

Adaptive Control Technique for Speed Control of Induction Motor with Current Source Inverter

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Abstract-This article represents an inclusive study of the current source inverter (CSI)-fed induction motor drives. It also reviews various control methods, selective harmonic elimination techniques and methods for decrease in switching losses in CSI fed IM drives. Power electronics has changed hastily through the last few decades and the number of applications has been increasing, mainly due to the developments of the semiconductor devices and the microprocessor technology. A dc-link current-source is provided by a Buck chopper. The amplitude and frequency of current-source inverter's output is controlled by asynchronous PWM-CSI method. Between the input terminal of induction motor and the current-source inverter a bank of capacitors is used to eliminate the high order harmonic currents, suppress the spike voltages across the IGBT switches and make guarantee the continuity of motor's current.

Keywords: Current source Inverter, high power switch, induction motor, PSO algorithm

I. INTRODUCTION

Induction Motor is very popular and extensively used in industry. It is simply excited ac machine which have a very good speed regulation and high starting torque [1]. To maintain the speed of the Induction motor there is need an electrical drive system [2]. In the past, the application of Induction motor was limited with constant speed because conventional method was used, but due to the evolution in inverter we can regulate the speed of Induction motor very easily[1,2]. There are various ways to control the speed of 3-φ Induction Motor. For this purpose PWM fed VSI electrical drive system is taken because the harmonic content is very low and it improves the performance of 3-φ Induction motor. In inverter six switches of bridge network is made of IGBT instead of SCR because of high switching frequency of VSI. The gate terminal of IGBT is fixed with pulses of PWM generator are the function of reference sine wave which has lower order harmonics are eliminated from the PWM fed VSI which makes the operation of 3-φ Induction motor smooth and noiseless[3].

II. PHOTOVOLTAIC EQUIVALENT CIRCUIT

The model of solar cell can be categorized as p-n semiconductor junction; when exposed to light, the DC current is generated. As known by many researchers, the generated current depends on solar irradiance, temperature, and load current. The typical equivalent circuit of PV cell is shown in Fig. 1.

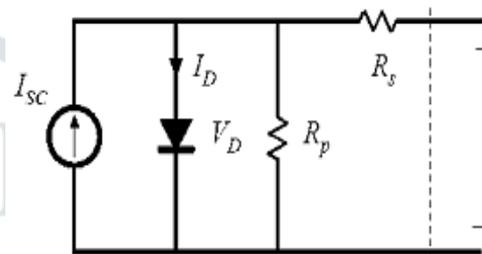


Fig. 1 Typical circuit of PV solar cell

The basic equations describing the I-V characteristic of the PV model are given in the following equations:

$$0 = I_{sc} - I_D - \frac{V_D}{R_p} - I_{PV} \tag{1}$$

$$I_D = I_0 (e^{V_D/V_T} - 1) \tag{2}$$

$$V_{PV} = V_D - R_s I_{PV} \tag{3}$$

Where:

I_{PV} : is the cell current (A).

I_{sc} : is the light generated current (A).

I_D : is the diode saturation current (A).

R_s : is the cell series resistance (ohms).

R_p is the cell shunt resistance (ohms).

V_D : is the diode voltage (V).

V_T : is the temperature voltage (V).

V_{PV} : is the cell voltage (V).

III. ROTOR FIELD-ORIENTED CONTROL

The existence of tight coupling between inner variables and output variables of induction motor makes difficult the control of motor's torque and speed. Decoupling the flux and torque of Induction machine by using a field-oriented control method is a good approach in the

control of induction machine [4], [5]. In order to realize this, the rotor flux is oriented into the direct axis of d-q reference frame. In other words, the d-q reference frame is chosen so that the rotor flux coincides with the direct d-axis. The machine equations, in the reference frame related to the rotor field are given by:

$$V_{sd} = R_{sd}i_{sd} + \sigma L_s \frac{di_{sd}}{dt} + \frac{L_m}{L_r} \frac{d\phi_r}{dt} - \omega_s \sigma L_s i_{sq} \quad (4)$$

$$V_{sq} = R_s i_{sq} + \sigma L_s \frac{di_{sq}}{dt} + \frac{L_m}{L_r} \omega_s \phi_r + \omega_s \sigma L_s i_{sd} \quad (5)$$

