IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 7, Issue 4 (Sep. - Oct. 2013), PP 01-05
www.iosrjournals.org

Synchronization of Photo-voltaic system with a Grid

[1]Muhammad Waqas Khan, [2]Muhammad Saleem,[3]Ashfaq Ahmad and [4]Ahmad Ayaz
[1, 2, 3,4]Department of Electrical Engineering,
Sarhad University of Science and Information Technology, Peshawar-25000, Pakistan

Abstract: *The study addresses the architecture of a hybrid PLL circuit technique for synchronizing a PV system with single phase grid. For determination of synchronization, the PV system is based on a reference system .The reference system is controlled by a microcontroller and pulse width modulation technique is used within the microcontroller to trigger the inverter in order to achieve efficient synchronization. Optocoupler is used to detect the real-time zero crossing detection and the digital phase lock loop system is used to control the phase angle and frequency of the system. The architecture of system is designed in Proteus simulator. The proposed architecture has performed well in reducing the harmonics produced because of inverter switching. Also if there are any abrupt changes in frequency or phase angle, the system can effectively manage changes.*
Keywords: *PV Array, Grid synchronization, Microcontroller, Optocoupler, DPLL, PWM and Power Quality.*

I. Introduction

The power generated through photo-voltaic system is used to operate the different types of loads. Solar energy is harnessed by means of photovoltaic (PV) systems[1], which use arrays of PV panels that convert solar energy into electrical energy. It is cheap and is more reliable as compare to other generating systems.The PV systems are suitable for applications such as battery charging, lighting and water pumping in remote areas. The solar energy charges a battery (DC supply) which is further connected to a DC-AC inverter that finally operates AC loads. This system can be used on small as well as for domestic use to fulfill the consumer demand for power.It is used as a backup Source for purpose when the load on the power station increases.For such purpose we synchronize our system to the Grid[2][3]to overcome low power problems. The inverter must convert the renewable energy stored in the battery bank into pure sinusoidal voltage that tracks the grid voltage in amplitude, frequency and phase. For this purpose the inverter must be synchronized with grid. The interconnection of photo-voltaic (PV) system[4] with a Grid requires an accurate control of synchronism between converter and grid. The parameters including voltage, phase and frequency of both systems need to be synchronized.There are different types of techniques [5][6]developed to achieve synchronization but the system used in this study is simple,reliable,requires small area for installation and need small circuitry. The proposed system is designed for 1.5kw.The main goal is to share the load during the peak load time on the power station as well as an accurate measuring of the phase-angle of the grid voltage.The parameters of the reference system (Grid) and photo-voltaic system must be equal for efficient synchronization.

II. System Analysis

The block diagram of the proposed synchronization of photo-voltaic system with a Grid is sketched in [**Figure 1.1**]. A sinusoidal input information *s(t)*arrived from reference system with frequency offset $\Delta f = f - f_0$ received at Optocoupler that converts *s(t)*to digital signal.This information is utilized in microcontroller which further triggers the inverter gates that allow DC to AC.The reference system's input information is:

$$S(t) = A_o \, Sin\,(2\pi f(t) + \Phi(t)) \qquad (1)$$

Where A_0shows the peak amplitude of input information, f is the frequency of signal while Φ represents the phase angle in degree.
The second signal arrives from battery after inverter with time delay t_0:

$$S'(t) = A_o \, Sin\,(2\pi f(t) + \Phi(t - t_0)) \qquad (2)$$

The sampled versions of (1) and (2) are given as:

$$S(k) = A_o \, Sin\,(2\pi f(k) + \Phi(k)) \qquad (3)$$

$$S'(k) = A_o \, Sin\,(2\pi f(k) + \Phi(k - k_0)) \qquad (4)$$

The error signal between two will be:

$E(t) = S(t) - S'(t)$ (5)

And is given by

$E(t) = F[\tan^{-1}(S'(k)/S(k))$ (6)

This error signal represents non-linear phase error that has a major effect as phase shift.

