Vector Control of Induction Motor Based Parameters Estimation for PV System with MPPT

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Abstract*— In the recent years, the PV panels is used as a direct source of the motors in many fields of industry and other applications. 1000W/m^2 irradiance, ambient and 25 C^0 temperature is considered as inputs of the PV panels to switch on the system simulation. This paper shows how the vector control or the field oriented control (FOC) is utilized to maintain the operation of the induction motor(IM) during the variable speed of operation with space vector pulse width modulation(SVPWM). The boost converter , Maximum power point tracking(MPPT) by incremental conductance method, inverter control, two level inverter ,flux torque estimator and the IM are the main components of the complete solar system. The boost converter is utilized to increase the low level of 36V DC to higher level of voltage needed for IM . senseless estimation of the torque and flux is used as preferred way reduce the components cost in the real time system. Matlab/Simulink 2018b is used in the implementation of the closed loop system. The results shows the effectiveness of the proposed algorithm and considered as a very attractive and useful in the analysis and implementation.

Index Terms—*Estimation, MPPT .IM ,Vector control.*

I. INTRODUCTION

The green energy is become a wide range of energy source within few years for most of the world-wide electricity[1]. The decreasing and relative low cost of PV technologies with freely available sunlight are the main advantages of renewable energy[2]. The solar panels used as off line mode with batteries, or online without batteries through power electronic converter[3].The induction motors is play vital role and can be considered as the work horse of the industry. A control malfunctions is occur in electronic converters when the solar panels is powered without controller or compensations [4]. Therefore, to obtain high efficiency and performance it is preferred for the power electric motor drives to equipped with one of the control techniques such as FOC, direct torque control(DTC)[5] . The generated voltage of the PV panel is depending on characteristics of current and voltage which is a few tens of volts[6]. The characteristics of V-I is shown in Figure1.

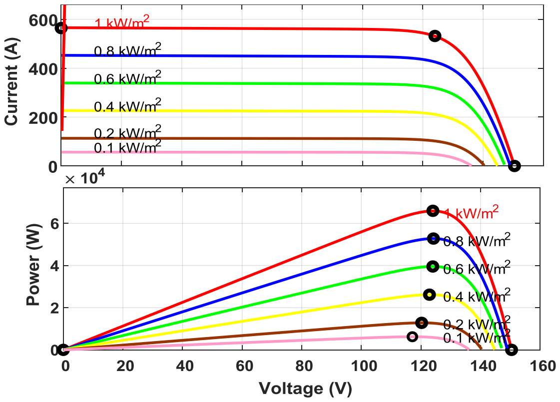

Figure.1. Characteristics of the PV panel

Many factors effects the voltage of a PV panel such as the IM loads, the irradiance and the temperature. To adjust the speed of the IM, inverter is utilized to drive the motor from DC voltage [7]. The inverter control ,boost converter and an inverter is utilized to generate high precise SVPWM signals for IM control. SVPWM for dead-time processing in 3-φ power converters used in [8]. Two phases failure with two SVPWM is used with FOC strategy in a 5-ϕ motor drive is studied in [9]. The MPPT is used to obtain the maximum power for operating IM [10]. In [11] ,adaptive fuzzy logic controller(FLC) for PV with different types of MPPT and DC–DC Converter is investigated. The incremental conductance and P&O are the main methods of the MPPT algorithm[12]. Variable speed drives(VSD) are responsible of efficiency improvement of IM equipment in the load variations requirements and continuous process control with accurate performance of the complete closed loop system[13].

The paper is organized as follows. In Section 2, the modeling of IM and FOC principle is introduced. Section 2. In Section 3, the MPPT control algorithm is introduced. In Section 4, the simulated results are presented followed by the conclusions of the results introduced In Section 5.

II. INDUCTION MOTOR MODEL

The IM is considered as a nonlinear in nature but it's have a great advantages like low cost and simplicity. The structures of FOC is used to control the IM in the variation of load . Hence the speed can be controlled. The SVPWM based three phase inverter frequency can be measured according to the motor speed and synchronous speed as well[14].