Fixing the d-axis in rotor field-oriented gives:

$$\phi_{rd} = \phi_r = cte \quad (6)$$

$$\phi_{rq} = 0 \quad (7)$$

The rotor flux and electromagnetic torque as a function of d-q components of stator current are expressed by:

$$\phi_r = \frac{L_m}{(\tau_r s + 1)} i_{sd} \quad (8)$$

$$C_{em} = \frac{p L_m \phi_r}{L_r} i_{sq} \quad (9)$$

The position of rotor field (ϕ_s) or d axis is calculated by indirect method:

$$\omega_{sg} = \frac{L_m}{\tau_r \phi_r} i_{sq} \quad (10)$$

$$\omega_s = \omega_r + \omega_{sg} \quad (11)$$

$$\theta_s = \int \omega_s . dt \quad (12)$$

The rotor flux is imposed by fixing i_{sd}^* and so the torque is made proportional to i_{sq} . Equations (9) and (10) show that the rotor flux ϕ_r and electromagnetic torque of motor C_{em} are only function of d-q components of stator current i_{sd} , i_{sq} respectively. The reference currents of motor are easily obtained by inverse Park transformation of d-q stator reference currents :

$$\begin{bmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{bmatrix} = C_{32} \cdot P(\theta_s) \cdot \begin{bmatrix} i_{sd}^* \\ i_{sq}^* \end{bmatrix} \quad (13)$$

Where the Concordia transformation matrix C_{32} and inverse park transformation p(ees) are:

$$P(\theta_s) = \begin{bmatrix} \cos(\theta_s) & -\sin(\theta_s) \\ \sin(\theta_s) & \cos(\theta_s) \end{bmatrix} \quad (14)$$

$$C_{32} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & -\sqrt{3}/2 \\ -1/2 & \sqrt{3}/2 \end{bmatrix} \quad (15)$$

IV. CURRENT-SOURCE INVERTER CIRCUIT [CSI]

Current-source inverter tends to see a DC current-source at the input gate. Output of current is independent from inverter's load, while output voltage is variable. A variable voltage source can be changed to a variable current source by keeping a high inductance in series with source and controlling the input voltage. Although for an ideal current source, L_d would be infinite but it would be determined by size and cost conditions in an appropriate limit. The variable DC voltage source can be obtained by rectifying the ac output voltage. The bridge inverter circuit consists seven IGBT switches and their drives. When a signal goes through these switches would turn them on and therefore the DC current would be applied to three phases of motor. Drivers are controlled by an algorithm which have been constructed in control system to reach the appropriate ac waveforms.

A. Bank of Capacitor at the output terminals of Current source Inverter

Due to the current's commutation from a pair of switches to another pairs, an output filter is used to eliminate spark of voltages at the output terminals. Three capacitors in star connection at the output terminal of CSI, allow filtering of high order current harmonics in addition to make sure continuity of motor's currents.

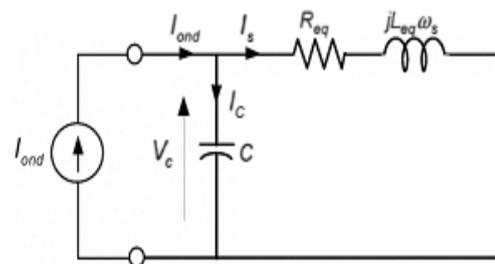


Figure 2. Single-phase equivalent circuit of the current inverter-capacity Induction motor.

By using the single-phase equivalent circuit of motor and the series capacitor shown in figure 2, equation 16 will be obtained which expresses the capacitor's current.

$$\frac{I_s}{I_{ond}} = \frac{\omega_0^2}{s^2 + \frac{\omega_0}{Q_0}s + \omega_0^2} \tag{16}$$

$$\omega_0 = \frac{1}{\sqrt{L_{eq} C}} \tag{17}$$

$$Q_0 = \frac{1}{R_{eq}} \sqrt{\frac{L_{eq}}{C}} \tag{18}$$

By frequency response of motor's current(I_s) and the output current of Inverter (I_{ond}) within different loads, the optimal capacitor would be determined [6] (L_{eq} and R_{eq} are the equivalent Inductance and the equivalent resistance of motor respectively).

