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DESIGN OF SOLAR POWERED INDUCTION MOTOR DRIVE FOR PUMPING APPLICATION

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Abstract- Nowadays people are chasing alternate energy sources due to the paucity of non-renewable energy sources. Because of which they are moving towards renewable energy sources. Renewable Energy is used to give energy in following areas: electricity generation, air, and water heating or cooling and transportation. This paper presents the efficient use of solar energy by operating Photovoltaic (PV) panels at the maximum power point (MPP) for powering the water pump. Such mechanisms are very useful where other sources such as grid power supply and other renewable sources are not easily available. These pumps are more economical due to less maintenance cost and operation. The main components of solar-powered pump system are the solar panel, control board, and pump set. The proposed system implemented the application to give power from solar energy to pump with the help of induction motor drive by converting the DC electric power generated from a PV panel to AC power using the inverter. In the proposed work solar panel of 2.4 kW, power generating capacity is used. Induction motor used is of 3 HP power rating. Three control strategies are used in this work namely SPWM, V/F, and MPPT. The control techniques are implemented by using the DS processor. The Induction Motor is working satisfactorily with the proposed design.
Keywords – Solar powered pump, photo-voltaic (PV) panels, renewable energy, induction motor, inverter, MPPT, V/F.

1. INTRODUCTION

In 2011, International Energy Agency asserted that technologies related to the solar energy will have the huge impact on its longer-term benefits which is widely spread all over the globe because it is clean, inexhaustible, independent resource and its development is affordable as it is climate friendly thus it is advantageous for mankind [1]. Photovoltaic pumps have experienced considerable attention in solar energy technologies. A number of PV pumps use DC motor in several parts of the world [2].

There are many advantages of Photovoltaic (PV) technology as described in various literature [3]-[6]. The advantages of sun oriented PV frameworks are: it retains the steadily enduring sun-powered vitality at free of cost, eco-accommodating without creating any sort of contamination in the environment, and offers commotion less operation and low support when contrasted and the other non-ordinary vitality sources.

The sun-powered PV course of action straightforwardly changes over the sun vitality into DC electric power. The generated DC electric power is then changed over to the required frame utilizing the power molding methods. The power molding unit incorporates converter or inverter as indicated by the application.

The usage of solar pumps has increased due to the subsidy provided by the government. The sponsorship by government diminished the cost of photovoltaic solar panels. For improvement in the performance of solar pumps, various techniques were tried in past. The techniques used were electrical array reconfiguration. The controller utilized gives a streamlined approach by giving an extensive variety of irradiance level for delivering adequate current to begin the pump [7].

Previously the PV fed DC motors was used for the pumping application. The control techniques are quite easy for the DC motors. By utilizing the most extreme power point track the greatest power can be achieved from the PV panels [8].

But induction motor is now replacing the DC motor as it has got several advantages over DC motor like DC motors endure from upkeep problem, due to the nearness of commutator and brushes, and are less reliable.

Here the application is to give power to induction motor drive this is done by converting the DC electric power generated from the PV panels to AC power using the inverter. The output power taken from the inverter is given to the induction motor for operating the pump. This is always desired that the PV panels work at the maximum power point(MPP) which gives the option to use the PV power efficiently [9][10].

The voltage source inverter (VSI) is utilized for control preparing applications, for example, AC motor drives, static compensator, and dynamic front end converter. In AC motor drives application, variable voltage and variable recurrence are required to control the speed of the motor.

The voltage source inverter (VSI) is used for power processing applications such as AC motor drives, static compensator, and active front end converter. In AC motor drives application, variable voltage and variable frequency are required to govern the speed of the motor.

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The voltage fed inverter has a fixed DC link voltage. The PWM waveforms for a VSI can be created by contrasting three-stage adjusting signals and a typical triangular bearer (triangle-examination strategy)[11]-[14]. Alternatively, the PWM generation could be based on the space vector approach.

The modulation index (m) here is the proportion of the major voltage delivered to the central voltage relating to six-stage operation for a given dc transport voltage, i.e

$$m = \frac{v_p}{v_{sixstep}} \quad (1)$$

Where V_p is the peak value of phase fundamental voltage which is given to the load, Vsixstep = (2Vdc/π) is the peak value of phase fundamental voltage during six-step operation, and V_{dc} is the bus voltage. The maximum possible 'm' with sine-triangle PWM (SPWM) is 0.785. With space vector PWM, linear modulation gets extended upto m = 0.907. Beyond m = 0.785 (in sine-triangle PWM) or m = 0.907 (in space vector PWM) the inverter should be worked in an over-modulation locale. Over-modulation increases the maximum possible modulation index (m) to 1 (six-step operation). In triangle-comparison-based methods such as sine-triangle PWM, the amplitude of the modulating sinusoids can be increased beyond the peak value of carrier for operation in the over-modulation region [14]-[16].

2. LITERATURE SURVEY

A valuable amount of research has been done on solar energy, speed control of induction motor, pumping applications etc. Some of the closely related work has been discussed in this section.

