International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-5 Issue-5, June 2016

Development of Prototype of Grid Tie Inverter (Grid Synchronization and Load Sharing)

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Abstract*— *Design the prototype model of grid tie inverter which includes synchronization, load sharing and reverse metering technique. Main part of the system that control everything is the SPWM based inverter which take the information from grid and independent source of energy and then synchronize the both signals. According to the demand of the load Microcontroller (MCU) makes decision that either the grid feed the load or independent source of energy or both share the load. By sharing the common load with the grid, design an algorithm by which the sharing power with respect to the main grid using droop control technique. This technique minimizes the contribution of the main grid towards the load. Sine Pulse Width Modulation (SPWM) Grid Tie inverter is the most commonly used technique because it is less complicated, more efficient the power loss is minimum and the output sine wave is very close to true sine wave. While in multi-level inverter there is more power loss due to number of components and due to the limitations the output wave is not much like true sine wave. Load sharing by designing buck-boost converter and an adaptive algorithm load sharing can be done automatically according to the demand of load. So, this is more better and efficient then Push buttons.

Index Terms*— Angle Drop Control, *Distributed Generation, Grid Synchronization, Grid Tie Inverter, Load Sharing, Microcontroller.

I. INTRODUCTION

World is facing huge power crises and now people are giving preference to renewable and more efficient energy systems. Huge investments are being made in power sector for alternate green power production and effective and efficient power management programs. A major thing to note here is that the research in areas of alternate power sources and power management systems and devices are running parallel but isolated. These areas have not been addressed together yet and if they have been, there are very few examples. There is a strong need and demand for such devices that are capable of uniting the green power production with effective power management. As the results of research grid systems with and without batteries, it has been found that the grid connected battery less systems are more efficient and optimized model for inverters [2,4].

In this solar power system grid feed load by separate meter that is called import meter and there is no need of grid synchronization and load sharing, it is very simple system but there is extra cost on import and export meter. There are two connections, and extra protection required and in this system battery storage also required but in this project

Import export meter replaced with grid synchronization and load sharing and battery replaced with buck boost converter. Buck boost converter more efficient then battery that can control more power loses, there is no need of push buttons to control power share. Power system is automatic and our Microcontroller can generate Waveform by getting reference from grid and then synchronize and share power with grid to satisfy load [4].

All those inverters that connected with photovoltaic plates and grid both are called Grid Tie inverters and inverter take decision to inject current into grid and load and these inverters are also share both PV and Grid power to feed load. In addition to large scale rural solar farms, the market of residential PV power generations has grown rapidly in recent years by the encouragement of local governments and utility companies. The Performance Analysis of the GTI was verified in our Electrical Machines Lab through proper experimental setup [3,4].

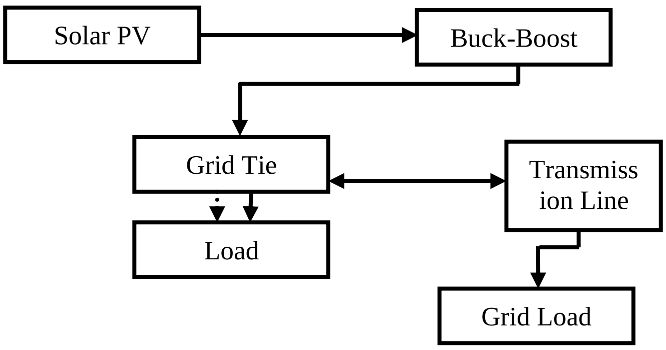

Fig.1 System Description

The PV Source for this Experiment was chosen with a total Capacity of 200W and solar plates are polycrystalline and these polycrystalline plates are more batter than Nano crystalline plates for radiations. The PV Array was made with 2 Nos. of solar plates each capacity varies between 110W-90W. In clouds it vary between 40W-80W, Each Panel have Terminals Output V_{op}=36V and V_{loaded}=12V so both plates total voltage vary between 24V-38VDC. There is too many variations in output voltage of solar plates due to intensity of light and manufacturing of plates so by using Buck boost to stabilize the voltage without using batteries because batteries are not good and cause of power losses and costly too. The terminal 38VDC to 24VDC of 2 Panels are connected in series for the Preliminary test of the PV Panel and gives a good result of 65% approximately.

Manuscript published on 30 June 2016.
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Buck Boost used to maintain DC output 24V stabilizes for the ease of controller. Otherwise due to variations in DC voltages it is very difficult to calculate duty cycle difficult. Buck Boost Converter is PWM based chopper IC, This IC SG3525 is feedback loop arbitrary reference, and this Buck Boost is an electronics circuit that used FETs inductor and diodes requirement is 24V output so reference is set at 24V and by using PWM technique feedback technique and chopper IC increase or decrease the duty cycle according to requirement of output that must be stabilize at 24V [2,3,8].

II. Literature Review

The use of renewable energy increased greatly just after the first big oil crisis in the late seventies. At that time, economic issues were the most important factors, hence interest in such processes decreased when oil prices fell. The current resurgence of interest in the use of renewable energy is driven by the need to reduce the high environmental impact of fossil-based energy systems. Harvesting energy on a large scale is undoubtedly one of the main challenges of our time. Future energy sustainability depends heavily on how the renewable energy problem is addressed in the next few decades. Although in most power-generating systems, the main source of energy (the fuel) can be manipulated, this is not true for solar and wind energies. The main problems with these energy sources are cost and availability: wind and solar power are not always available where and when needed. Unlike conventional sources of electric power, these renewable sources are not “dispatch able” the power output cannot be controlled.