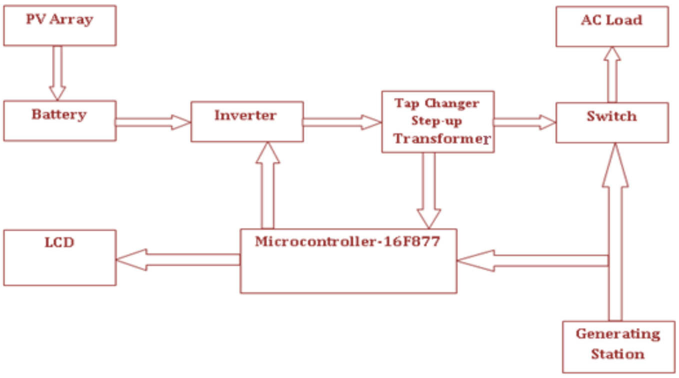


Figure 1: The block diagram of synchronization of Photo-voltaic system with a Grid

III. Zero-crossing Detection

Synchronization is an operation based on detection of phase. Optocoupler is an electronic device which is used to detect the Zero-crossing detection and also used as Analog-to-Digital converter to operate microcontroller. The functionality of optocoupler is to take the real time information from the reference system and use this information to trigger the gate of the inverter which belongs to MOSFET transistor family. The optocoupler plays a key role for synchronization of frequency and phase angle of the two systems.
At every half cycle $t_{on}$and t_{off}provides total switching time period, *T*.

$T_{switch} = t_{on} + t_{off}$ (7)

And the frequency is:

$F_{switch} = 1/T_{switch}$ (8)

Phase angle detection describes the starting and end point of reference system

$\Phi_{Reference} = 2\omega t$ (9)
Where $\omega = 2\pi f t$

The switching operation of optocoupler is very quick having period of 1μsec
The angular velocity of switch will be

$\omega = 2 \times 3.14 \times 50 \times 10^{-6} = 3.14 \times 10^{-4}$ radian/sec (10)

IV. RLC low pass filter

Power *L-C* filters are used to reduce the harmonics or ripple from

- The rectifier output (dc filter)
- The inverter output (ac filter).

The same type of filter is used in the inverter output to filter PWM harmonics, leaving the relative low frequency modulation frequency. The *L-C* filter fundamental cut-off frequency is dependent on *L, C* and the load impedance Z_L

$$H(j\omega) = V_0/V_i = \frac{1}{1+j\omega L\ (\frac{1}{ZL} + j\omega C\ )} \quad (11)$$

$$H(j\omega) = V_0/V_i = \frac{1}{1-\ \omega 2LC + j\ (\frac{\omega L}{ZL})} \quad (12)$$

The basic function of the filter used here is to remove high frequency harmonics from the phase-detector output in order to obtain low-frequency error voltage required for driving the switching control circuit. The selection of filter is made on the basis of loop performance. A widely used passive low-pass filter and its transfer function is given in equation (11, 12);the schematic diagram of RLC-low pass filter is given in [Figure 2].

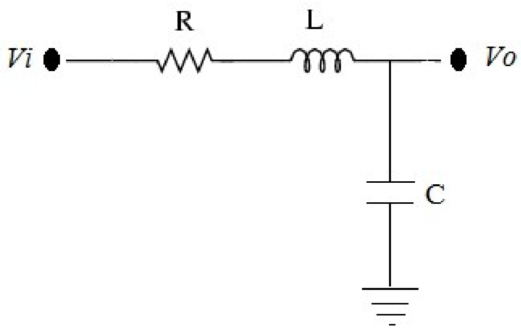


Figure 2: RLC low-pass filter

V. Pic Microcontroller-16F877

It is the Major controlling portion of the whole system. Microcontroller [7]acquires information of the reference system through optocoupler which used to detect the zero-crossing detection and make logic (1 and 0) by passing a complete sinusoidal cycle of the reference system. The 1 and 0 information is transmitted to microcontroller. After that reference system information (phase angle and frequency) is locked through the programming in the microcontroller. Pulse Width Modulation has been performed for triggering the inverted system .The switches of the inverter are controlled through the power transistor and AVR. After triggering, the inverted output frequency must be same like the reference system and for voltage synchronizing the inverted output voltage is step up though tap-changer transformer and the results are observed on the LCD display.

VI. Simulation Results

The proposed structure has been simulated in Proteus. The sketch of system diagram is shown in figure 3.Real time monitoring of the both systems shows that the accurate Synchronization is achieved. PV system output is pure sinusoidal and there is a zero-phase angle difference with a Reference System. The result clearly shows that the signal starting and end point are same.[Figure 4] shows the frequency of WAPDA (Green) and Photo-voltaic inverted system (Pink).