Fourth-order state space model is used to describe the electrical part of IM which is given in (1).

$$\begin{bmatrix} v_{qs} \\ v_{ds} \\ v_{qr} \\ v_{dr} \end{bmatrix} = \begin{bmatrix} R_s + s*L_s & -\omega_e*L_s & s*L_m & -\omega_e L_m \\ -\omega_e*L_s & R_s + s*L_s & -\omega_e*L_m & s*L_m \\ s*L_m & (\omega_e-\omega_r)*L_m & R_s + s*L_s & -(\omega_e-\omega_r)*L_r \\ -(\omega_e-\omega_r)*L_m & s*L_m & -(\omega_e-\omega_r)*L_r & R_s + s*L_s \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \quad (1)$$

Where

R is a matrix representing the winding resistances in d-q axis.

$$d\phi/dt = Mdi/\mathrm{dt} = \begin{bmatrix} L_s & 0 & L_m & 0 \\ 0 & L_s & 0 & L_m \\ L_m & 0 & L_r & 0 \\ 0 & L_m & 0 & L_r \end{bmatrix} \begin{bmatrix} \dot{i}_{qs} \\ \dot{i}_{ds} \\ \dot{i}_{qr} \\ \dot{i}_{dr} \end{bmatrix} \quad (2)$$

L is a matrix representing the winding self and mutual inductances in d-q axis.

$$W*\phi = \begin{bmatrix} \omega_r & 0 & 0 & 0 \\ 0 & \omega_r & 0 & 0 \\ 0 & 0 & \omega_o & 0 \\ 0 & 0 & 0 & \omega_o - \omega_r \end{bmatrix} \begin{bmatrix} \phi_{qs} \\ \phi_{ds} \\ \phi_{qr} \\ \phi_{dr} \end{bmatrix} \quad (3)$$

Where:

ω is a matrix depending on rotor speed ωr and reference frame ω0

The produced instantaneous torque is given by:

$$T_{em} = 1.5*(p/2)*(\phi_{rq}*i_{rd} - \phi_{rd}*i_{rq}) \quad (4)$$

The torque also can be expressed by:

$$T_{em} = 1.5*(p/2)*\mathrm{L}_m*(i_{sq}*i_{rd} - i_{sd}*i_{rq}) \quad (5)$$

III. FIELD ORIENTED CONTROL

Different techniques in the control system of IM are used,

1. Direct Field Oriented Control (DFOC) : is used for better decoupling between torque and flux as in a DC machine. The flux sensor requirement is the drawback of the structure[15].

2. Indirect Field Oriented Control (IFOC): the main advantage is eliminates the need of flux sensor as can be seen in figure2.

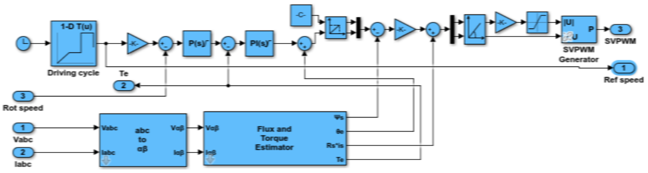

Figure2. FOC implementation circuit

The voltage and current vector is applied to obtain a fixed switching frequency for the SVPWM. A proportional and integrating controller (PI) is used for controlling the stator flux and the torque[16]-[17].

The flux –torque estimation is used with IFOC as can be seen in the Figure3.

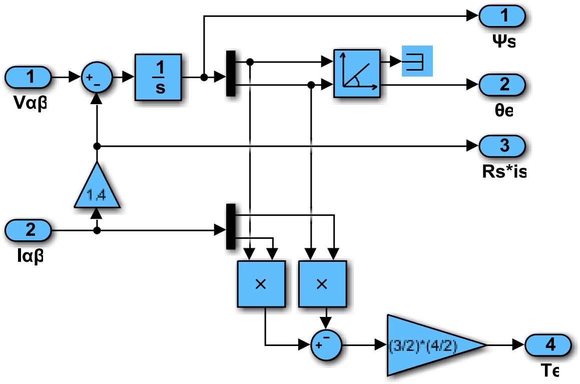

Figure3.Flux torque estimator

The output of the FOC is used as gate signal of the inverter that shown in the Figure4.

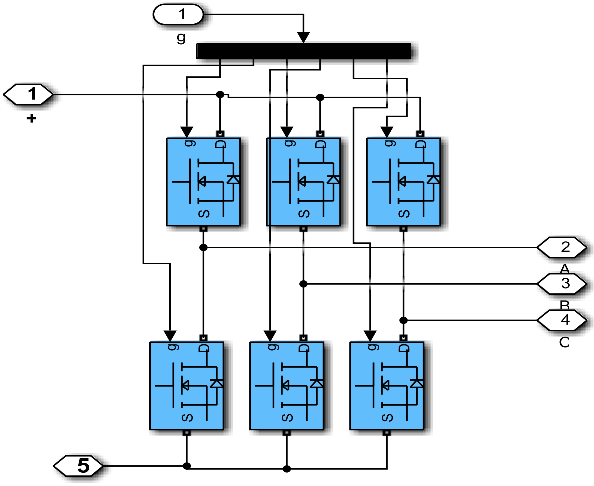

Figure4. Inverter implementation

The SVPWM sectors and switching states is shown in Figure5.