Daily and seasonal effects and limited predictability result in intermittent generation. Grid synchronization and load sharing promise to facilitate the integration of renewable energy and will provide other benefits as well. Industry must overcome a number of technical issues to deliver renewable energy in significant quantities.

Control is one of the key enabling technologies for the deployment of renewable energy systems. Solar and wind power require effective use of advanced control techniques. In addition, this cannot be achieved without extensive use of control technologies at all level. solar and wind power plants exhibit changing dynamics, nonlinearities, and uncertainties challenges that require advanced control strategies to solve effectively. The use of more efficient control strategies would not only increase the performance of these systems, but would increase the number of operational hours of solar and wind plants and thus reduce the cost per kilowatt hour (KWh) produced. Both wind and solar have tremendous potential for fulfilling the world’s energy needs [1].

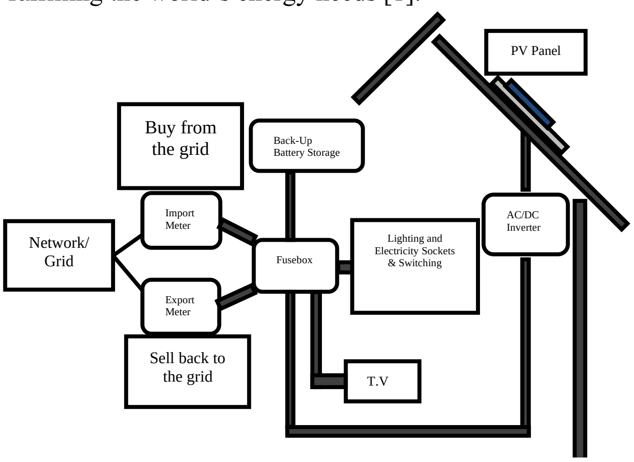

Fig.2 Solar generated power sell back to grid by export meter.

Build a system that stands alone, but have the flexibility to switch over to utility power when we run out of renewable power. The system that should be sized to provide all the energy that a house needs during the best irradiation day in the year, the system like any standalone system consists of panels batteries, inverter, and a new component is Automatic Transfer Switch, which is going to switch over to grid power once the inverter shuts down. The advantage of this system is using grid-tied or connected solar PV power can have economic as well as environmental advantages. [3]

Where utility power is available, consumers can use a grid-connected PV system to supply most of the power they need and use utility-generated power at night and on very cloudy days. When a home requires more electricity than the PV array is generating, the need is automatically met by the grid or utility power. When that home requires less electricity than the PV array is generating, the excess can often be fed (or sold) back to the utility through net metering,[4] At the end of the month, a credit for electricity sold may be deducted from charges for electricity purchased[2].

PV systems with batteries for storage are excellent for supplying electricity when and where you need it. These systems are especially suitable in areas where utility power is unavailable or utility line extensions would be too expensive. The ability to store PV-generated electrical energy makes the PV system a reliable source of electric power both day and night, rain or shine. PV/battery systems by connecting the photovoltaic modules to a battery, and the battery, in turn, to the load. During the day, the PV modules charge the battery, and then the battery supplies power to the load as needed.

A simple electrical device called a charge controller keeps the batteries charged properly and helps prolong their life by protecting them from overcharging or from being completely drained[2,4]. Synchronization of inverter with grid requires inverter frequency to be equal to that of grid. Grid has almost constant frequency, however difference in frequency of inverter output and grid results in high power imbalance. Phase difference is key factor which determines the active and reactive power flow to and from grid [5].

The research conducted to support is focused on making improvements of the behavior of grid converter connected to the utility grid through a LCL filter, where the following three attributes are fully developed and considered for improving grid-connected inverters for renewable energy applications [6]. Novel design of DC/AC Inverter is presented. The inverter is allowing for the connection of any DC alternative power source such as solar cells, wind turbines, to the AC grid. Therefore, in peak load times, every household can perform as a clean micro power station. The inverter is implemented as a phase shift synchronous generator and it is controlled by means of a DSP Sampling the grid voltage makes it possible for the Inverter to synchronize with the grid at a zero angle. Then the DSP synthesizes the AC voltage wave form to be shifted, with respect to the grid, with a software controllable leading angle. This configuration makes it possible to transfer the clean energy omitted by the alternative power source to the grid [7].

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This evaluates the capability of grid to accommodate the solar Photovoltaic power through the dispatching method that deploying the solar energy between the PV power and the grid load. Since no storage device is included, the capital investment of such PV integration method is reduced. [8] A grid tie inverter for photovoltaic, PV application with a combination switching strategy of square wave and the sinusoidal pulse width modulation, SPWM [9].

III. GRID TIE INVERTER (GTI):

It converts Direct Current (DC) power of Renewable source into Alternating Current (AC) power for an existing grid. In GTI there is H-Bridge Full inverter is to convert DC into AC. And there is a microcontroller that control and generate the higher pulses according to desired frequency with reference to grid. Due to variations in our DC output from Renewable source (solar cell) without using DC batteries, that why to obtain constant DC output from solar plates Buck Boost converter is used. This maintained DC output from Buck Boost converter is converted into AC by using H-Bridge Full inverter. Filter is used to obtained clean AC output waveform for synchronization with an existing Grid. The output of inverter is connected with Grid, that's why inverter frequency, voltage, and phase must be synchronized with Grid frequency, voltage and phase [5].

