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Control of Induction Motor Fed from Solar Photovoltaic Array

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ABSTRACT

Isolated operation and control of induction motor fed from a solar photovoltaic array along with resistive loads is presented in this paper. New controllers are proposed to control the induction motor used for water pumping systems and for controlling of resistive loads with the varying solar irradiation are proposed. The simulations are performed in MATLAB/ SIMULINK environment. Performance of new proposed controllers is compared with that of conventional controllers.

Key words: Photovoltaic, Irradiation, Induction motor, Maximum Power Point Tracker (MPPT)

INTRODUCTION

Energy deficiency for many developing as well as developed countries is becoming a major problem as the conventional non-renewable resources such as coal, gas and oil are depleting, the renewable energy form is going to be widely accepted around the world. These renewable energy resources such as Wind, Solar, Tidal, Geothermal, etc. are of plentiful amount in our nature. Among these resources it is expected that 45% of necessary energy in the world will be generated from solar resource with the help of photovoltaic arrays [1]. Many countries in the world have taken certain steps to use the renewable resources (Solar, Wind, Tidal, etc.) to cater the ever increasing energy demand [2]. The photovoltaic (PV) power generation around the world is shown below in bar graph form. The cumulative installed Solar Photovoltaic capacity is as shown in bar graph [Fig. 2].

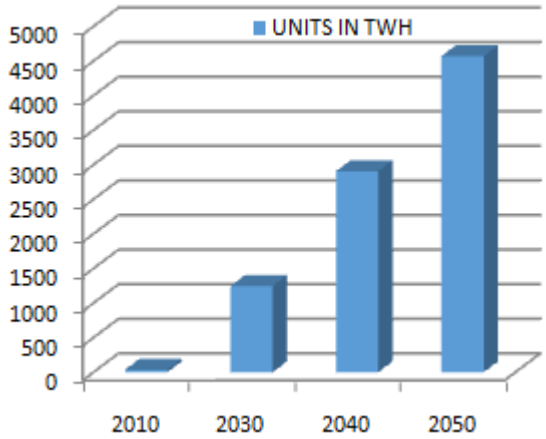

Fig. 1 Projected PV energy generation scenario in the world [source: International Energy Agency (IEA)]

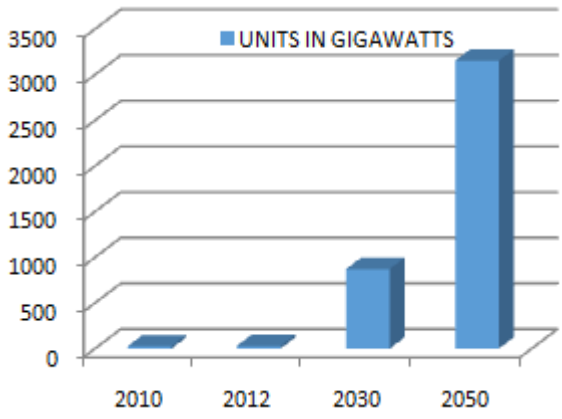

Fig. 2 Projected PV installed capacity scenario in the world [source: European PV Industry Association (EPIA)]

From this data it becomes clear that the use of solar energy is expected to increase at a very high rate and soon this source of energy will become dominant among other form of energy resources. The prime advantage of using the photovoltaic (PV) solar energy is that it is economical and eco-friendly to the environment. Among various applications water pumping system is one of the most attractive and eco-friendly system for agricultural activities. Use of photovoltaic generators for water pumping systems is well-accepted in many countries since 1977 [5]. The technology was found suitable for isolated areas [6]. Solar PV systems had established economic feasibility and reliability as compared with diesel powered water pumping systems [7]. Photovoltaic systems were also found

advantageous due to cleanness maintenance-free, inexhaustible and noiselessness operation [5] and [8]. Earlier, PV generation has some draw backs that the installation cost of solar panels was very high and conversion efficiency was very low and thus use of this power was limited. But at present, these disadvantages have been overcome by new advancements in this field. The cost of solar PV modules has decrease at a very high rate and it is projected that the cost of the PV modules will be reduced by 75% in 2020 [9]. Although the use of PV power in the earlier time was not huge but with the decrease in cost and increase in efficiency, these are now widely used in many applications such as: with grid connected mode and isolated mode. The electric power output and efficiency of these systems is largely dependent upon weather conditions, ambient temperature and irradiation level [10].