2.1 Effect of Dead-Time on Performance of Inverter–

The paper proposed by N Urasaki et al. [17], explains the effect of dead-time on the performance of the inverter. In this paper method to compensate the dead time for induction motor drives is explained. The amplitude of the dead time compensation voltage is estimated on-line from the disturbance voltage due to non-ideal inverter affects. The experimental results indicate that the adaptive DTCV reduces error between the calculated and actual power.

The work proposed by Seung-Gi Jeong and Min-Ho Park [18], focuses on the compensation of dead-time effects in PWM Inverters. To avoid short-circuit in the dc link a time delay is provided in switching signals of inverters. This time delay results in the dead-time effect, which is harmful to the performance of inverters. In this paper dead time effects in pulse width modulated (PWM) inverters are covered. Dead time effect results in an increase in the low-order harmonics in output voltage of the inverter and decrease of the fundamental component. There are two methods to compensate the dead time effect which are useful for memory-based PWM and sinusoidal PWM are explained here. The experimental results show the witness of the analysis and the usefulness of the compensation methods.

2.2 V/F Control and MPPT–

The paper presented by Ramulu Chinthamalla et al. [10], in 2016 suggested a single-stage solution for PV array fed three-phase induction motor (IM) drive based water pumping system. The given solution uses two two-level cascaded H-bridge inverters to give three level voltage output to the IM pump drive which is tested. The system proposed in this paper is operated using the control strategy which includes Maximum Power Point Tracking (MPPT), Space Vector Pulse Width Modulation (SVPWM) and V/f control. The MPPT algorithm generates the modulation index 'm_a' which is used to operate the cascaded inverter and generates three-level output voltage under all environmental conditions. The updated value of modulation index helps in improving the THD of IM phase current, thereby reducing the torque ripple. In addition, the modulation index value is used to define operating frequency of induction motor. This helps in further improvement in the IM performance. In addition, the comparison of the proposed solution with the conventional system i.e., two-level inverter connected PV pumping system is presented in this paper.

The research done by N. Rebei et al. [19], in which they explained about the MPPT algorithm. Maximum power point trackers (MPPTs) play an important role in photo-voltaic array (PV) systems because MPPT increases the power output by improving the efficiency of solar photo-voltaic system. As PV arrays have non linear voltage-current characteristic in which maximum power is produced at a unique point thus there is necessity of MPPT algorithm. The solar panel's output power varies with solar irradiance, temperature and load. Different performances of photo-voltaic water pumping unit are presented in this paper. The laboratory of INSAT Tunisia has an installed, prototype of experimental bench to drive the dc-dc boost converter for tracking maximum power point. This paper presents the design and implementation of perturb observe (PO) MPPT algorithm which thereafter feeds a pump through a DC/AC inverter. All components of solar pumping system are matched for better electrical and mechanical performance. The obtained experimental results illustrated by curves are represented and analyzed.

The paper by JVM Caracas et al. [9], proposes a battery-less converter for photovoltaic water pumping application. The design of converter is such that it drives the three-phase induction motor directly from PV energy. For water pumping application the use of three phase induction motor is preferred over the commercial DC motor. Induction motors are more efficient, maintenance free, reliable and cheaper than that of standard DC motors or low voltage synchronous motors. The development of the system is based on the current fed multi-resonant converter also known as resonant two inductor boost converter and a three phase full bridge voltage source inverter. The topology of the two inductor boost converter has features like low input current ripple and high voltage gain. In this paper, it is further improved with the use of a non-isolated recovery snubber along with a hysteresis controller and the use of a constant duty cycle control to improve its efficiency. For dc-dc converter plus three phase VSI the experimental results show a maximum efficiency of 91 percent at a rated power of 210 W and for the only dc to dc converter the maximum efficiency is percent. Due to the in-existence of electrolytic capacitors, it is expected high life time and total cost of the converter is below 0.43 dollar per W_p. As a result, the system is a promising solution to be used in isolated locations and to deliver water to poor communities.

The work done by MS Taha and K. Suresh [20], in which he has written that PV fed inverters are becoming popular for water pumping application in remote areas. The feasibility of these pumps depends on the amount of power extracted from the photovoltaic array. The algorithms for maximum power point tracking and trajectory tracking have been discussed in the literature survey. The MPPT as applicable for the V/F controlled induction motor for driving submersible pump is explained in detail. In MPPT for utilizing the maximum power available under different irradiation conditions, the speed of the motor is varied. Tests are conducted on a 1 HP pump operating from a PV fed inverter to verify the subject.

The paper presented by Bhat et al. [21], “Performance Optimization of Induction Motor-Pump System Using Photo-voltaic Energy Source” describes a photovoltaic pumping system which consists of dc-dc converter, a three phase inverter and induction motor. Here induction motor is used for driving the pump due to its advantages over dc motor as dc motors are less reliable and makes maintenance difficult due to commutator and brushes. This paper presents the technical studies relating the optimized power requirement of induction motor which drives the pump. The induction motor is powered by solar array as input power requirement which depends on load, excitation voltage and frequency which lead to an optimum V/F relationship. If proper choice of motor rating is used then it is easy to make use of maximum power available from solar array. The dc-dc converter is used here as power conditioning unit and its duty cycle is controlled to match load array which is done by microprocessor based system.

