage is boosted up to 1340v DC. The result of Vdc is publicized in below figure (5). In that case the 1340v DC voltage is directly fed to the inverter circuit for function of convert the DC supply into AC supply.

That is the 1340v DC supply converted into required 480v AC supply as shown in below figure (6), and at this point current is maintained as constant by using FLC based HCC. Then the 480 v AC supply is given to the second order low pass filter for eliminate the harmonics if it is presented in 480v AC supply. The inverter maintained the current if any alteration in grid power supply. The inverter current for a choice of power factor is shown in figure (7). The FLC output pulses are shown in figure (8). But the other generating station i.e. source (1) produced only 480v and 24A current is shown in below figures (9,10). The harmonics are reduced more and that the harmonics levels are maintained up to 0.07 % in this proposed scheme. It is shown in below figure (11). Here, suppose any load demand is created means, outstanding power qZSI will be compensated. The details of the simulation parameters are shown in below Table II

Table II

| S.NO | Specifications | Value |
|------|--------------------------------|------------------|
| 1. | Grid | 480v,50Hz |
| 2. | PMSG Stator Phase resistance | 0.425ohm |
| 3. | Load ₁ Active power | 10e ³ |
| 4. | Load ₂ Active power | 12e ³ |
| 5. | DC link Capacitor voltage | 1000v |

| | | |
|----|-------------------|-----------------------|
| 6. | DC link Capacitor | 3200e ⁻⁶ F |
|----|-------------------|-----------------------|

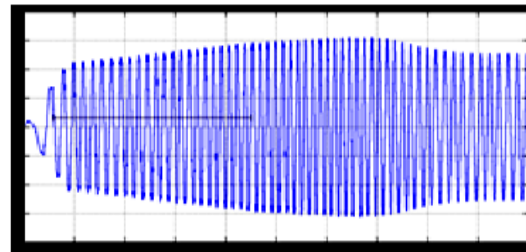


Fig. 3. PMSG Output Voltage.

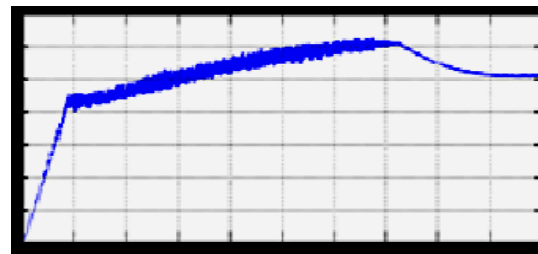


Fig.4. Diode Rectifier Output Voltage.

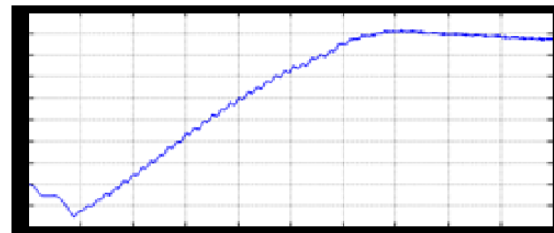


Fig. 5. DC Boost upped Voltage (Vdc).