MATLAB / SIMULINK MODELING

(i) Conventional Controller

Fig. 3 shows the block diagram of the complete system. In this model a three phase induction motor is shown, that is connected to the solar photovoltaic (PV) array with the help of DC-DC boost converter and constant voltage source converter (CVSC). The main purpose of the boost converter is to boost the output voltage of the photovoltaic array up to the desired limit. Whereas, the main purpose of the constant voltage source converter (CVSC) is to convert the direct current (DC) into three phase alternating current (AC). Motor control action takes place at the voltage source converter end with the help of the controller. In order to control the motor, many controllers based on scalar and vector control techniques are developed [12-14].

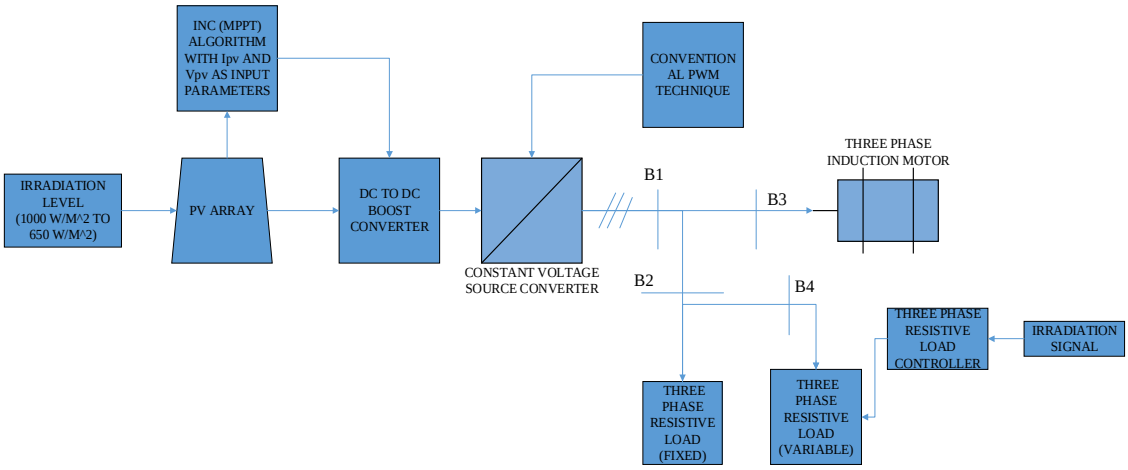

Fig. 3 MATLAB Simulink model with Conventional Controller (CC) [Source: Mathswork.com] [11]

In this research work, two controllers are designed. One controller based on the scalar control methodology is used to control the output of the converter as per requirement of the induction motor, whereas second controller is designed to trigger the variable resistive loads to match the variation in solar irradiation. Both these controller works independently and hence help in maintaining the power flow between sending end and the receiving end.