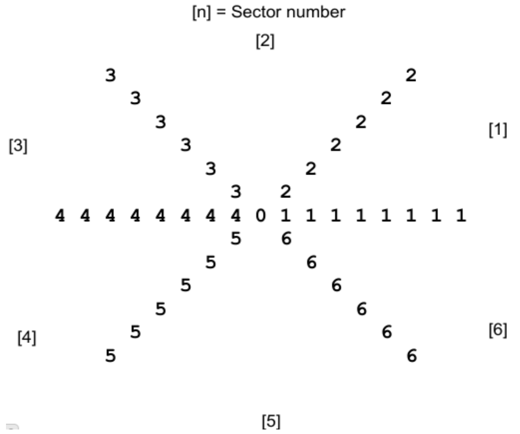

Figure5. Basic space vectors and switching states of the SVPWM

These six generated SVPWM modulation is shown in Figure6.

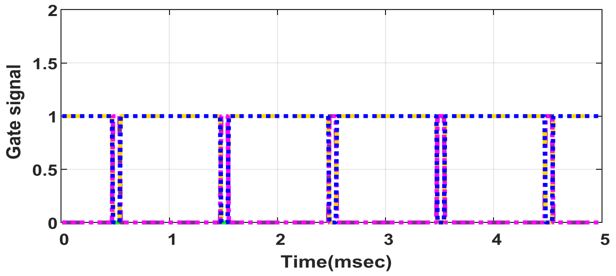

Figure6. SVPWM inverter control signals

IV. MPPT CONTROPL

The incremental conductance method is used in this work. The MPP is obtained when the derivation of power with respect to the voltage equal zero as can explained below[18]-[19].

$$\frac{dP}{dV}=0 \tag{6}$$

Where

$$P=V*I \tag{7}$$

$$\frac{d(V*I)}{dV}=I+V\frac{dI}{dV}=0 \tag{8}$$

Where

$$\frac{dI}{dV}+\frac{I}{V}\textit{ should be equal to zero}$$

Is considered as the error and reduced by the integral component of the MPPT . The regulation output is the duty cycle correction[20].

Where

dI, dV is the fundamental components of I and V respectively

The Simulink implementation of the MPPT control shown in Figure7.

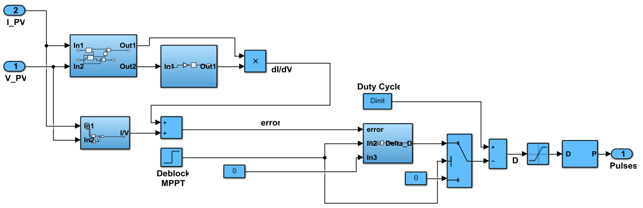

Figure7. MPPT controller circuit implementation

V. RESULTS

The Simulink implementation of the complete closed loop system is shown in Figure8.

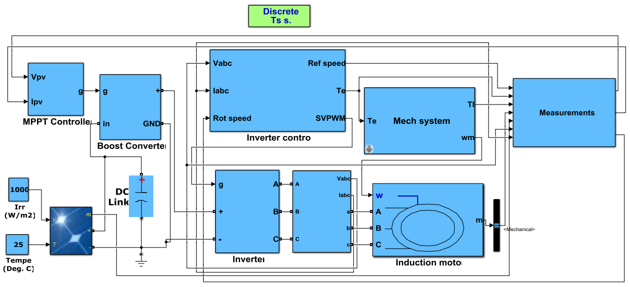

Figure8. Complete closed system

In this figure, the MPPT system with incremental conductance scheme were carried out to verify the desired performance signal for the boost converter. The DC voltage is utilized as an input for the inverter which received the SVPWM signal from the inverter control module. This signal is formulated due to FOC control algorithm.

The FOC control strategy make it easy to control the torque and the flux of the IM independently. The space vector trajectories of stator flux and the rotor flux as shown in Figure9.