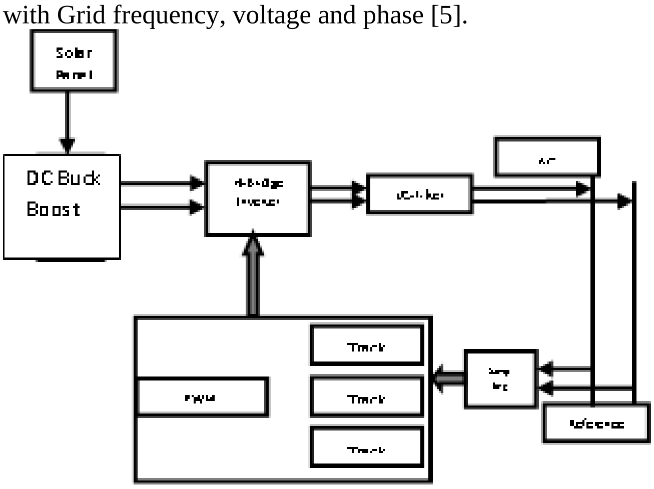

Fig.3 Grid Tie Inverter

A. *Synchronization Technique:*

For parallel operation of distributed generated (renewable energy source) and grid design an SPWM grid tie inverter i.e. the output voltage wave form of inverter should be synchronized with that of grid voltage wave form.
For synchronization following conditions must be met:
1-The voltage magnitude of inverter should be similar to that of grid.
2-The frequency of voltage output of inverter should be exactly similar to that of grid.
3-The voltage wave forms of both inverter and grid should be exactly in phase i.e. there should be no phase difference.
There is a technique for designing grid tie inverter i.e.

B. *Digital Technique*

As discussed earlier that for Grid Synchronization three parameters of Inverter should be matched with that of Grid i.e. Voltage Magnitude, Frequency and Phase. In digital technique measured grid voltage, grid frequency and give these references to inverter for grid synchronized sine wave generation. For keeping inverter synchronized with the grid, Measured grid parameters after a certain regular intervals and generate voltage according to those references. In digital technique, MCU's used for these measurement and tracking purposes.one ATMEGA32 microcontroller and one PIC18F4520/ATMEGA32A microcontroller due to high clock speed and built-in analog to digital converter (ADC) which measure voltages of grid and inverter. One PCB PIC 18F4520/ATMEGA32A is used for measurement and tracking purposes. This PIC 18F4520/ ATMEGA32 take the grid and inverter voltage, grid and inverter current, grid frequency and compare these for synchronization. This microcontroller also sends voltage and frequency reference for synchronization through serial communication to inverter microcontroller ATMEGA32A microcontroller takes synchronization references and generates SPWM accordingly and automatic load sharing between grid and inverter. This PIC 18F4520/ATMEGA32 also operates the relay for making/breaking the connection between grid and inverter after getting a signal from other microcontroller. This microcontroller also measures the power factors of both grid and inverter. The PCB PIC 18F4520 calculates RMS voltages and currents of both grid and inverter. 12 kHz SPWM for driving inverter. In this project 12 kHz SPWM generated whereas 50kHz SPWM generated easily, by using microcontroller and IRF3205 MOSFETs which is more efficient because of more better sine wave output and filter designing. Measure and track grid parameters in real time for keeping inverter synchronized with grid. If 50kHz SPWM generated then time period of SPWM becomes 20us and for obtaining 50Hz sine wave needed 500 SPWM cycles in one 10ms i.e. one half cycle of 50Hz sine wave. This time is not enough for microcontroller to receive the grid references from one controller to other through serial communication and generate the SPWM. Then MCU reduced the SPWM frequency to 12 kHz because it has time period of 120us that is comparatively much more time than that of above case and controller can receive and track grid parameters easily.

C. *Voltage Measurement:*

PT or voltage senor, as discussed above, our micro-controller has built-in ADC channel to measure voltage of Grid. First of all, we converted the grid AC voltages to DC Voltages using Transformer, Bridge Rectifier, and capacitor and resistor divider circuit.

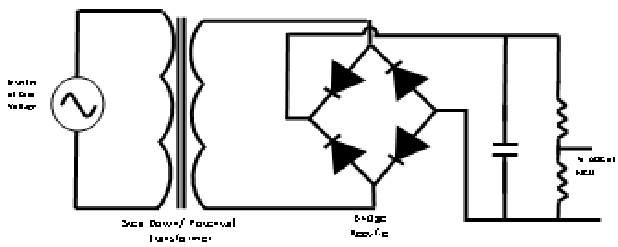

Fig.4 Voltage Measurement Circuits

The complete procedure of AC voltage measurement using ADC is an alternative method that is given below, but in this project voltage directly measured with Potential transformer that convert directly voltage according to the required demand of MCU.

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1. Stepped down the grid and inverter voltage to Main AC by using step down transformer/PT then I further used isolation transformer that secondary isolation winding output is 12V ac output and 230V output of isolation transformer and 12V of secondary is given input as feedback to primary winding of isolation transformer for synchronization with grid voltage [6-8]. Measurements more accurate by increasing the sampling rate i.e. number of samples per unit time. But to find the rms value of AC voltage MCU have to store those samples in memory, since MCU measured a number of parameters so a lot of memory is required to save all samples that is not feasible.

5. Then MCU take square of each sample, further average of all squared samples and then take square root of this average voltage.