(ii) Proposed New Controller

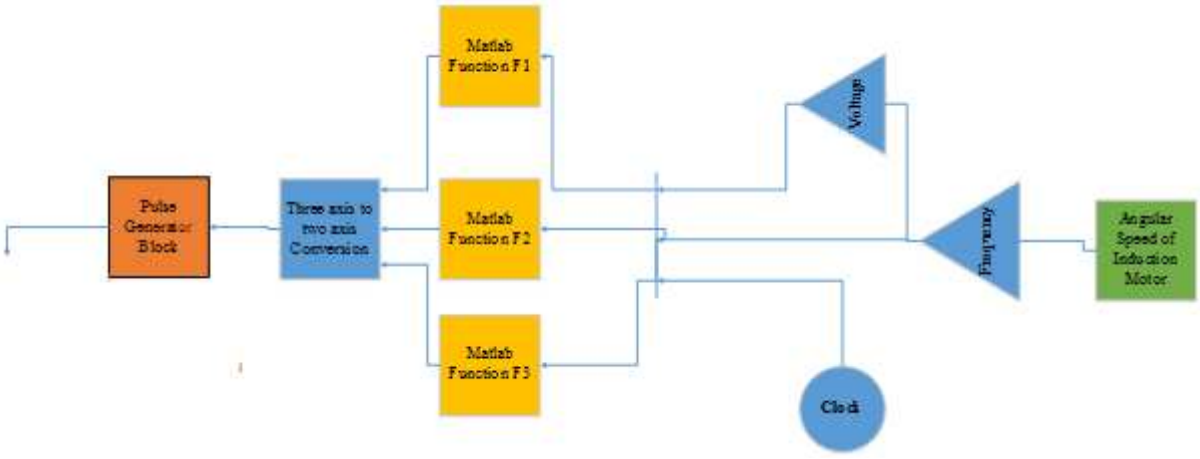

Fig. 4 Proposed new controller

The proposed new controller for speed control of induction motor is based on constant v/f control strategy. Constant angular speed signal of 188.4 r.p.s is taken as the reference input signal to the converter. This signal is used to generate corresponding voltage and frequency signals. These two constant signals and a clock signal is used to generate the three sinusoidal signals, with the help of three function blocks (phase generator) that actually uses three function of sinusoidal waveform that are phase separated from each other. These functions blocks help in generating the sinusoidal signals with phase shift. After this point Clarke's transformation takes place with the help of phase converter function blocks in which three phase signals are changed into two phase signals as shown in the fig. 6. After that x, y and z signals are generated from the modulating signal (two phase signal U_{alpha} and U_{beta}) and the reference dc voltage signals of 250 V. With the help of a PID controller these sinusoidal signals x, y & z are used to generate the carrier triangular signals of high frequency. As the IGBT used in this inverter are 12, thus twelve pulses are generated to trigger the gate of the inverter according to the sequence.

SIMULATION RESULTS AND DISCUSSION

Based on the proposed controller and conventional controller, results are simulated and performance of both controllers is analysed. This section shows the comparison result of the two controller i.e. conventional and proposed controller. From the comparison result it becomes clear that after controlling the ratio of two parameters i.e. voltage and frequency (v/f) speed variation is within the limit of 3% to 5% from no load to full load [15]. Because of this controlling action torque and power etc. are controlled in the best way. This thing becomes clear from the comparison results as shown in figure 5-10.

It is clear from the comparison of the results of conventional controller and proposed controllers that the proposed controller gives better results as compared to conventional controller and helps to maintain the desired limits. Further these new techniques also help in reducing the total harmonic distortion (THD) in current below 10% according to IEEE 519-1992 [16].