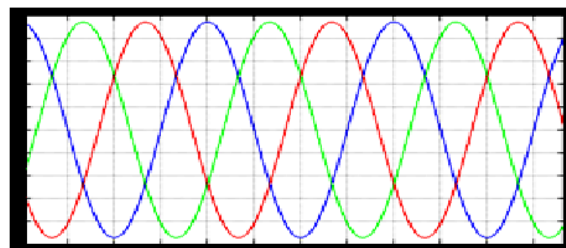


Fig. 6. Inverter Output Voltage

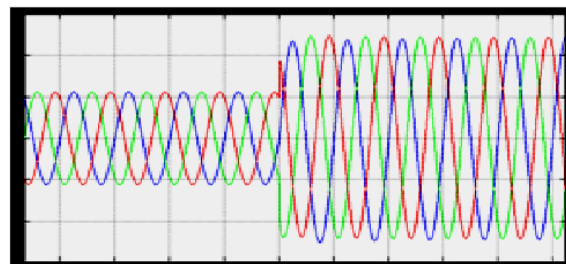


Fig. 7. Inverter Output Current

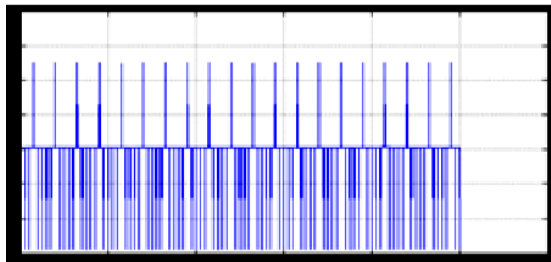


Fig. 8. Fuzzy Output Pulses

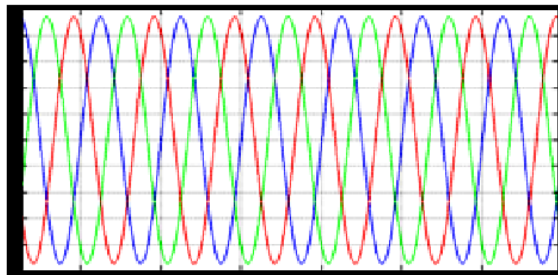


Fig. 9. Source I voltage

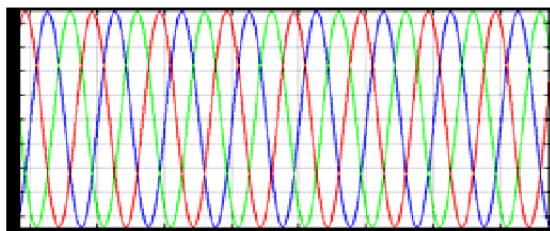


Fig. 10. Source I Current

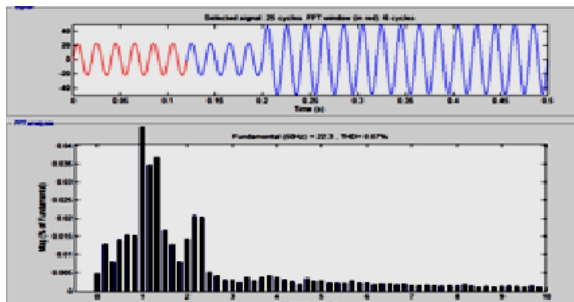


Fig. 11. Harmonics of Inverter

3.2 EXPERIMENTAL RESULTS

The use of fuzzy logic control has become popular over the last decade because it can deal with imprecise inputs, does not need an accurate mathematical model and can handle nonlinearity. Microcontrollers PIC16F87XA have also helped in the popularization of fuzzy logic control. The

proposed wind energy conversion system, hardware block diagram with prototype experimental setup of Quasi Z- Source Inverter and Grid system as shown in the below figure (12, 13).

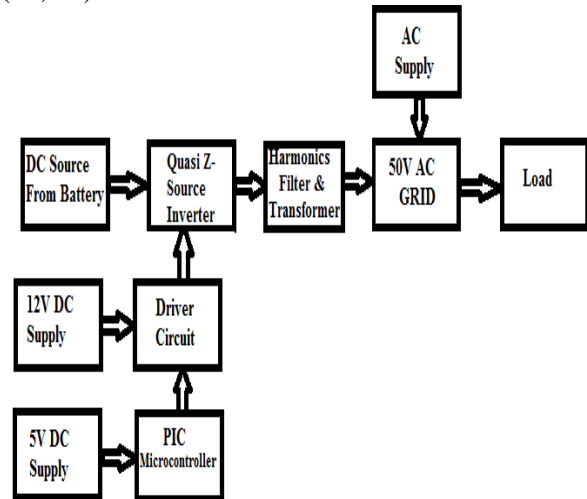


Fig.12. Hardware Block Diagram of Proposed System.

While 6.67v DC voltage applied from the 7V Battery as shown in below figure (13), this DC voltage fed to the Quasi Z- Source Inverter. At this point Quasi Z-Source Inverter DC side have been boosted, and then DC boosted voltage given to the inverter section. While inverter converts the DC supply to AC supply, then the AC supply given to the shunt Transformer, using the shunt Transformer reducing the Harmonics presents in the system. That time inverter controlled by fuzzy logic controller techniques. Further, transformer output voltage given to Grid system. Here initially Grid maintains the 50v AC Supply. That time 40w inductive load should be applied initially, and then after few second RL (R=4.70hms, L=700mH) load have been connected. That time grid voltage drop should be occurred. At this movement Grid voltage is 44v, using that renewable energy system, the 06v volt drop should be compensated as shown in below figure (13). Mutually shoot-through states and the transformer turn ratio can be synchronized to control the boost voltage gain. Consequently, the output voltage can be adjusted over a wide range, and can be boosted to a higher value. The details of the prototype model parameters are shown in below Table III.