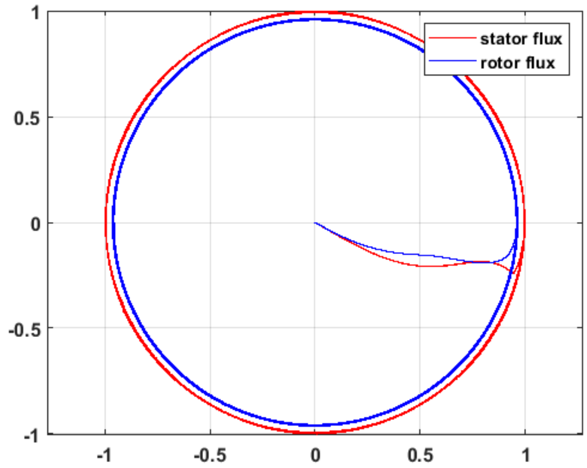

Figure9. Flux space vector trajectory

The d-component and q-component of the rotor flux is shown in Figure10.

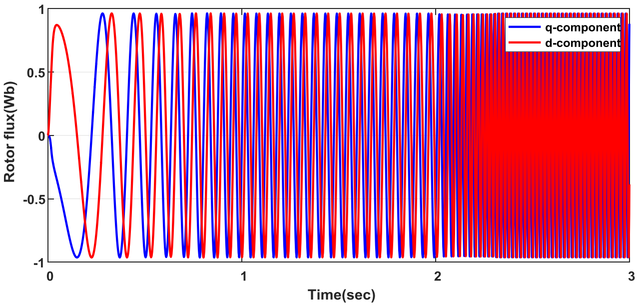

Figure10. Rotor flux d- q-components

The d-component and q-component of the stator flux is shown in Figure11.

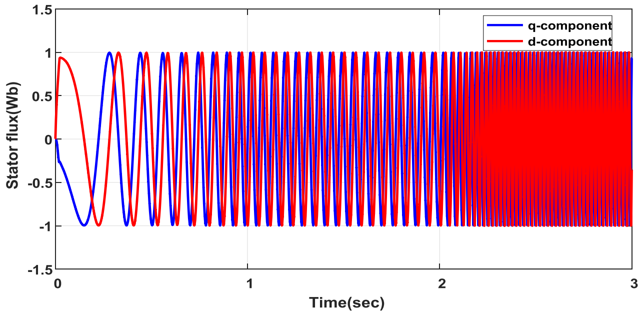

Figure11. Stator flux d- q-components

The robustness verification of the proposed algorithm is carried out when the IM is performed at a reference control input of 500 rpm after 1 sec at load of 2.5 N-m. At 2 sec, the reference input is changed to 1470 rpm with transient period of 0.25 sec and settled on 12 Nm torque. In Figure12, its observed that, the actual speed is follow the command speed perfectly with zero steady state error(S.S.E) due to the PI controller action.

The machine electromagnetic torque increased gradually after the start of operation to a value of load torque limiter, which is the12Nm as in Figure13.

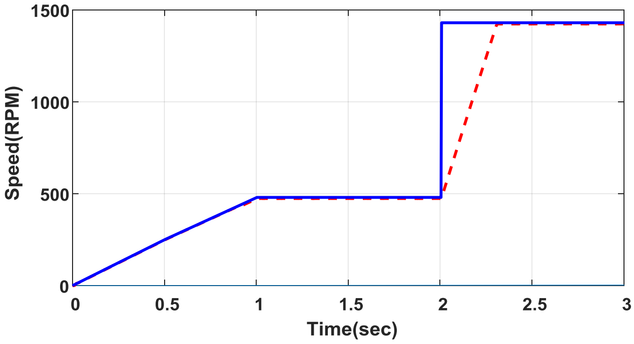

Figure12. IM reference and actual speed

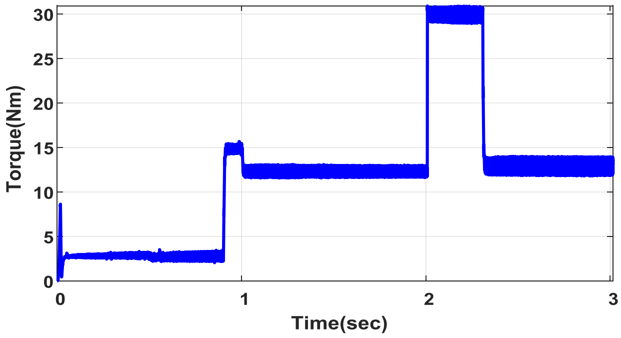

Figure13. IM reference and actual speed

Figure 14 shows the output responses of 3-phase stator currents. The maximum stator current at the time of starting is approximately 28 A. after 1 sec the value become 8A and 12A during 0.25 sec of transient period. Eventually settled on 12A with highly smooth of operation.