6. The resultant of step 1,2,3,4 and 5 will be root mean square (RMS) of grid AC voltages. The formula of finding RMS of AC voltage is given below:

$$V_{rms} = \sqrt{\frac{\sum_{i=1}^{N}[V_i]^2}{N}} \qquad (1)$$

$\boldsymbol{V}_i$ represents the instantaneous ac voltage. **N** represents the total number of samples i.e. 255. The relationship between RMS, peak and average voltage is shown in figure below:

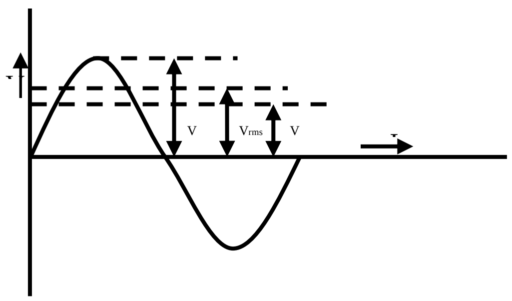

Fig.5 Relationship between peak and RMS voltages

In case of ac sine wave

$$V_{rms} = 0.707V_p \qquad (2)$$

$$V_{ac} = 0.637V_p \qquad (3)$$

By using the above method of finding RMS voltage, measured the both grid and inverter ac voltages and also used these measured voltages in power calculation and voltage tracking. For measuring DC voltage through ADC of micro-controller the voltages should be greater than equal to zero or less than equal to 5V/reference voltage for ADC. For measuring AC voltages directly through ADC of micro-controller the peak to peak amplitude of clamped AC voltage should be less than equal to 5V/ reference voltage for ADC. Application of voltage higher than 5V can damage the microcontroller [1,10].

D. Voltage Tracking:

After measuring grid and inverter voltage, started work on voltage tracking i.e. matching of output voltage of GTI with that of grid. Firstly, built-in sine functions of MCU for generation of SPWM. For voltage tracking, the PCB PIC 18F452/ATMEGA32A sends the serial command to increase or decrease the duty cycle to SPWM MCU ATMEGA32 and to increase or decrease the inverter voltage the built-in sine function have to execute completely. In the case of sine function, the micro-controller calculates the duty cycle by using sine function which takes a lot of time and due to this time delay SPWM interrupts because after each voltage variation or frequency variation micro-controller calculates new sine function table. Due to this interruption, the GTI comes out of synchronism and power flows from grid to inverter which is extremely dangerous and not desired. To overcome this problem of delay and to reduce calculations look-up tables of sine function of different duty cycles and hard coded them in micro-controller. Feedback Voltage Control System (Proportional Controller). For voltage tracking feedback system in which generated SPWM having lowest duty cycle and measured the grid reference voltage, the output voltage of GTI and compared with that of grid reference [9,12].

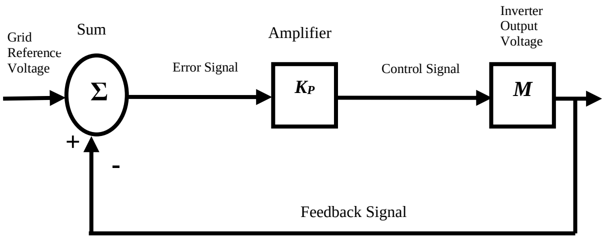

Fig.6 Proportional controller

If the grid voltage is greater than GTI output voltage then PCB MCU PIC18/ATMEGA32A send a serial command to SPWM MCU to increase the duty cycle by a certain step size. For increasing the duty cycle the SPWM MCU selects a next look-up table of higher duty cycle. The PCB PIC 18F452/ATMEGA32A repeatedly compares both voltage and if inverter voltage is less than that of grid, it sends a serial command to SPWM MCU which keeps on increasing duty cycle until both voltages matches. If due to overloading/ dip grid voltage become less than that of GTI voltage, controller decreases the duty cycle by a certain step size i.e. SPWM MCU selects a look-up table of slightly lower duty cycle and keeps on decreasing duty cycle until both voltages matches. Inverter voltage slightly higher than that of grid for inverter protection. If the GTI voltage becomes less than that of grid then GTI becomes a load and it start taking power from grid which is very dangerous for inverter and not desired.

E. Phase and Frequency Measurement

It measure frequency and period of signals. Measure frequency number of cycle measured one or more time for accuracy. For synchronization, fast and accurate frequencies are required. For AC voltages, zero crossing is the point where no voltages present.

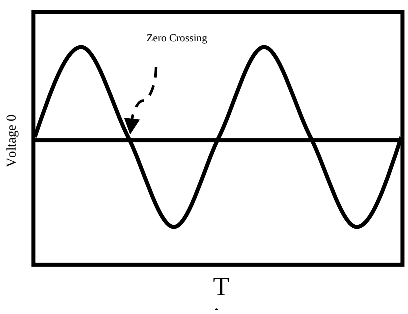

Fig.7 Zero crossing detection

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International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-5 Issue-5, June 2016

F. *Frequency Calculation:*

Pulses obtained at zero crossing are used to calculate the time period between two consecutive pulses. By using the external interrupt of ATMEGA32A (INT0) and Timer (TIMER0) the time period is calculated, when the first external interrupt occur timer0 start calculating the time in 8-bit mode till the second interrupt occur then timer0 stop. And using that timer value we calculate the frequency of the input signal by using following formulae.

$$I_C = \frac{External\ Crystal}{4} \tag{4}$$

$$T_p = \frac{Timer\ Value \times 2}{I_C} \tag{5}$$

$$F = \frac{1}{T_p} \tag{6}$$

I_C = one instruction cycle execution time
Tp = time period of input signal
F =frequency of the sine input

G. *Generating PWM of Desired Frequency (with Reference to Grid):*

The time period of the sine wave is calculated and it is then used to calculate the look up table for SPWM generation. The number of cycle of PWM in half cycle of sine wave determines the frequency of SPWM. Using the frequency of 12 KHz for the PWM calculated the number of cycle and fixes it and now for any change in frequency of input sine wave no cycle is fixed only changing the duty cycle of PWM cycle for obtaining the desired frequency of the invertor [11-13].

H. *Phase Tracking:*

After achieving the frequency the look up table for the SPWM is obtained now due to the microcontroller instruction execution cycle delay and switching of the MOSFET cause a delay which creates a phase difference. For synchronization it is necessary that the two waves must be in phase. There is a method of tracking the phase is Close loop Method [14].