The work presented by R. Sridhar et al. [21], in which he has focused on a financially savvy PV powered three-phase induction motor drive which is utilized for pumping application. More often than not, in an independent framework, the sun oriented boards produced power is put away in rechargeable batteries, and then battery set-up will fill in as a hotspot for the inverter. In this paper, a solitary stage battery less power transformation framework is utilized planning most extreme power point tracker (MPPT) installed support converter which reforms the present convention and makes the general cost of the setup to go down significantly. In this paper, a model comprising PV exhibit of 500 Watts, three stage inverter, a three stage squirrel confine enlistment drive of 357 watts and a MPPT included lift converter. For actualizing the unmistakable irritate and watch MPPT calculation a productive and ease DSPIC4011 is utilized as a stage to code. For the control of three-stage VSI sinusoidal heartbeat width adjustment system is employed. For the approval of trial results reenactment of the entire set up is done in Matlab/Simulink. Reproduction and equipment comes about tell that the framework is versatile.

The work carried by Muljadi [22] on “PV Water pumping with a Peak-Power Tracker Using a Simple Six-Step Square-Wave Inverter” describes a photovoltaic (PV) water pumping system which is used for agriculture and in household. This system is highly popular in remote areas as this system uses the application of solar energy which is easily available immensely over the globe. This system consists of PV array, water pump, induction motor, a variable-frequency inverter. The inverter is operated at variable frequency, which takes input from PV array to fed induction motor, to vary the output of pump by generating six-step quasi-square wave. Here inverter acts as peak power tracker too because of the use of six-step square-wave inverter which also reduces the number of switches. The advantage of this system is that in case of short circuit the system is protected as the current is limited to upper limit of PV array current. This system described in this paper does not include battery module which makes the system more efficient as the entire generated power is utilized by pump.

2.3 Field Oriented Control–

The paper by Utkarsh Sharma and Chinmay Jain [24], in which they have explained about field oriented controlled (FOC) three phase induction motor drive (IMD) for water pumping fed by solar PV array. It includes solar PV array, a voltage source inverter (VSI) and a three phase induction motor and submersible pump. The aim is to control the motor in rotor reference frame as well as extract maximum power from the PV array. For the initial start-up of pump soft start feature is used. An adaptive incremental conductance method is used for extracting maximum power. For good estimation of maximum power point (MPP), the tangent of the power versus voltage curve is tracked. The vector control provides smooth startup and reduces the starting current. The system is designed and simulated in MATLAB/Simulink software. Simulated results are demonstrated for validation of the system.

The objective of D Foito et al. [25], paper is to present a centrifugal pump control system driven by a single-phase induction motor (SPIM) that is supplied by a photo-voltaic generator. The study system consists of a PV array, a DC/DC converter, a DC/AC converter and a single-phase AC motor. The DC/DC converter is controlled in order to ensure the maximum power of the PV array. For the maximum power point tracking (MPPT), classical perturb and observe method is used. In order to control the flow of the centrifugal pump a controller based on a diametrical inversion (DI) of the stator voltage is proposed. All the components of the system are implemented, modeled and simulated using the program Matlab/Simulink. The obtained results show the effectiveness and validity of the proposed control system.

3. DESIGN OF PROPOSED SYSTEM

Figure 1 shows the designed system for a 3 HP PV fed water pumping system. It consists of a 3 HP motor coupled to a Pump. The system is designed to be powered from solar PV source. The induction motor is supplied from and three phase voltage fed inverter (VSI). A DC link capacitor is placed to store the energy during the transient conditions such as varying radiation.

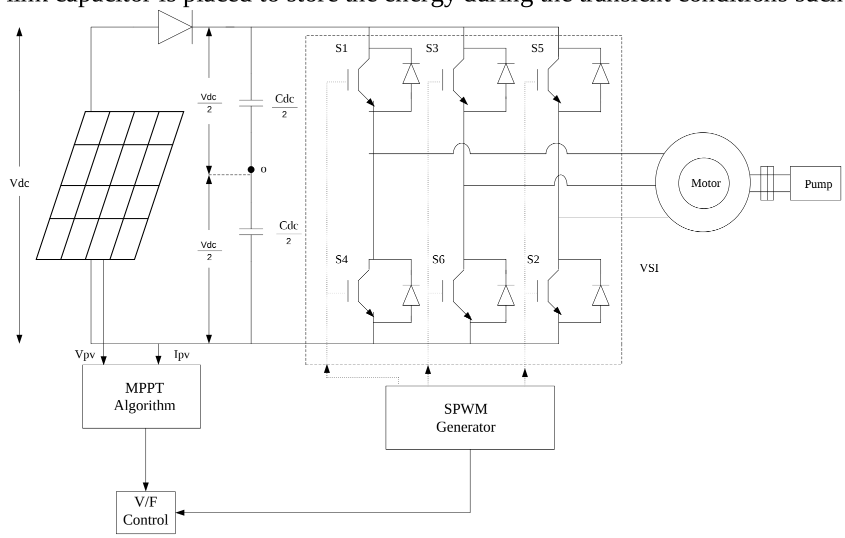

Figure1. Proposed water pumping system fed by PV

The various design parameters calculated in this paper are as follows:

3.1 Solar PV Selection–

The PV array is designed such that it can deliver 2.4 kW peak power taking account of system losses. The extreme power which can be obtained from the system is given as,

$$P_m = (N_2 \times V_m) \times (N_1 \times I_m) \tag{2}$$

$$P_m = (N_2 \times 0.85 \times V_0) \times (N_1 \times 0.85 \times I_s)$$

$$P_m = 2.4kW$$

Where, V_m is module voltage at MPPT, I_m is the module current at MPPT, P_m is the module extreme power at MPPT and N_1 and N_2 are parallel and series connected PV modules. The open circuit voltage of the panel is selected as 400 V, for the purpose of MPPT. The single module's open circuit voltage is V_O = 32.9 V. The single module's short circuit current is I_s = 8.21A. Therefore,

$$V_0 = 12 \times 32.9 = 395V$$

So, by combining 1-module in parallel and 12-modules in series, the PV array of a 2.4 kW capacity can be designed.

3.2 Selection of DC Link Voltage–

The DC bus voltage of Voltage source inverter can be calculated as,

$$V_{dc} = \frac{2\sqrt{2}V_{LL}}{3} \tag{3}$$

$$V_{dc} = 375\ V$$

Therefore, the voltage of DC link is selected as 400 V.

3.3 Design of DC Link Capacitor–

At the time of transients, it is desired that DC link capacitor will provide sufficient energy because at the time of transient there is an increase in the load and fall in radiation. The value of DC link capacitor can be calculated as

$$C_{dc} = \frac{6 \times \alpha \times V \times I_m \times t}{[V_{dc(ref)}^2 - V_{dc1}^2]} \tag{4}$$

$$C_{dc} = \frac{6 \times 1.2 \times 133 \times 8.2 \times 0.005}{[400^2 - 375^2]}$$

$$C_{dc} = 2026\ \mu F$$

Where, $V_{dc(ref)}$ is the reference DC interface voltage of inverter, α is the over-loading component, V_{dc1} is slightest DC transport voltage, I_m is the per stage current of induction motor drive and t is the time span in which voltage decreases to least permissible DC connect voltage. The capacitor value is chosen as 2200 µF.

3.4 Design of Pump–

For a centrifugal water pump, by using affinity law the attributes of the pump can be discovered as,

$$K_p = \frac{T_l}{\omega_r^2} \; N - m/(\frac{r}{s})^2 \tag{5}$$

Where, T_l is the heap torque of water pump, which is equivalent to the torque offered by the induction motor under unfaltering state operation and ω_r is the rotational speed of the rotor in rad/sec. For recreation reason, the appraised torque and evaluated speed of the induction motor are 14.69 N-m and 1430 rpm. At that point proportionality consistent (K_p) is assessed as

$$K_p = \frac{14.69}{(2\pi \times \frac{1430}{60})^2} \; N - m/(\frac{r}{s})^2$$

$$K_p = 6.55 \times 10^{-4} \; N - m/(\frac{r}{s})^2$$

4. CONTROL TECHNIQUES

The proposed framework is a solitary stage framework which comprises of just a single power converter. Here three control techniques are used for Sin-triangle PWM generation, MPPT and V/F (Scalar) control of IM.

4.1 Maximum Power Point Tracking –

Maximum power point tracking is an algorithm which includes in charge controller. To extract maximum power from the PV array under some specific condition this algorithm is used. The voltage point at which PV panel gives maximum power is known as the maximum power point. Most extreme power delivered changes with sun powered radiation, encompassing temperature, and sun based cell temperature. The Maximum power point can be achieved by reducing the frequency in the current source region and by raising the frequency in the voltage source region. A single stage system is proposed which comprises of the single power converter. In the proposed work two algorithms are implemented for Maximum Power Point Tracking (MPPT) and Open loop Scalar or V/F control of induction motor. The method which is used in the proposed system for implementing the MPPT algorithm is Adaptive Incremental Conductance (AINC) [19][24].