Table III

| S.NO | Specifications | Value |
|------|-----------------|--------------------------|
| 1. | Load Resister | 4.7 Ω |
| 2. | Load Inductor | 700mH |
| 3. | Inductor Load | 40w |
| 4. | Transformers | 40v/06v,230v/5v,230v/12v |
| 5. | QZSI | 200v,50Hz |
| 6. | Microcontroller | 5vDC, PIC16F87XA |
| 7. | QZSI- Inductors | 700mH (L_1, L_2) |
| 8. | QZSI-Capacitors | 1000 μ F, 35v |
| 9. | Grid | 50v,50Hz |

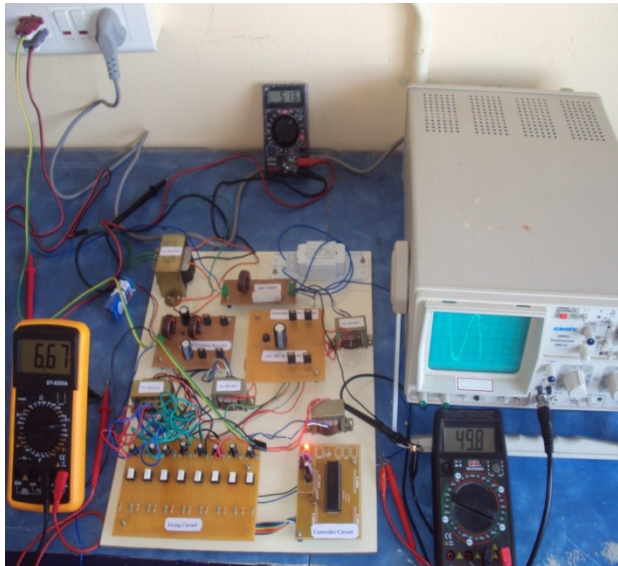


Fig. 13. Experimental setup of the Quasi Z- Source Inverter system and Grid System.

The fuzzy member ship functions for inputs and outputs are written as embedded C language Program as shown in below.

```
#include<pic.h> //PIC16F877A
#include<stdio.h> //C initialization
#include "delay.c" //Delay Program
#define R1 RC0
__CONFIG (0x3f71);
float L1=0,L2=0;
unsigned char GetADC1(void);
unsigned char GetADC2(void);
```

```
Void main () // Main Program
{
ADCON1=0x00;
DelayMs(10);
R1=0;
while(1)
{
L1=GetADC1();
L1=L1/51;
L2=GetADC2();
```

```
L2=L2/51;
if(L1>0.5 && L2<1)
{
PORTC=0x09;
DelayMs(15);
PORTC=0x06;
DelayMs(15);
}
else if(L1>=1 && L2<1.5)
{
PORTC=0x09;
DelayMs(13);
PORTC=0x06;
DelayMs(13);
}
else if(L1>1.5 && L2<2)
{
PORTC=0x09;
DelayMs(10);
PORTC=0x06;
DelayMs(10);
}
else if(L1>2 && L2<2.5)
{
PORTC=0x09;
DelayMs(16);
DelayUs(250);
PORTC=0x06;
DelayMs(16);
DelayUs(250);
}
else if(L1>2.5 && L2<3)
{
PORTC=0x09;
DelayMs(16);
DelayUs(250);
DelayUs(250);
PORTC=0x06;
DelayMs(16);
DelayUs(250);
DelayUs(250);
}
else if(L1>3 && L2<3.5)
{
PORTC=0x09;
DelayMs(16);
PORTC=0x06;
DelayMs(16);
}
else if(L1>3.5 && L2<4)
{
PORTC=0x09;
DelayMs(13);
PORTC=0x06;
DelayMs(13);
}
else if(L1>4 && L2<4.2)
{
PORTC=0x09;
```

```

DelayMs(10);
PORTC=0x06;
DelayMs(10);
}
else if(L1>4.2 && L2<4.3)
{
PORTC=0x09;
DelayMs(16);
DelayUs(250);
PORTC=0x06;
DelayMs(16);
DelayUs(250);
}
else if(L1>4.3 && L2<4.4)
{
PORTC=0x09;
DelayMs(16);
DelayUs(250);
DelayUs(250);
PORTC=0x06;
DelayMs(16);
DelayUs(250);
DelayUs(250);
}
else if(L1>4.4 && L2<4.5)
{
PORTC=0x09;
DelayMs(16);
PORTC=0x06;
DelayMs(16);
}
}
}
}
unsigned char GetADC1( )
{
ADCON0=0x41;
DelayMs(1);
ADGO=1;
While (ADGO==1);
return ADRESH;
}
unsigned char GetADC2( )
{
ADCON0=0x41;
DelayMs(1);
ADGO=1;
While (ADGO==1);
return ADRESH;
}

```

4 CONCLUSION

This paper is accessing a fresh proposed scheme of FLC based HCC technique for quasi Z- source inverter and connecting the output power to the grid. Compare to conventional methods, this proposed method produced the more voltage, current as well as especially less harmonics.

Additionally, proposed FLC has more compensation, such as privileged flexibility, control, enhanced dynamic and static performance compare with conventional controller. The simulation results for 580v AC input and 480v to 1000v (phase-to-phase) output has been verified, and the simulation results demonstrate the proposed quasi Z- source inverter has greatest boost potential. The proposed FLC based HCC method for quasi Z-source inverter is concentrate the harmonics up to 0.07% evaluate to conventional methods. The prototype experimental results are verified.

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