V. FUZZY LOGIC CONTROLLER

The fuzzy logic controller unlike conventional controllers does not require a mathematical model of the system process being controlled. However, an understanding of the system process and the control requirements is necessary. The fuzzy controller designs must define what information data flows into the system (control input variable), how the information data is processed (control strategy and decision) and what information data flows out of the system (solution output variables) [11]. In this study, a fuzzy logic based feedback controller is employed for controlling the voltage injection of the proposed dynamic voltage restorer (DVR). Fuzzy logic controller is preferred over the conventional PI and PID controller because of its robustness to system parameter variations during operation and its simplicity of implementation [12]. The proposed FLC scheme exploits the simplicity of the mamdani type fuzzy systems that are used in the design of the controller and adaptation mechanism.

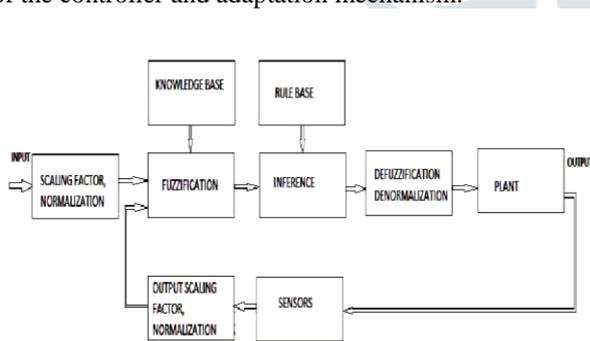


Figure 3: Fuzzy logic controller

The fuzzy logic control scheme (shown in figure 3) can be divided into four main functional blocks namely knowledge base, fuzzification, inference mechanism and defuzzification.

The knowledge base is composed of database and rule base. Data base consists of input and output membership functions and provides information for appropriate fuzzification and defuzzification operations. The rule base consists of a set of linguistic rules relating

the fuzzified input variables to the desired control actions. Fuzzification converts a crisp input voltage signals, error voltage signal (e) and change in error voltage signal (ce) into fuzzified signals that can be identified by level of memberships in the fuzzy sets. The inference mechanism uses the collection of linguistic rules to convert the input conditions of fuzzified outputs to crisp control conditions using the output membership function, which in the system acts as the changes in the control input (u).

'e'	NB	NM	NS	ZE	PS	PM	PB
'ce'	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table 1: Rule base for fuzzy logic controller