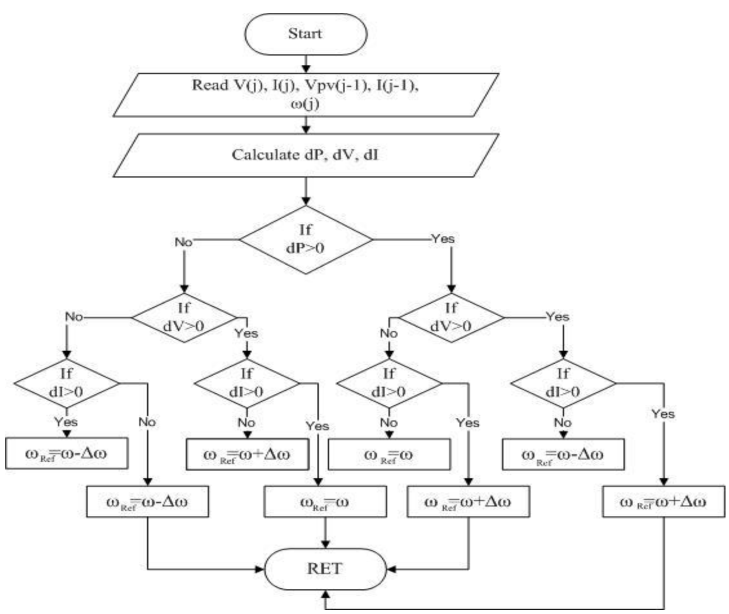

Figure2. Flow Chart of MPPT Algorithm

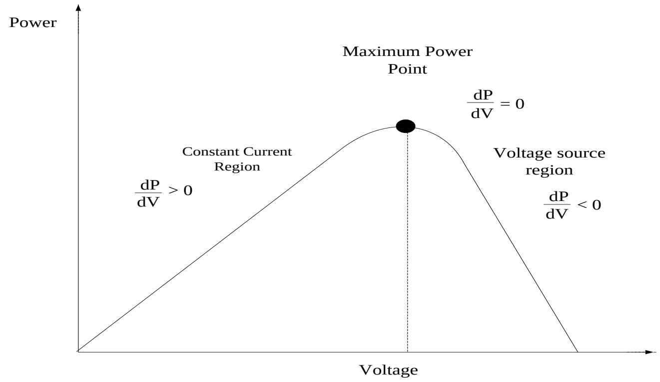

Figure.3 AINC approach using the slope of P-V curve

The power versus voltage characteristics of the PV array is non-linear. There are various methods available for MPPT but the simplest method is Perturb and Observe mechanism. In Perturb and Observe method of maximum power point tracking the reference quantity which is either voltage or frequency is disturbed until the increment in power is seen. Perturbation suffers from the inefficient performance at maximum power point due to the continuous disturbance and power losses associated with it.

4.2 Pulse Width Modulation–

In sine-triangle PWM [11][12], 3-ϕ sinusoidal modulating signals are compared with a triangular carrier of high frequency to get the 3-ϕ PWM waveforms. The 3-ϕ adjusting signals are given by

$$MI_r = V_m Sin(\omega t) \tag{6}$$

$$MI_y = V_m Sin\left(\omega t - \frac{2\pi}{3}\right) \tag{7}$$

$$MI_b = V_m Sin\left(\omega t - \frac{4\pi}{3}\right) \tag{8}$$

By controlling the modulating signal, magnitude and frequency of the line side voltage can be controlled. As long as the peak of the modulating signal is less than or equal to the peak of the carrier, the operation is in linear region. Whenever peak of the modulating signal is higher than carrier, the operation is in non-linear region. This non-linear region of operation is called over-modulation region.

4.3 Open Loop Scalar Control–

For controlling Induction Motor by V/F control, the speed is controlled by calibrating the greatness of stator voltages and frequency such that at unfaltering state the normal estimation of flux is constant. This plan is otherwise called the scalar control since it just offers significance to the consistent state dynamic. The voltage of the Induction Motor can be controlled to control the flux and frequency or slip can be controlled to control the torque. In any case, flux and torque are additionally the elements of frequency and voltage separately. Scalar controlled drives are anything but difficult to actualize and are broadly utilized as a part of the business. There are two scalar control procedures voltage fed and current fed inverter systems.

The open loop scalar control otherwise called V/F control is the most famous technique for speed control on account of its straightforwardness and simple to execute. Most commonly the induction motors are used with open loop at 50/60 Hz power supplies for the constant speed applications. For variable speed applications, controlling of frequency is common however voltage is required to be corresponding to frequency with the end goal that the flux stays steady. The power circuit consists of converter or three phase AC supply, filter and PWM voltage fed inverter.

5. IMPLEMENTATION

The line to line voltage rating of the induction motor is 415 V and rated frequency is 50Hz. So, the V/F ratio will be,

$$V_{ph} = 239.6\ V$$

Therefore, the phase voltage of Induction motor is 239.6 V.

$$F_r = 50\ Hz$$

Hence, the V/F ratio will be,

$$\frac{V}{F_r} = 4.792 \tag{9}$$

In V/F control of the induction motor this ratio of V/F is always to be maintained constant. V/F ratio for the proposed system is 4.792.

Here, V_{dc} is the DC voltage generated from the PV array and C_{dc} is the total DC link voltage which is connected in series as half of its total value. V_{Ph} is the phase voltage of the induction motor and V_L is the line to line voltage of the induction motor.

