Modelling And Analysis of Solar Powered Induction Motor Drive

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Abstract- *With the constant increase in demand of energy, the non-renewable energy sources are depleting at fast pace. So, the renewable energy sources like solar, wind, hydro etc. are needed to be upgraded for proper utilization. Nowadays, the photovoltaic (PV) energy system is widely used. As Induction Motor is the most used machine in industrial application. In this paper, the Simulink models show the behavior of solar power fed 3-phase, 5.4HP, 4kW squirrel cage induction motor with and without V/f control. A PV array connected with Boost-Converter and 3-phase inverter is simulated. Three control techniques are used in the simulation i.e., MPPT, SPWM and V/f control. The results related to PV array and induction motor has been discussed.*

Keywords- PV panel, Squirrel cage induction motor, MPPT, SPWM, V/f.

I. INTRODUCTION

The non-renewable energy sources are depleting at a very high pace due to our constantly increasing energy demand. So, to fulfill our future energy demand we need to have new and efficient ways of energy production. Here, renewable energy sources like solar, wind, tidal etc. comes into the picture. As these are sources are in abundance.at least 30 nations around the world already have renewable energy contributing more than 20 percent of their energy supply.[1]
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.[2] The recent upsurge in the demand of PV systems is due to the fact that they produce electric power without hampering the environment by directly converting the solar radiation into electric power. India ranked 3rd in the renewable energy country attractiveness index released by Ernst & Young Global with an addition of 39GW solar energy capacity in 2020.

A MPPT is effective DC to DC converter which is used to maximise the output power of a solar panel. The first MPPT was invented by an Australian company called AERL in 1985, and this technology is now used in nearly every solar application.The MPPT is designed to continually track and adjust the voltage so that the maximum power output can be attained no matter what time of day or weather condition it is.
Three phase induction motors are the most widely used for industrial control and automation. They are often called the workhorse of the motion industries due to their robustness, reliability, less maintenance and of high durability.[3]For adjustable speed applications, the induction machine, particularly the cage rotor type, is most commonly used in industry. These machines are very cheap and rugged, and are available from fractional horsepower to multi-megawatt capacity.Previously the PV fed DC motors was used for the pumping applications. 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.[4] But nowadays, induction motor is replacing the DC motor in most conditions as it has more advantages. As DC motor needs more maintenance to commutator and brushes and are less reliable.

Indeed, with the advent of advancement in manufacturing & designing, AC drives are overshadowing the DC drives because of their better performance and reliability. The most important advantages of AC drives over DC drives are faster predictable dynamic response, constant and better Power Factor (PF).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.[5]

Here, sinusoidal PWM is adopted in this paper as PWM control technique. Behavior of motor is observed. Then another circuit is made in which V/f control is applied so to get the speed equal to the reference speed. The induction motor drive can be controlled by using V/f control and Proportional-Integral (PI) controller to obtain the better performance.

II. LITERATURE SURVEY

A valuable amount of work has been done on solar energy, speed control of induction motor, MPPT etc. Some of these works are discussed here:

In the work proposed by Seung-Gi Jeong and Min-Ho Park,[6] explains the effect of the dead time on the performance of the inverter. It also focuses on the compensation of dead time effect in PWM inverters. To avoid short circuit in inverter circuit a small switching time delay is provided i.e., dead time. It is harmful for the performance of inverters. This paper also shows the methods to compensate this. In the research paper by N. Rebei et al,[7] explained about the MPPT algorithm. It explains that PV array has a non-linear voltage-current characteristics in which maximum power is produced at a unique point thus MPPT algorithm is used to find that point. This paper also presents the Perturb & observe (P&O) MPPT algorithm. Pabitra Kumar Behera, et. Al 2014[8],presents a research paper which shows the design and implementation of scalar control of Induction motor. In this method, the speed of the motor can be controlled by V/f control i.e., Controlling the stator voltage and frequency. It also presents the comparative analysis of open and closed loop V/f control.

In the research paper by Devraj Jee, Nikhil Patel [9]presents the need for the speed control in induction motor. It shows the implementation of V/f control and it is most versatile. PWM Inverters have been modelled and their output is fed to induction motor. The uncontrolled transients and steady state response of induction motor have been analyzed. Riya Elizabeth Jose, Maheshwari K. 2015[10] in their research paper proposed that by controlling V/f ratio the magnetizing flux remains constant so that maximum torque remains unchanged. PWM based firing of inverter provides the best constant V/f control. Among the PWM techniques, sinusoidal PWM is good enough and most popular. That's why the V/f control is used for the Induction motor. As it controls the magnitude of voltage and frequency instead of phase and magnitude of currents. It is low performance but it is a stable control technique.