VI. MATLAB/SIMULINK RESULTS

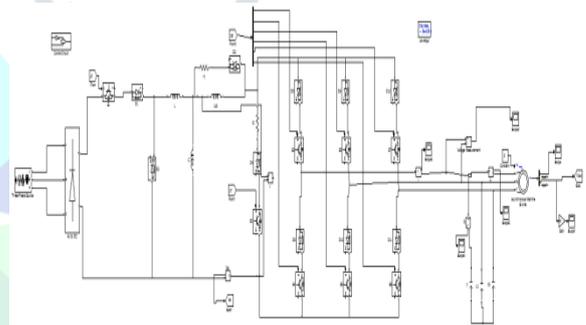


Fig.4. Matlab/Simulink model of proposed converter



Fig.5.shows the speed at 700rpm

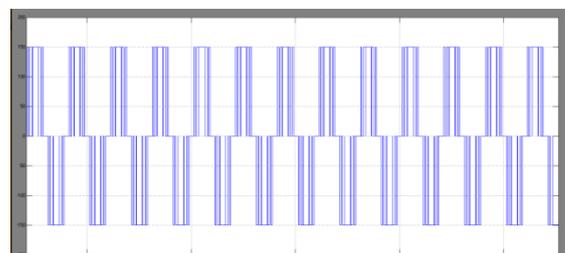


Fig.6.shows the voltage at 700 rpm

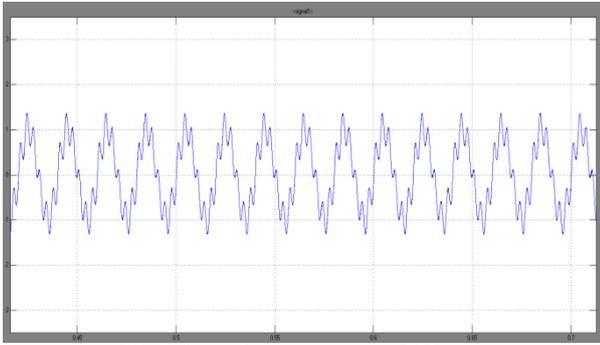


Fig.7.shows the stator current at 700 rpm

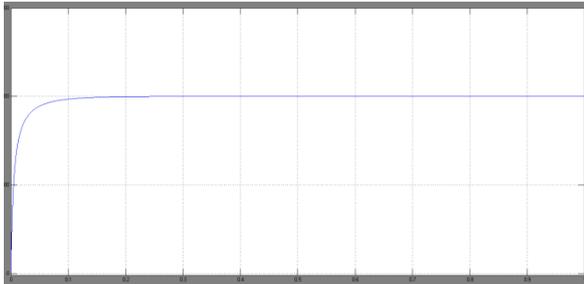


Fig.8.shows the speed at 1000 rpm

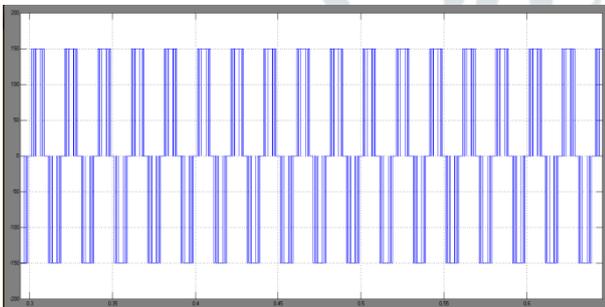


Fig.9.shows the voltage at 1000 rpm

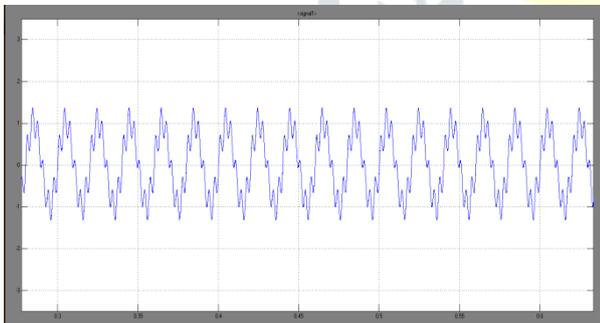


Fig.10.shows the current at 1000rpm

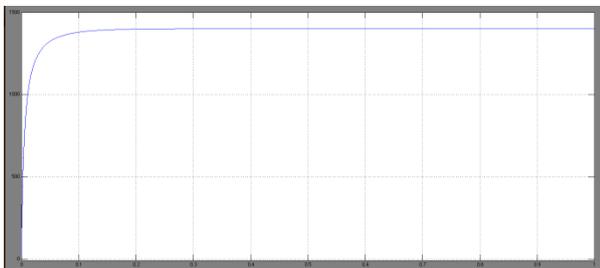


Fig.11.shows the speed at 1400

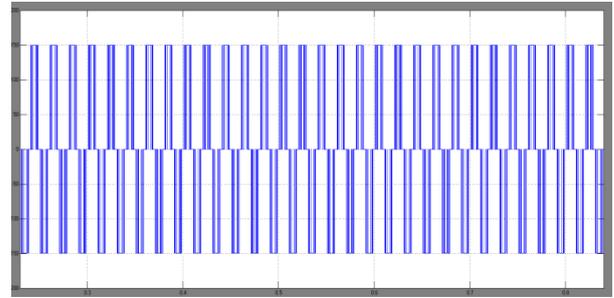


Fig.12.shows the voltage at 1400

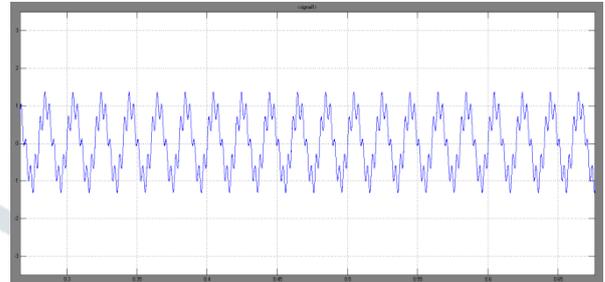


Fig.13.shows the current at 1400

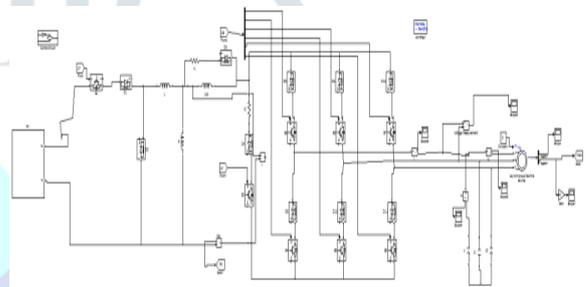


Fig.14.Matlab/Simulink model of variable speed PV and fuzzy controlled converter

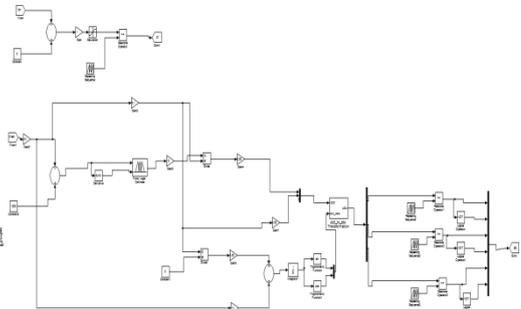


Fig.15 Matlab/simulink model of fuzzy controller

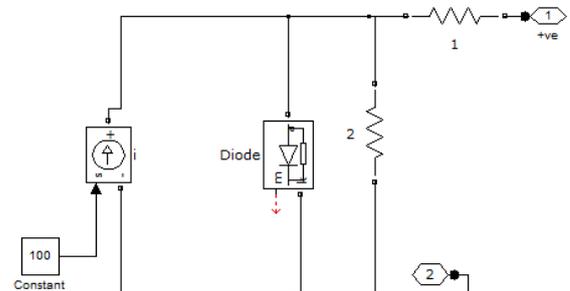