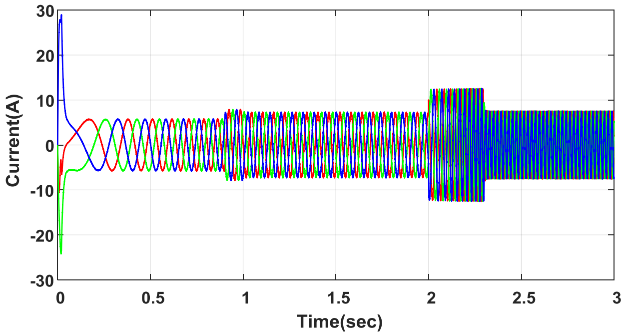

Figure14. 3-φ IM stator current

The duty cycle waveform is demonstrated in in Figure15.

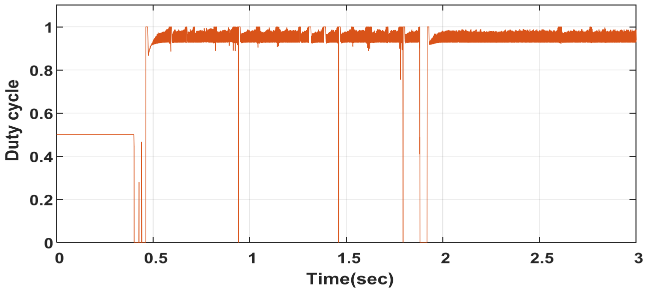

Figure15. Duty cycle waveform

400 V DC voltage is measured as in Figure16. The response is distorted in the instant of speed variation and due to PI controller action, the response is compensated quickly to a uniform and smooth response.

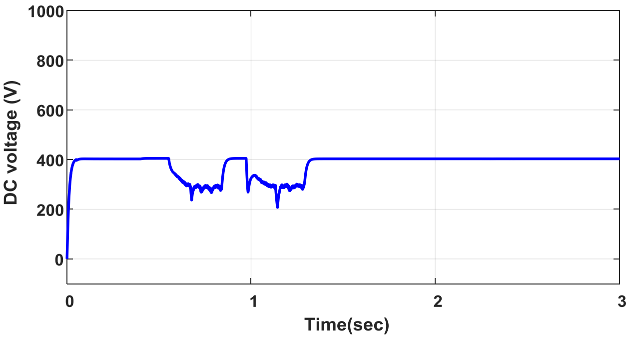

Figure 16.DC voltage

The angle of rotation between (π and –π) is shown in Figure17.

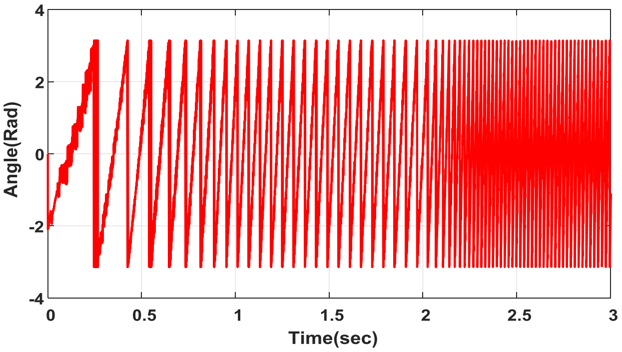

Figure17. Angle of rotation

In Figure 17, frequency of the rotor position is very low at IM low speed and increases with increasing of rotor speed.

CONCLUSION

In this paper, a FOC for MPPT control scheme are implemented to develop the integrated closed loop control system of IM. SVPWM modulation technique is utilized as inverter control with boost converter as complete set to obtain sufficient performance specifications of speed and torque of IM. The minimum steady state error of operating speed and torque is performed. Variable speed is used as a reference input to check the robustness of the proposed algorithm. voltage control and DC voltage control together with the FOC of the IM are used in this paper. Flux space vector trajectory of the stator and rotor flux is aligned to the d-q axis. The stator and rotor flux orientation ensure that the IM behaves like a separately excited DC motor. MPPT with incremental conductance scheme is utilized as powerful tool for power tracking for better regulation and control. Matlab/Simulink 2018b is used to implement the complete system. Simulation results proves the effectiveness of the implemented PV system.

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