If voltage generated by solar panel is 100 V (i.e $V_{dc)}$ then for sinusoidal pulse width modulation,

$$V_{peak-ph1} = \frac{V_m}{V_p} \times \frac{V_{dc}}{2} \tag{10}$$

Where, ratio of V_m and V_p is the modulation index (MI) and this is 1 always.

$$V_{peak-ph1} = 1 \times \frac{100}{2}$$

$$V_{peak-ph1} = 50V$$

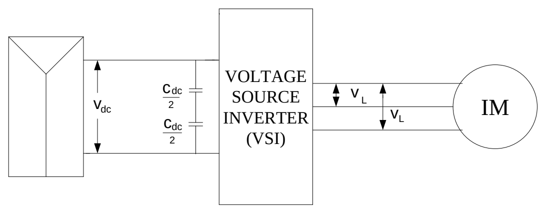

Figure.4 PV fed VSI induction Motor Drive

Hence, peak phase voltage is 50 V. Therefore the RMS voltage per phase will be calculated as,

$$V_{RMS-ph1} = 35.35\ V$$

Now, from V/F ratio the frequency at which the induction motor is operating at 100 V DC link voltage.

$$\frac{35.35}{f} = 4.792$$

$$f = 7.37\ Hz$$

From this it can be concluded that the frequency will vary according to the variation in DC link voltage. At 100 V DC link voltage the motor is operating at 7.37 Hz frequency. So, this can be concluded that the V/F ratio is maintained constant.

All the implementation is done with the help of the DS processor. DS processor senses the voltage and current of motor and PV panel through voltage sensor. After reading the ADC channel the PV voltage and PV current are used for MPPT implementation. Once the code for MPPT is implemented, after this the PWM pulses are generated such that sinusoidal voltage is obtained from the inverter output. The switching of IGBT is responsible for the sinusoidal voltage. Here, sin triangle PWM technique is used. Code is written for the implementation of the control techniques.

6. EXPERIMENTATION AND RESULTS

For the experimentation Chroma Solar Simulator, Induction Motor, TMS320F28377S DS processor and Tektronics DSO is used. For loading purpose PMSM generator loaded with load bank is used. Along with these equipments prepared hardware works in co-ordination. The Induction motor used is a three-phase star connected 3HP, 2-pole, 415 Volt, 50Hz and 0.79 pf. The TMS320F28377S is a 32-bit floating point processor having 200MHz clock. The DS processor used have 12-bit ADC channel. The Tektronics MDO03014 DSO is a mixed domain oscilloscope it is 100MHz bandwidth and 2.5GS/s sampling rate. Figure.5 shows the experimentation set up of the work.

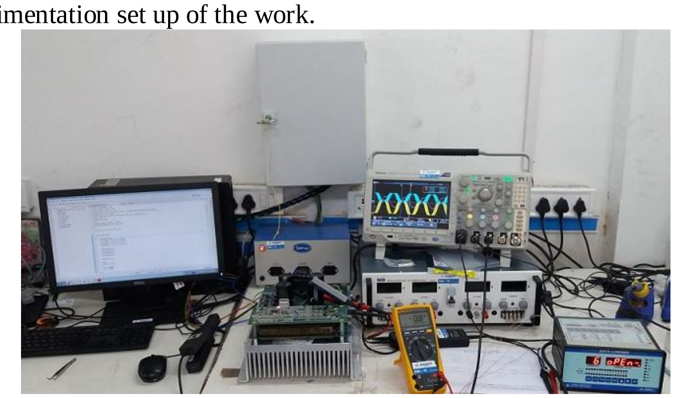

Figure 5. Experimentation Set-Up

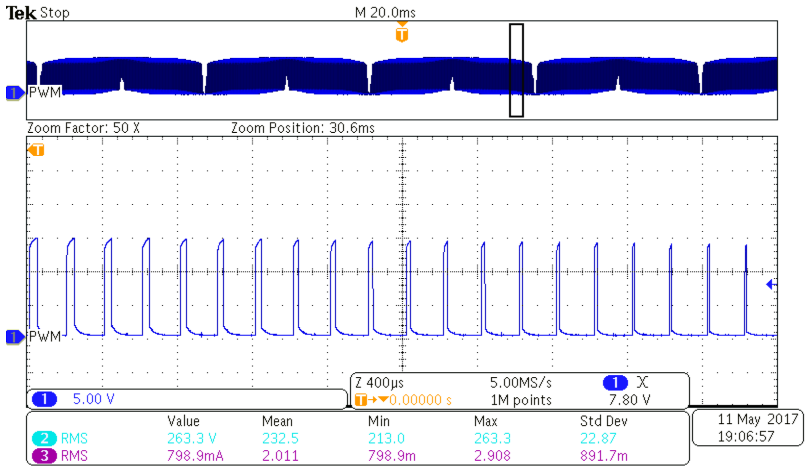

Figure 6. PWM Pulses

Figure.6 showing the PWM pulses obtained. These PWM pulse provides the switching pattern for the Voltage Source Inverter's IGBT switches. Six different switches are there in the VSI which are needed to be triggered such that the sinusoidal voltage and current can be taken as output from the Voltage Source Inverter. So, there will be PWM pulses of the same type as shown in figure for triggering purpose.