Fig.16 Matlab/simulink model of PV system

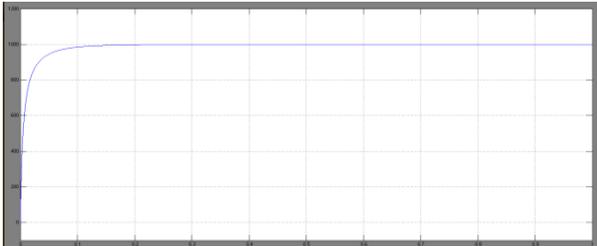


Fig.17.shows the speed at steady state value of $t=0.1$ sec

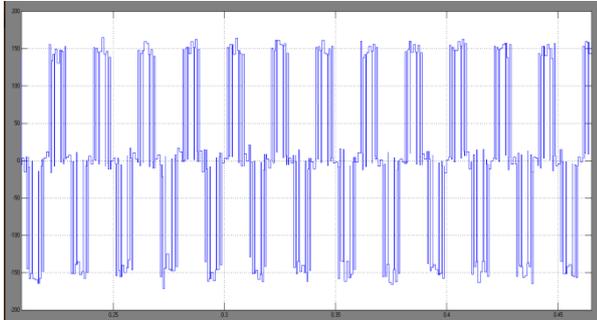


Fig.18.shows the voltage of modified converter

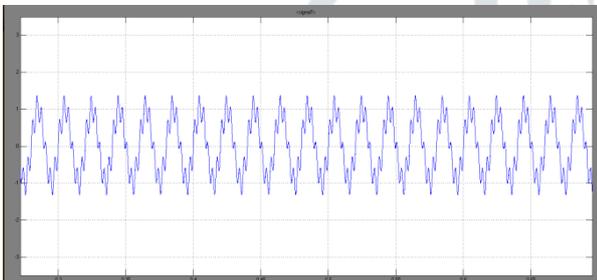


Fig.19.shows the current waveform of modified converter

VII. CONCLUSION

Vector control of induction motors made these motors wide spread in variable-speed applications in comparison with DC motor drives. Applying indirect method of vector-control, the flux sensors would be eliminated and also motor's speed can be controlled as well. At different speed conditions the speed of the motor is reached steady state value at different time periods, and also output voltage and stator current are varied at different speeds is observed. Compared to open loop operation of the motor in closed loop operation we can get steady state value of speed very quickly and these observations can be studied from simulation results.

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