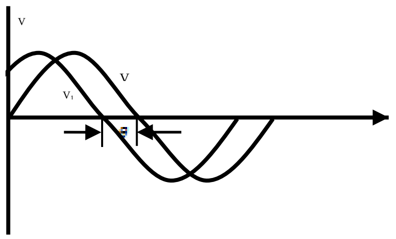

Figure.8 Phase tracking

I. *Close loop method:*

It is a control method that generates an output whose phase is related to the phase of the input "reference" signal. This circuit consists of a variable frequency Voltage controlled oscillator and phase detector. This phase detector compares the phase of the signal derived from the oscillator to an input signal. The signal from the phase detector is used to control the oscillator in a feedback loop. The circuit compares both signal to keep the phases matched [14].
It consists of three parts:
1) Phase detector
2) Low pass filter
3) Voltage Control Oscillator

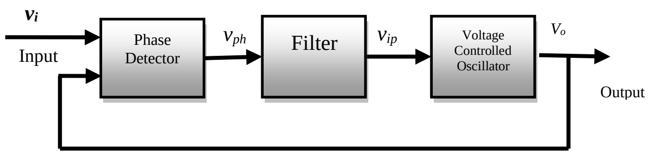

Fig.9 Close Loop Method

J. *Phase Detection:*

$$V_1 = \text{Sin}\ (wt) \tag{7}$$

$$V_2 = \text{Sin}\ (wt+\Phi) \tag{8}$$

This delay is reduced by calculating the difference of phase between the two wave by converting the both waves into square wave using op amp (LM741) and then XOR these two waves [15].
For every input the phase delay is constant due to the filter. This delay measured by MCU and starts the timer that measures the delay from the Vxor and generates SPWM to subtract this delay.
After subtraction this constant delay is removed and the sine wave that obtained is in phase with the reference wave i.e. Grid.

K. *Power Measurement:*

In this project microcontroller based power meter designed. This digital power meter measures power that is delivered by renewable energy source and grid to the local load. In the case of DC circuit, the power absorbed by the load is calculated by the product of voltage across the load and current through the load. There is no concept of phase difference between voltage and current waveforms, i.e. there is no concept of power factor. The power absorbed by the load in a dc network is the active power. In case of ac network, the situation is complex due to presence of phase difference between current and voltage waveforms. This phase difference is due to complex ac impedance [17,18].

$$\boldsymbol{Z} = R + j\boldsymbol{X} \tag{9}$$

Where, ***Z*** represents the complex ac impedance.
R represents the resistive or real part of complex ac impedance.
X represents the imaginary part of complex ac impedance.
As the ac impedance is made up of real and imaginary components

$$\mathbf{S} = P + jQ \tag{10}$$

IV. METHODOLOGY

A. *Angle Droop Control:*

As in frequency droop case the real power is changed by droop system frequency. The frequency will change with the changes in the system load. The reference power is modified to restore the frequency which is equivalent to shifting the power frequency curve vertically.
In conversational frequency droop the frequency deviation is used to set the power output of the converter. The angle droop control strategy is applied to all the DGs in system.

B. *Angle Droop Control and Load Sharing:*

The average real power is denoted by P and reactive power is denoted by Q. This power from DG to micro grid can be calculated as

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$$P = \frac{E*V}{x}\sin(\delta) \quad (12)$$
$$P = \frac{E*V}{x}\delta \quad (13)$$
$$Q = \frac{EV\cos\delta - V^2}{x} \quad (14)$$
$$Q = \frac{V}{x}(E - V) \quad (15)$$

It is obvious that VSC does not have any direct control over the micro grid. By changing the behavior of its own output voltage waveform it can change its real and reactive power absorption/ injection. Real power can be controlled by changing the phase angle and reactive power is controlled by changing the voltage magnitude [17].

C. *Derivation:*

The power flow in to a line at point A, as represented in figure given below as S

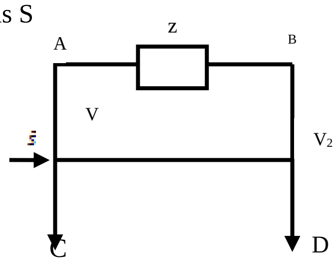

Fig.10 Power Flow through a Line

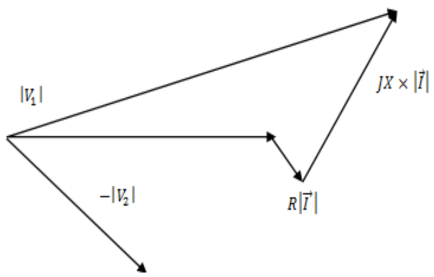

Fig.11 Voltage of inverter and Grid Lag and Lead by angle

Table.I States of Voltage of inverter and Grid Lag and Lead by angle

$\vec{Z}=R+j\vec{X}$	Impedance of the line
$\vec{V_1} - \vec{V_2} < 0$	Voltage of grid-tie-inverter (GTI)
$\vec{V_1} - \vec{V_2} < -\partial$	Voltage of grid, lagging by angle ∂ with respect to GTI reference voltage.
$\vec{I} = [I] < -\varphi$	Current entering in to the line at point "A", current is lagging with respect to GTI reference voltage by angle "φ"