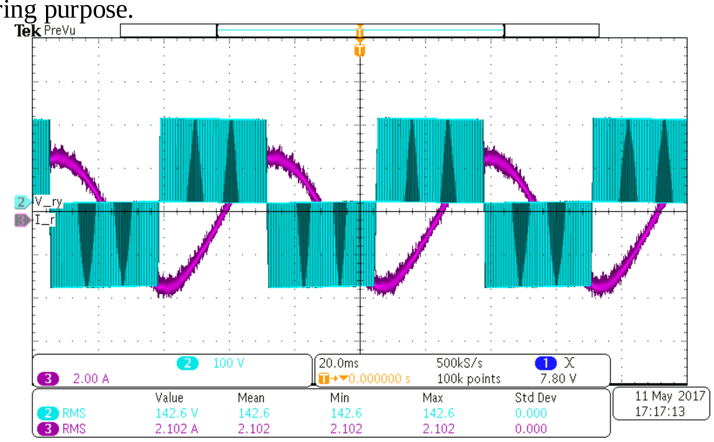

Figure7. Result Obtained at 200V DC link on No Load

Figure.7 shows the output phase voltage and phase current of the motor. The result is captured at DC link voltage equals to 200 V and Load Current equals to 2 A and motor load power is 140 W. The result captured is V_{ry} line voltage of RY and I_r phase current of R-phase. The citation is given in the snapshot of results.

For 200 V DC link Voltage;

$$V_{peak-ph1} = 100\ V$$

Hence, peak phase voltage is 100 V. Therefore the RMS voltage per phase will be calculated as,

$$V_{RMS-ph1} = 70.7\ \ V$$

$$V_{RMS-LL} = 122.47\ \ V$$

From equation (9)

$$\frac{70.7}{f} = 4.792$$

$$f = 14.75\ Hz$$

Hence, the motor will be running at 14.75 Hz frequency.

Now, speed of induction motor in RPM will be;

$$N = \frac{120 \times f}{P} \tag{11}$$

Where, P is the no. of poles which is 2 for this case.

$$N = 885.3\ RPM$$

Angular speed of motor will be;

$$\omega = 2\pi f$$

$$\omega = 92.70\ rad/sec$$

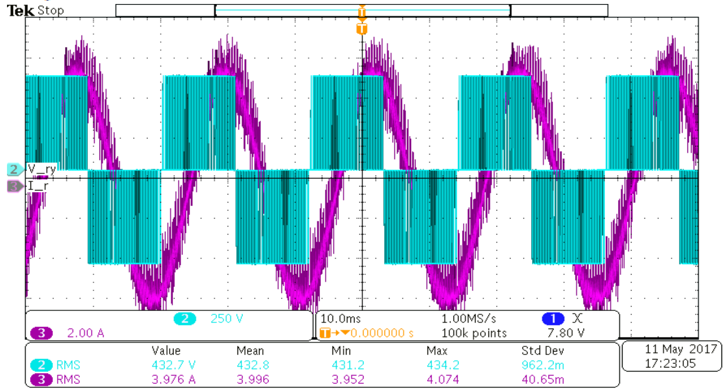

Figure8. Result at 2kW load at 500V DC link Voltage

Figure.8 shows the output phase voltage and phase current of the motor. The result is captured at DC link voltage equals to 500 V and Load Current equals to 3.7 Amp and motor load power is 2 kW. The result captured is V_{ry} line voltage of RY and I_r phase current of R-phase. The citation is given in the snapshot of results.

For 500 V DC link Voltage;

$$V_{peak-ph1} = 250\ V$$

Hence, peak phase voltage is 100 V. Therefore the RMS voltage per phase will be calculated as,

$$V_{RMSPh1} = 176.80\ V$$

$$V_{RMSLL} = 306.2\ V$$

From equation (9):

$$\frac{176.80}{f} = 4.792$$

$$f = 36.89\ Hz$$

Hence, the motor will be running at 36.89 Hz frequency.

Now, speed of induction motor in RPM will be;

$$N = \frac{120 \times f}{P}$$

$$N = 2213.4\ RPM$$

Angular speed of motor will be;

$$\omega = 231.79\ rad/sec$$

The motor is rotating at 2213.4 RPM.

7. CONCLUSION

The PV powered Induction Motor drive can be utilized to drive the pump. This drive utilizes VSI inverter for changing over the DC voltage obtained from the PV array to the sinusoidal AC voltage which is acquired by operating the IGBT switches specifically designed with the assistance of PWM pulses produced with help of Sine-triangle PWM system. To get the maximum power from the PV array the Adaptive Incremental Conductance approach is utilized for actualizing the MPPT calculation. For the better operation of the IM V/F control procedure is likewise executed. From this work, it can be concluded that for rural zones where there is no power, there for satisfying the demand of water for irrigation and general use the PV supplied water pumping framework can be introduced. The PV fed water pumping system with the control techniques discussed in this paper can be considered as an efficient system.

8. REFERENCES

[1] Solar energy perspective: Executive summary. International Energy Agency, 2001.

[2] Small scale solar powered irrigation pumping system: Technical and economic review. Worldbank UNDP Project [GLO-78-004] Report, September 1981.

[3] J. Philip, C. Jain and K. Kant "Control and implementation of a standalone solar photo-voltaic hybrid system", IEEE Transactions on Industrial Electronics, Vol. 52, No. 4, pp. 3472–3479, July-August 2016.