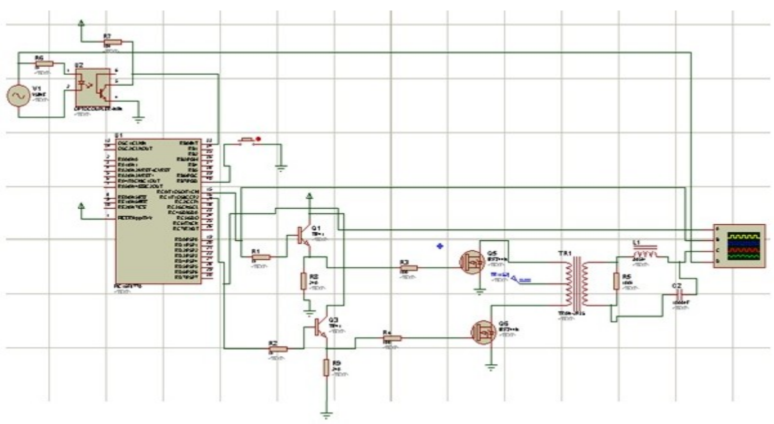


Figure 3: The proposed structure simulated in Proteus

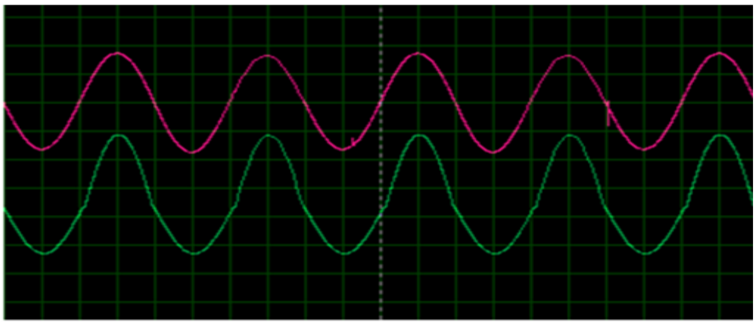


Figure 4: The frequency of generating system (Green) and Photo-voltaic inverted system (pink)

The change in frequency of reference system is shown in figure 5.In case of disturbance produced in the phase detection. If the small delay occurring in the reference system then the result will not be affected. The digital phase locked loop system set up the output information with a reference system with a very small harmonics. If the lower order harmonics are not in phase, the zero crossings are changed automatically. The verticals lines on the curve show the harmonics clearly in the simulation[Figure 6 and 7] shows result in case of greater delay.

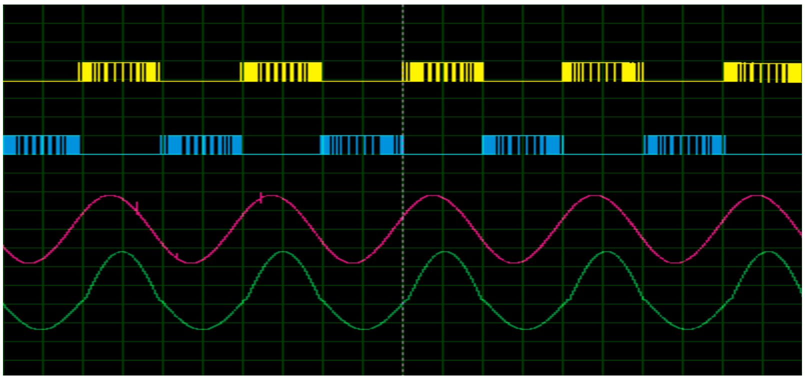


Figure 5: Reference system frequency changed to 48 Hz. Yellow and Blue shows operation of PWM