III. EQUIVALENT CIRUIT DIAGRAM OF INDUCTION MOTOR

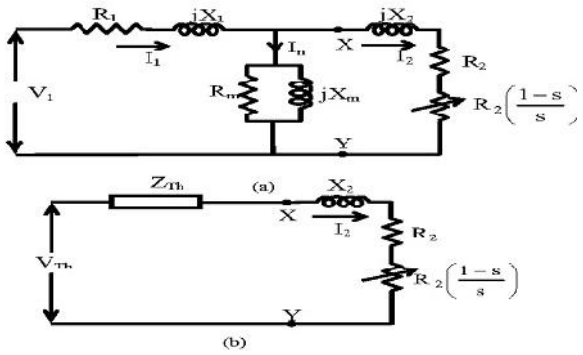

Fig 1: *Equivalent circuit diagram of induction motor to stator side*

Slip is given as:

$$S = \frac{sync.\ speed - rotor\ speed}{sync.speed}$$

The equation of Torque is:

$$T = \frac{sE_2^2R_2}{R_2^2+(sX_2)^2}$$

The torque will be maximum when slip=R_2/X_2

Substituting slip value on torque equation we get:

$$T = \frac{kE_2^2}{2X_2}$$

IV. CONTROL TECHNIQUES

a) Maximum power point tracker (MPPT):

It is an electronic DC to DC converter which is to extract maximum output power form solar panels. The voltage current curve is non-linear and power delivered by solar panel changes with irradiation and temperature of the cell. So single stage system is proposed. MPPT take DC input from the solar panels, change it to high frequency AC and then convert it back down to a different DC voltage and current. Recently, digital MPPT controller are available that are microprocessor controlled. The method used in this proposed system for implementation of MPPT algorithm is Adaptive Incremental Conductance (AINC).

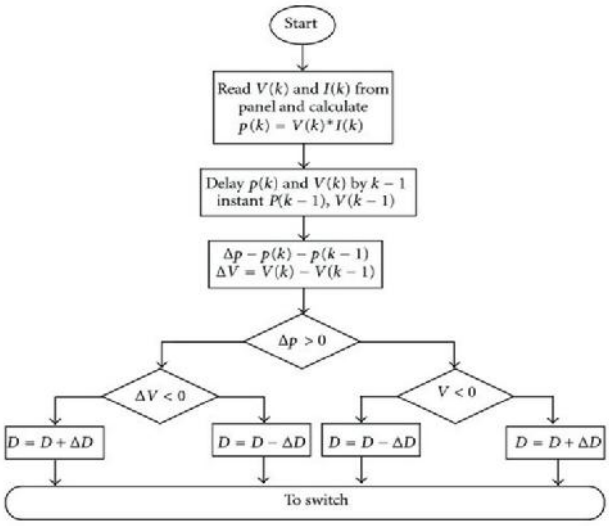

Fig 2: *Flow chart of MPPT algorithm*

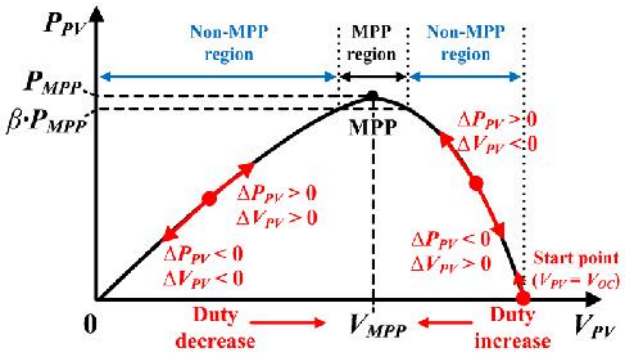

Fig 3: *AINC approach using slope of P-V curve*

In P&O approach of MPPT the voltage is disturbed until there is a change in power value.

b) Pulse width modulation:

Here sinusoidal pulse width modulation technique is used.Sinusoidal PWM is a typical PWM technique. In this PWM technique, the sinusoidal AC voltage reference v_{ref} is compared with the high-frequency triangular carrier wave v_c in real time to determine switching states for each pole in the inverter.[11] After comparing, the switching states for each pole can be determined based on the following rule:

•Voltage reference v_{ref}>Triangular carrier v_c: upper switch is turned on (pole voltage=Vdc/2)
•Voltage reference v_{ref}<Triangular carrier v_c: lower switch is turned on (pole voltage=−Vdc/2)

c) V/f control:

V/f control is a scalar control system. Scalar control (frequency control) is a control technique of AC motor, which is to keep the voltage/frequency ratio (V/Hz) constant throughout the full operating speed range, with control only the magnitude and frequency of the supply voltage.As the speed increases, the stator supply voltage must also increase proportionally. However, the synchronous speed (frequency) of the induction motor is not equal to the rotation speed (frequency) of the shaft, and the slip of the induction motor depends on the load. Thus, the controller with scalar control without feedback cannot accurately control the speed when there is a load. To solve this problem, speed feedback and, therefore, slip compensation can be added to the control system.[12]

V. SIMULATION AND RESULTS

Fig. (4) shows the MATLAB model of solar energy fed to 5.4HP squirrel cage induction motor. It is an open circuit model i.e., no feedback loop. The system is designed such that solar panel is followed by boost converter and controlled by MPPT then the energy is provided to PWM inverter which then goes to induction motor.

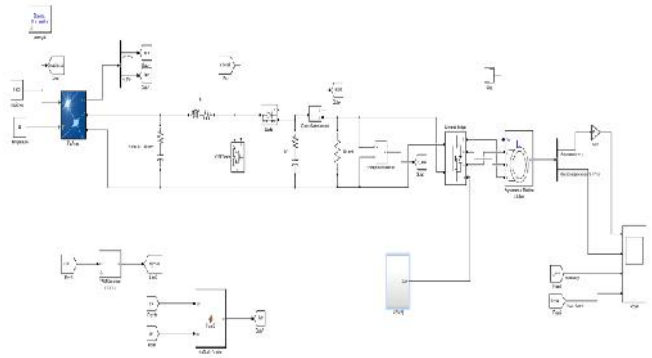

Fig 4: *MATALAB model of open loop solar powered induction motor*

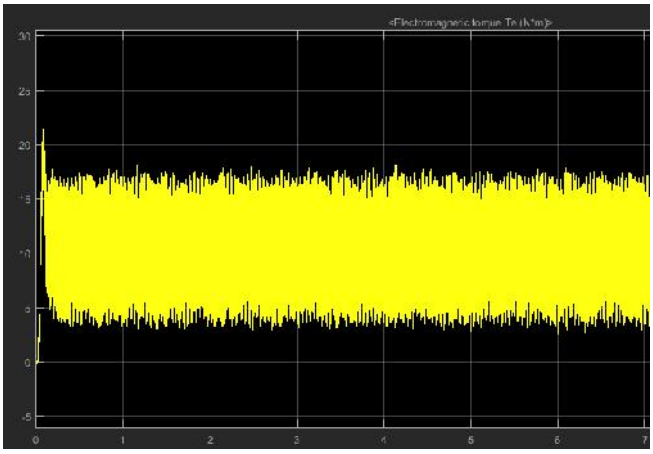

Fig 5: *Electromagnetic Torque*

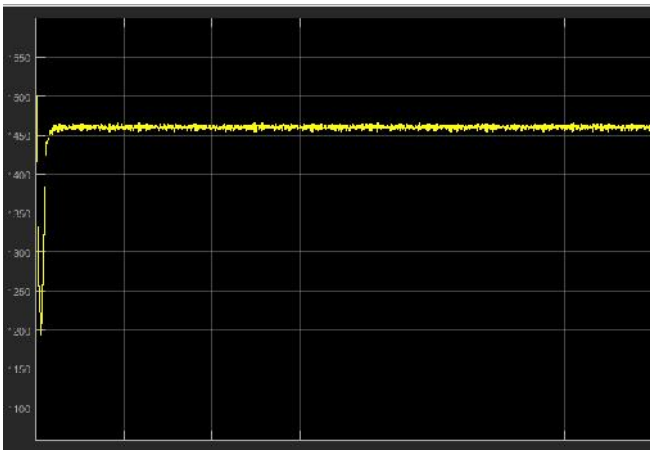

Fig 6: *Speed response of induction motor*

Fig. (5) shows the electromagnetic torque characteristics of induction motor. Fig. (6) shows the speed response of the induction motor. It shows that the induction motor is running at synchronous speed constantly.