[4] Dylan Dah-Chuan Lu Le An, "Design of a single switch dc/dc converter for a PV powered pump system with pfm+pwm control.'' IEEE Transaction on Industrial Electronics 62(2): 910-921, Feb 2015.

[5] Ramulu Chinthamalla, Olorunfemi Ojo, Sanjeevikumar Padmanban, Ahmet H Ertas, and Sachin Jain, "Dual mppt algorithm for dual PV source fed open-end winding induction motor drive for pumping application.'' International Journal of Engineering Science & Technology, Elsevier Publication, July 2016.

[6] V. Ferno Pires, J.F. Martins, D. Foito, and Chen Ho, “A grid connected photovoltaic system with a multilevel inverter and le-blanc transformer.” International Journal Renewable Energy Res., 2(1), 2012.
[7] Ziyad M. Salameh and Fouad Dagher, “The effect of electrical array reconfiguration water pump on the performance of a PV powered volumetric.” IEEE Transaction on Energy Conservation, 5(4):653-658, December 1990.
[8] Y.R. Hsiao and B.A. Blevensr, “Direct coupling of photovoltaic power source to water pumping system.” Solar Energy, 32(4):489-498, December 1984.
[9] JVM Caracus, Guilherme de Carvalho Freitas, Luis Felipe Moreira Teixeira, and Luiz Antonio de Souza Ribeiro, “Implementation of a high efficiency, high life-time and low cost converter for an autonomous photovoltaic water pumping system.” IEEE Transaction on Insustrial Applications, 50(1):631-641, February 2014.
[10] Ramulu Chinthamalla, Sanjeevikumar Padmanaban, Ramsha Karampuri, Sachin Jain, Ahmet H. Ertas, and Viliam Fedak, “A solar PV water pumping solution using a three level cascaded inverter connected inverter motor drive.” Engineering Science and Technology, an International Journal , 19:1731-1741, December 2016.
[11] J. Holtz, “Pulse width modulation – a survey .” IEEE Transaction on Industrial Electronics, 39(5):410-420, December 1992.
[12] J. Holtz, “ Pulse width modulation for electronic power conversion.” Proceedings of IEEE, 82(8):1194-1214, August 1994.
[13] G. Narayanan, “Synchronized pulse width modulation strategies based on space vector appraoch for induction motor drives.” Ph.D Thesis, Department of Electrical Engineering , Indian Institute of Science, Bangalore, August 1999.
[14] Venugopal S., “Study on overmodulation methods for pwm inverter fed ac drives.” M.Sc. Thesis, Department of Electrical Engineering, Indian Institute of Science, Bangalore, May 2006.
[15] Vikram Kaura, “ A new method to linearize any triangle comparisonbased pwm by reshaping the modulation command.” IEEE Transaction on Industry Applications, 33(5):1254-1259, October 1997.
[16] R.J. Kerkman, Timothy M. Rowan, David Leggate, and Brain J. Seibel, “ Control of pwm voltage inverter in the pulse dropping region.” IEEE Transaction on Power Electronics, 10:559-565, September 2006.
[17] Naomitsu Urasaki, Tomonobu Senjyu, Katsumi Uezato, and Toshihisa Funabashi, “On line dead time compensation method for voltage sourse inverter fed motor drives.” Applied Power Electronics Conference and Exposition, 3:122-127, February 2004.
[18] Seung-Gi Jeong and Min-Ho Park, “The analysis and compensation of dead time effects in pwm inverters.” IEEE Transaction on Industrial Electronics, 38(2):108-114, April 1991.
[19] N. Rebei, Rabiaa Gammoudi, Ali Hmidet, and Othman Hasnaoui, “Experimental implementation techniques of p&o mppt algorithm for pv pumping system.” IEEE 11th International Multi- Conference on Signal Systems & Devices, May 2014.
[20] MS Taha, “ Maximum power point tracking inverter for photovoltaic source pumping applications.” Proceedings of IEEE, pp:883-886, January 1996.
[21] S.R. Bhat, Andre Pittet, and B.S. Sonde, “Performance optimization of induction motor pump system using photovoltaic energy source.” IEEE Transaction on Industry Applications, IA-23(6):995-1000, November 1987.
[22] R. Sridhar, K.C. Jayasankar, D.V.S. Aditya, and G. Vinod Kumar, “Photovoltaic (pv) fed three phase induction motor drive for rural pumping applications based on single stage power conversion.” International Journal of Control and Automation, 5:135-142, 2015.
[23] Eduard Muljadi, “PV water pumping with a peak –power tracker using a simple six-step square wave inverter.” IEEE Transaction on Industry Applications, 33(3):714-721, May/June 1997.
[24] Utkarsh Sharma and Chinmay Jain, “Single Stage Solar PV array fed field oriented controlled induction motor drive for water pump.” National Power Electronics Conference, December 2015.
[25] M. Guerreiro, D. Foito, and V. Fernao Pires, “Single phase induction motor controller for photovoltaic powered water pump.” International Power Electronics and Motion Control Conference and Exposition, pp:622-627, September 2014.