The power flow to the point A is S

$$P + jQ = S = V_1 \times I^* = VI \times \left[\frac{V_1 - V_2}{z}\right]^* \quad (16)$$
$$I = \frac{V_1 - V_2}{z} \quad (17)$$
$$V_1 = |V_1| \times e^{j0} \quad (18)$$
$$V_2 = |V_2| \times e^{-j\partial} \quad (19)$$
$$Z = |Z| \times e^{-j\theta} \quad (20)$$
$$S = V_1 \times \left[\frac{[V_1]\times e^{-j0} - [V_2]\times e^{j\partial}}{|Z|\times e^{-j\theta}}\right] \quad (21)$$
$$\therefore V_1 \times V_1 = [V_1]^2 \;;\; [V_x] = V_x \;;\; [Z] = Z$$

$$S = \frac{V_1^2 \times e^{j\theta}}{z} - \frac{V_1 \times V_2 \times e^{j(\theta+\delta)}}{z} \quad (22)$$
$$\therefore \frac{V_1 \times e^{-j0}}{Z \times e^{-j\theta}} = \frac{V_1 \times e^{j\theta}}{Z}$$

The active and reactive powers flowing in to the line are described as:

$$P = \frac{V_1^2 \times \cos\theta}{z} - \frac{V_1 \times V_2 \cos(\theta+\delta)}{z} \quad (23)$$
$$\therefore R = Z\cos\theta \;;\; \sin\theta = \frac{R}{z} \;;\; \sin\theta = \frac{X}{z}$$

Cos $(\theta + \delta)$= $\cos\theta \times \cos\delta - \sin\theta \times \sin\delta$ (24)

Multiplying and diving equation 3.14 by Z and putting the above value we get

$$P = \frac{V_1^2 R}{z^2} - \frac{V_1 \times V_2 \,\mathrm{R}\cos\delta}{z^2} + \frac{V_1 \times V_2 \times \mathrm{X}\cos\delta}{z^2} \quad (25)$$
$$\therefore Z^2 = R^2 + X^2 \quad \text{and} \quad X \gg R$$

So equation 3.16 can be simplified as

$$P = \frac{P_1 \times P_2 \sin\delta}{x} \quad (26)$$

Since R=0 so we can ignore that factor of equation 3.16 that contain "R"

For Reactive Power

$$Q = \frac{V_1^2 \times \sin\theta}{z} - \frac{V_1 \times V_2 \sin(\theta+\delta)}{z} \quad (27)$$
$$X = Z \times \sin\theta \;;\; \sin\theta = \frac{X}{z} \;;\; \cos\theta = \frac{R}{z}$$

And

$\sin(\theta + \delta) = \sin\theta \times \cos\delta + \sin\delta \times \cos\theta$ (28)

Putting these values in to equation 3.18 then we get

$$Q = \frac{V_1^2 \times X}{z^2} - \frac{V_1 \times V_2 \times \mathrm{X} \times \cos\delta}{z^2} - \frac{V_1 \times V_2 \times \mathrm{R} \times \sin\delta}{z^2} \quad (29)$$

$\therefore$ $Z^2 = R^2 + X^2$ and $X \gg R$ for example $R \approx 0$ for overhead lines.

So ignore that factor for equation 3.20 that contain "R",

$$Q = \frac{V_1^2}{x} - \frac{V_1 \times V_2 \times \cos\delta}{x} \quad (30)$$

Equations 3.18 and 3.20 are actual equations of power flow but after ignoring 'R' resistance of line, equations 3.16 and 3.21 that are most famous equations of power sharing. If the power angle is small then,

$$\sin\delta = \delta$$

and

$$\cos\delta = 1$$

Equation 3,16 and 3.18 then becomes

$$P = \frac{V_1 \times V_2 \times \delta}{x} \quad (31)$$
$$\delta = \frac{XP}{V_1 \times V_2} \quad (32)$$
$$Q = \frac{V_1^2}{x} - \frac{V_1 \times V_2}{x} \quad (33)$$
$$V_1 - V_2 = \frac{XQ}{V_1} \quad (34)$$

For $X \gg R$, small power angel "δ" and small voltage difference $V_1 - V_2$ equation 3.23 and 3.25 shows that:

- The power angel depends predominately on P.
- The voltage difference depends predominately on Q.

From 3.23 the active power sharing does not depend only on power angle it also varies slightly with the voltage difference From 3.25 the reactive power sharing does not depends only on voltage difference it varies slightly with the power angle but on the bases of "Fast.

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International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-5 Issue-5, June 2016

Decouple Method”

$P \propto \delta$ Active power is directly proportional to power angle

$Q \propto V_1 - V_2$ Reactive power is directly proportional to voltage difference [18].

D. Load Sharing between Inverter and Grid:

The distributed generation is interfaced to the grid through power electronics controller and storage systems. It is a vital alternative when renewable energy is available. These resources can be connected to the local low voltage electrical power networks called micro grids through power conditioning ac units i.e. inverter which can be operate in either grid connected mode or island mode. Grid connected operation consists of delivering power to local loads and to the utility grid. In such a case, the output voltage reference is taken from the grid and inverter is behaving as a current source inverter [19].