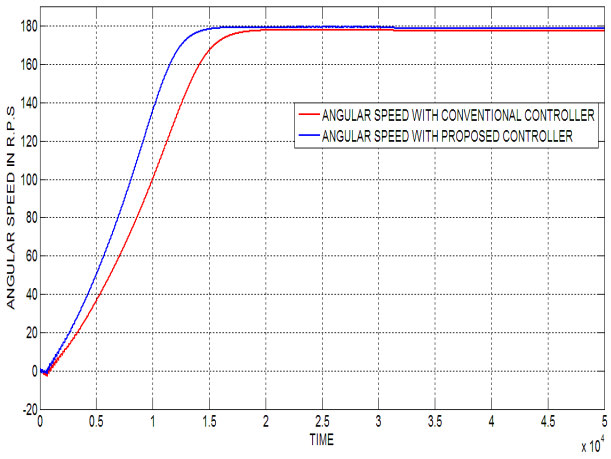

Fig. 5 Speed of IM with Conventional Controller and Proposed Controller

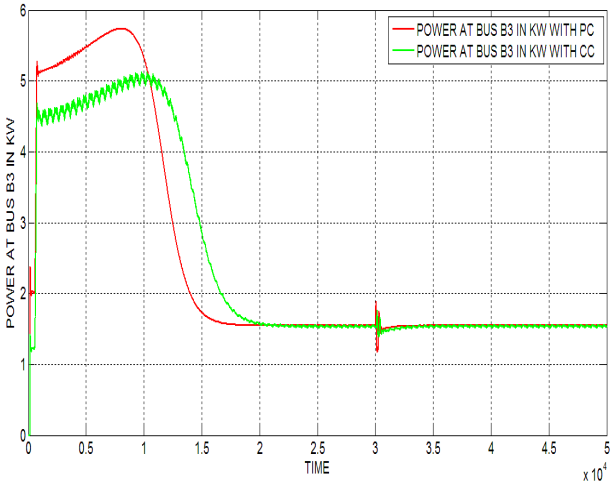

Fig. 6 Power at IM with Conventional Controller and Proposed Controller

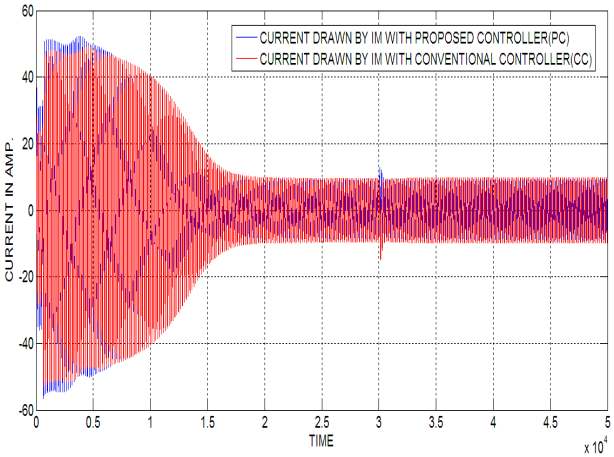

Fig. 7 Current drawn by IM with Conventional Controller and Proposed Controller

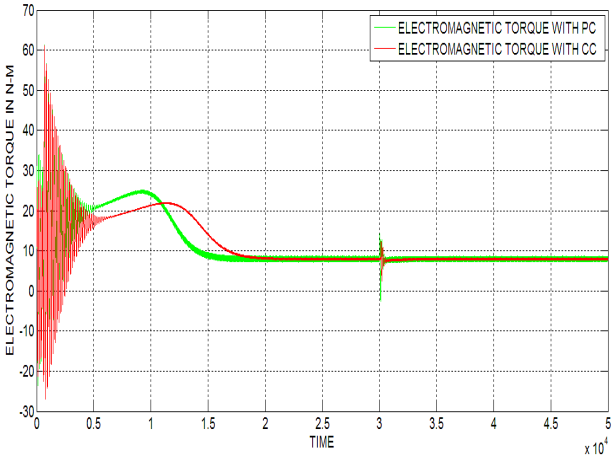

Fig. 8 Torque developed by of IM Conventional Controller and Proposed Controller

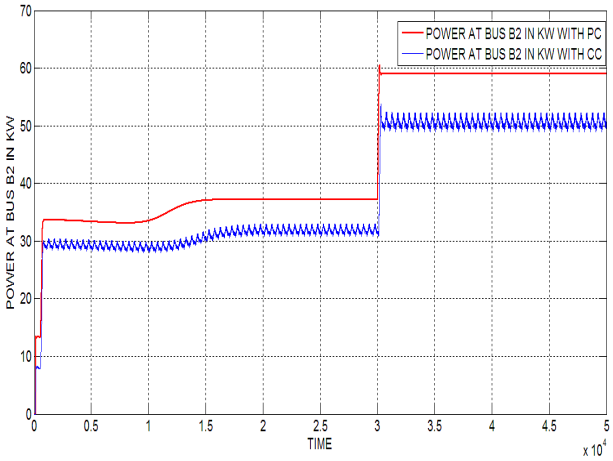

Fig. 9 Power at bus B2 with Conventional Controller and Proposed Controller

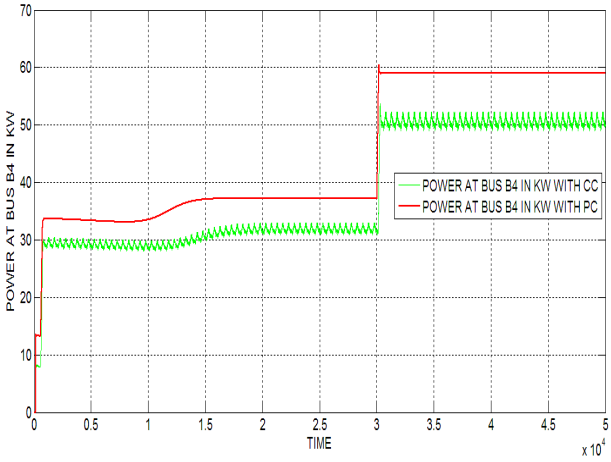

Fig. 10 Power at bus B4 Conventional Controller and Proposed Controller

CONCLUSION

Control strategy based on scalar control method is employed for the induction motor to improve its efficiency and to maintain the constant torque load. This control strategy has made the system to work efficiently and has improved the power quality. Furthermore, secondary controller has helped in maintaining the power balance of this isolated system. The proposed controller showed better performance than the conventional controller.

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