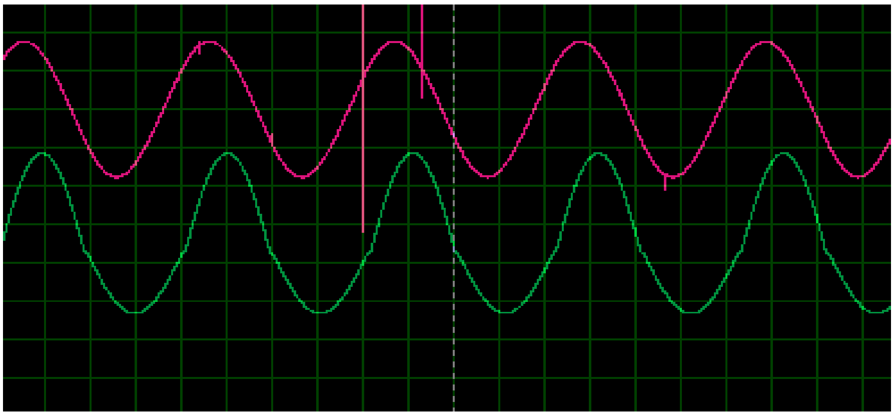


Figure 6: Result at frequency 49.5Hz with Harmonics

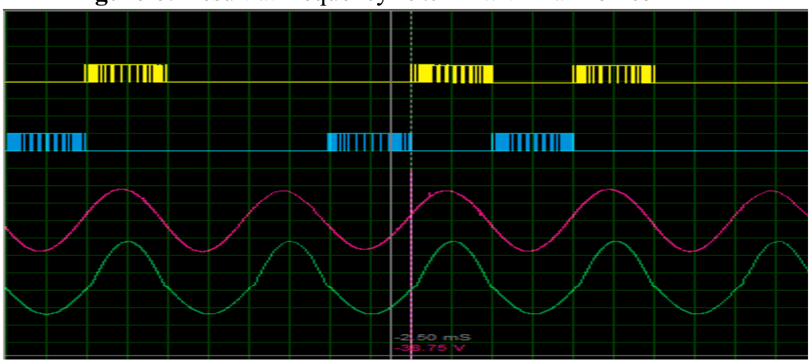
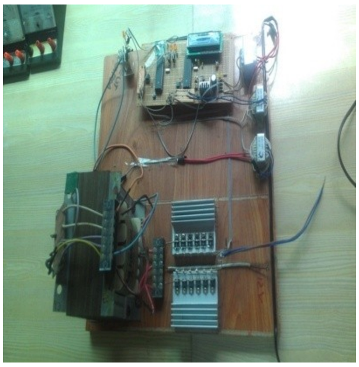


Figure 7: Shows the results when harmonics are eliminated by PWM

VII. Hardware Implementation

In hardware implementation, a sine wave from the reference system is passed through the Optocoupler to detect the Zero-crossing detection. The Optocoupler generates binary digits i.e. 1 and 0 which is fed to the microcontroller as real time information of the reference system. Two types of information are received at microcontroller that are frequency and phase angle. The controller is programmed to lock the frequency and Phase angle of the reference system for the purpose to trigger the inverted system (MOSFET) in real time. The pulse width modulation (PWM) is used to control the triggering of the inverter gate. The purpose of inverter is to convert the DC power to AC power. At this stage, the frequency and phase angle are synchronized but still the third parameter i.e. voltage has to be synchronized. For this purpose, step-up tape changer transformer is used to step-up the low voltage arriving from inverter. The RC low-pass filter is used at the transformer's output to remove ripples and acquired pure sine wave for best synchronization. The voltage and frequency of both systems can be monitored on LCD display. It has been observed from the monitoring LCD that synchronization of parameters has been achieved and system is now capable to connect to the load. In case voltage is out of phase, an additional functionality in the system has been added. Two potentiometers have been used to change the voltage manually. The hardware picture of the proposed system is shown below in [Figure 8];



VIII. Conclusion

Synchronization of the photo-voltaic system with a grid represents real time monitoring of the both system and used to share the load of the distributed system. Simulation results Clearly describe the operation of the systems. It shows that harmonics produced due to disturbance are reduced to such an extent that the effective results of the systems are achieved. In all over the world energy crises increases due to population growth and other economic and political reasons. The generation of power through PV system is more economical, easy and reliable because sun light is available. We have used this power as a backup source and also used in case when demand of power increases. Such system can easily solve or reduce the problem. The function has less started time when compared to other generating systems i.e. it takes micro seconds to synchronize with the reference system to manage the load.

References

[1] M.A.S Masoum, H. Dehbonei and E.F. Fuchs, "Theoretical and Experimental Analyses of Photovoltaic System with Voltage- and Current-Based Maximum Power-Paint Tracking,'' IEEE Trans. Energy Conversion, Vol.

[2] Z. Yishu, et al., "The circuit topology for single-phase Grid connected system and the control technology on converters, International Conference on Sustainable Power Generation and Supply, SUPERGEN '09, 2009, pp. 1-5.

[3] F. Blaabjerg, R. Teodorescu, M. Liserre, A. V. Timbus Overview of control and grid synchronization for distributed power generation systems, IEEE Trans. On Ind. Electronics, vol.53, pp. 1398-1409, Oct.2006.

[4] P. W. Sauer, M. A. Pai, Power Systems Dynamics and Stability, Pren-tice-Hall, 1998.

[5] J.svensson, "synchronization methods for grid connected voltage source converters", IEE proceedings Generations, Transmission and Distribution, vol. 148, N^0 3s, pp.229-235 May 2001.

[6] R. Weidenbrug, F.P. Dawson, and R. Bonert, "New synchronization method for Thyristor power converters connected to weak AC system" , IEEE Trans. On Industrial Electronics, vol. 40, N^0 5, pp.505-511, Oct 1993.

[7] TMS320F/C240 DSP Controllers Reference Guide: Peripheral Library and Specgc Devices, Texas Instruments Incorporated.1999.17, No. 4, pp 514-522, Dec. 2002.