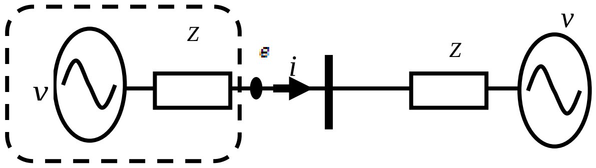

Fig.12 Current Source Inverter

V. HARDWARE MODEL AND SIMULATION

E. Block Diagram

Master MCU Unit ATMEGA32/PIC18

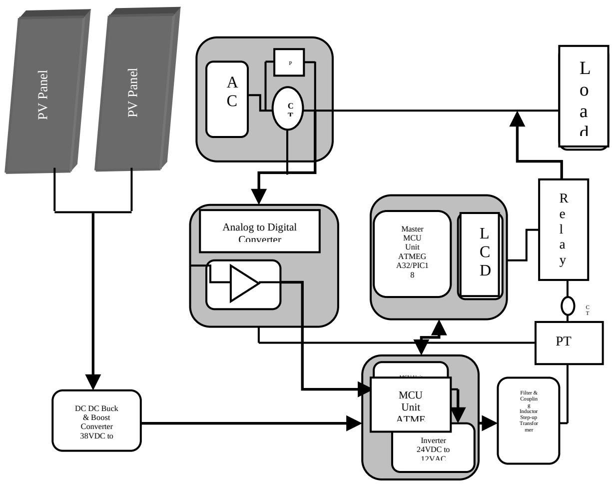

Fig.13 Block Diagram of Hardware Model

F. Grid and Inverter Synchronization Mode:

In this mode inverter controller adjust the SPWM according to required waveform for synchronization with grid AC waveform.

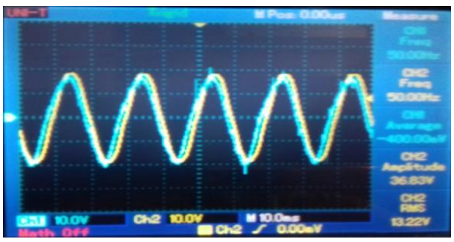

Fig.14 Synchronization Mode

Synchronization Simulation Results

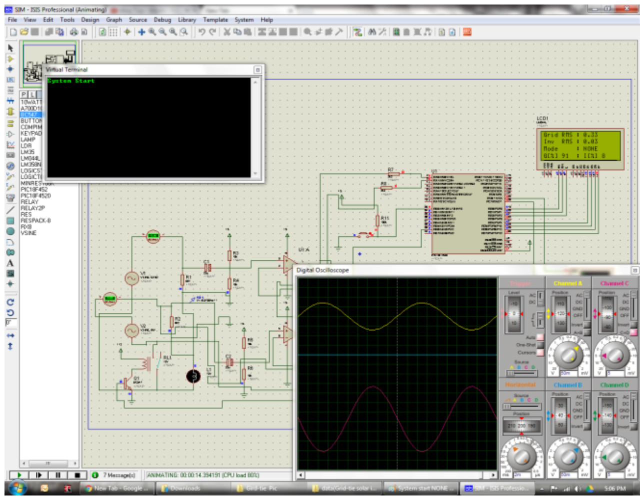

Fig.15 Grid and Inverter not Synchronized

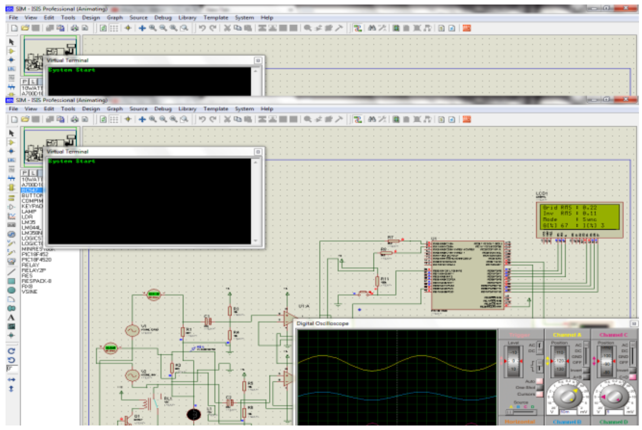

Fig.16 Grid and Inverter Synchronized

G. Load Sharing (None Mode):

When system start grid feeding the Load then MCU gives none mode on screen because this time inverter start synchronize and sharing load power is only from grid. This time solar contribution is zero. Because first inverter required to synchronized with grid and then it start sharing power according to its capability or generating power from solar panels.

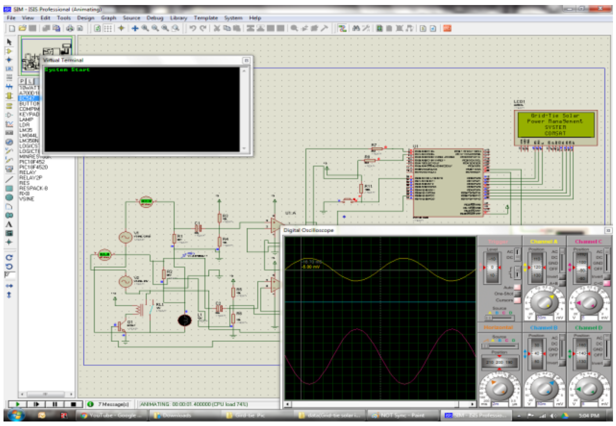

Fig.17 System Start None Mode Simulation

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H. Inverter mode:

When inverter synchronized with grid then it start sharing power with load and its contribution is increases according to generatig capacity of solar so solar share more power then grid to our load. So this is inverter mode when inverter share more power then grid it is called inverter mode. Its result show on LCD in figure 4.7:

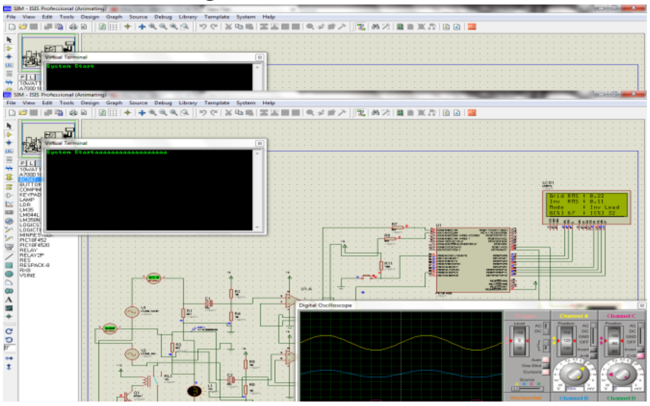

Fig.18 Inverter Lead Command send to Inverter board.