Now, in Fig. (7) a feedback with PI controller is added with the reference speed so to control the speed of the induction motor.

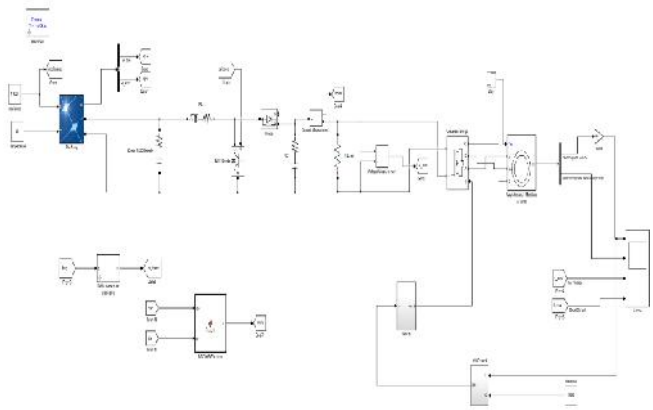

Fig 7: *MATLAB model of closed loop solar powered induction motor drive*

The speed characteristics at different reference speed are as follows:

Case 1: Reference speed = 1000 rpm

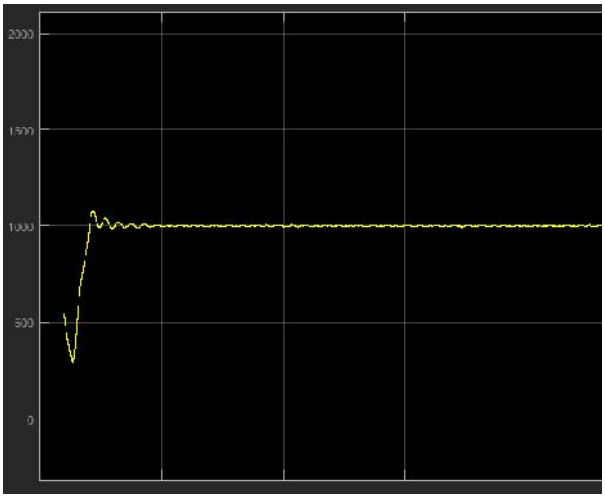

Fig 8: *Speed response*

Case 2: Reference speed = 1200 rpm

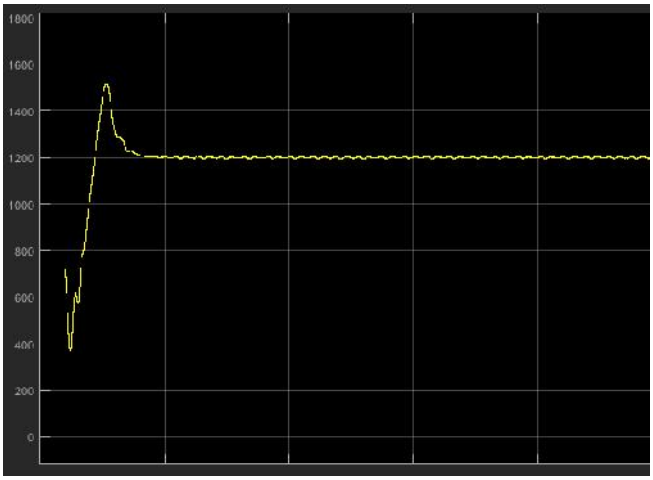

Fig 9: *Speed response*

So, by adding the feedback loop controlled by PI controller we can get desired speed of the induction motor. This is helpful where speed control of induction motor is our main objective.

VI. CONCLUSION

So, an induction motor can be run without any problem using solar energy. Scalar control is a low-cost method, simple and immune to errors of feedback signals, open loop deals with constant speed applications.Many applications in the industry operate with this control technique. By adding feedback loop compared with reference speed and controlled by PI controller we can adjust the speed of the induction motor. sensibility, high performance and smooth speed response. The simulation results showed that a good dynamic performance can be obtained from the PI controller compared with the V/F.

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