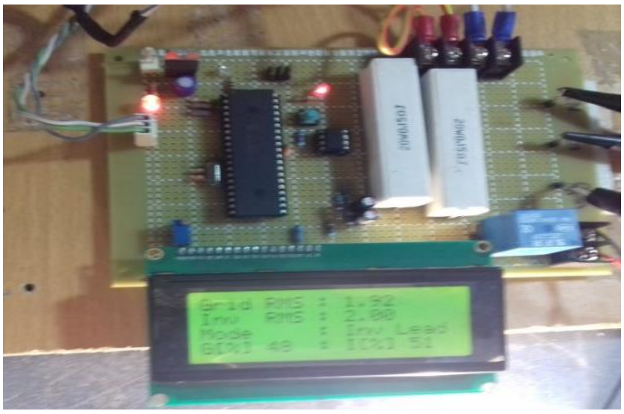

Fig.19 Inverter Mode measurements

I. Grid Mode:

In this mode grid share more power to load then inverter, its result and Mode show result on sacreen in figure.

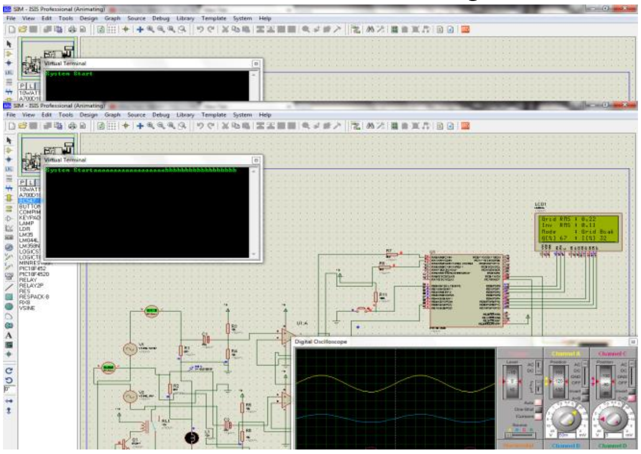

Fig.20 Grid lead Command send to Inverter board

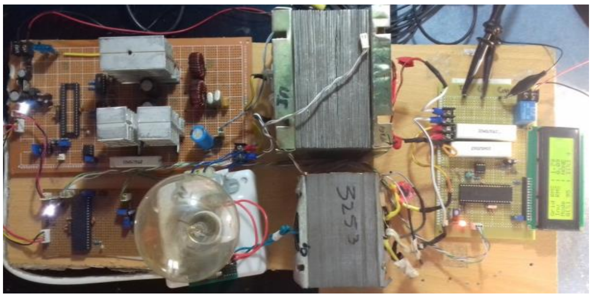

Fig.21 Full Grid Tie Inverter Hardware Model

V. CONCLUSIONS AND FUTURE WORK:

SPWM Grid Tie inverter is the most commonly used technique because it is less complicated, more efficient the power loss is minimum and the output sine wave is very close to true sine wave. While in multi-level inverter there is more power loss due to number of components and due limitations the output wave is not much like true sine wave. Load sharing by designing buck-boost converter and an adaptive algorithm load sharing can be done automatically according to the demand of load. So, this is more better and efficient then Push buttons.

The major drawbacks of this grid reference voltage measurement technique are

1. Since grid voltage fluctuate almost all the time, when the capacitor is get charged to 12V if at next instant grid voltage becomes 11V then capacitor will not get discharged due to absence of discharging path. If connect a resistor of very large value in parallel with 36 the capacitor then capacitor will not remain charged to AC peak value and then voltages will not be measured accurately.

2. Measured power factor angle, frequency, active and reactive power that is flowing from the grid to load which can be measured with a zero-crossing detector circuit, current sensors and potential transformers. Use AC to DC rectifier then rectifier circuit will be extra and this will increase the hardware complexity and cost.

On the basis of drawbacks of above technique moved to measurement of AC voltages directly by using ADC. PIC18F4520 which is not too much efficient to control all the calculations in the project. For that purpose 2 controllers are used and divide this task i.e. explained above chapters. At the end by further research I find out that ARM based controllers can handle all the calculations needed in project and by using ATMEGA32A MCU all the task can be done and the size of the project can be more compact. So then I used one PIC18F and one ATMEGA32A for accuracy and precession.

A. Regulated transformer

The output of non-regulated transformer changes with the change in load that is the problem faced in reverse metering. By using the regulated transformer reverse metering can be done more easily and efficiently.

B. Power Loss

Be doing the above improvements the power loss can be made minimum i.e. by replacing three PCB's with single one.

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ACKNOWLEDGMENT

All thanks to almighty Allah, the most gracious and the beneficent, who loves and cares us the most. I would like to express my most sincere gratitude to my supervisor Prof. Dr. Nasarullah Khan for his support, encouragement, and guidance through every step of this research. His kind efforts contributed greatly to my knowledge, understanding, and enthusiasm for this research. I have not only learnt from his insight, deep technical knowledge, and practical experience, but also a lot of things from him as a person. It has been a real honour for me to work under his supervision and to attend his lectures and talks. This project is supported by financial aid from COMSATS Institute of Information Technology, Islamabad. I am grateful to organization as well as Aamir Shafi for the technical help for the deployment of this project.

I would like to thank my affectionate parents for their unwavering love, moral support, and encouragement. They always prayed for me in my hard times. I also thank to my sincere friends for their moral support to conduct this research and also for all the great times we had growing up together.

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