MASTER SLAVE VECTOR CONTROLLED DOUBLE INDUCTION MOTOR USING UNITY POWER FACTOR CONTROLLED PWM RECTIFIER

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Abstract

In the recent days most of the industries uses Induction motors as the primary loads. In order to meet the total load requirement multiple motors are used. In this paper two Vector Controlled (VC) Induction Motors and a double closed loop PWM rectifier are used to explain the operation of Master Slave Configuration. The work mainly concentrates on the operation of a Unity Power factor Controlled (UPFC) PWM Rectifier as the input source for both the Vector Controlled Induction Motors. This UPFC PWM Rectifier uses two closed loop pi control algorithms the inner loop controls the current and the outer loop controls the DC voltage. The proposed model is simulated in Matlab/ Simulink and the results shows good synchronization for two induction motors operated in master slave configuration.

Keywords: *Vector Control, Induction Motor, PWM Rectifier, and Unity Power Factor Control*

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1. INTRODUCTION

In recent years induction motors are widely used in industries due to theirs advantages such as speed capability, robustness, cheapness and ease of maintenance. When the induction motor is operated in oriented control scheme it can compete with dc motor in high performance applications [1]. Due to the perfect decoupling control of flux and electromagnetic torque in the vector control of induction motor, it gains great interest in many industrial applications.

In this paper one of the motor is operated master and the other as slave, the speed of the master motor is a reference signal in a closed loop control system which can control the speed of slave motor and tract the speed of master.

2. UNITY POWER CONTROL METHOD OF PWM RECTIFIER

Figure 1 gives the basic structure of PWM rectifier ea (t), eb (t), ec (t) are the three phase voltages. L is the filter inductance. R is the equivalent resistance .c is the support capacitance of dc side. RL IS the load resistance and EL is the load voltage [2].

When the load force voltage is either zero or less than DC voltage across the capacitor then the rectifier operates in rectifier mode otherwise in active inverter mode.

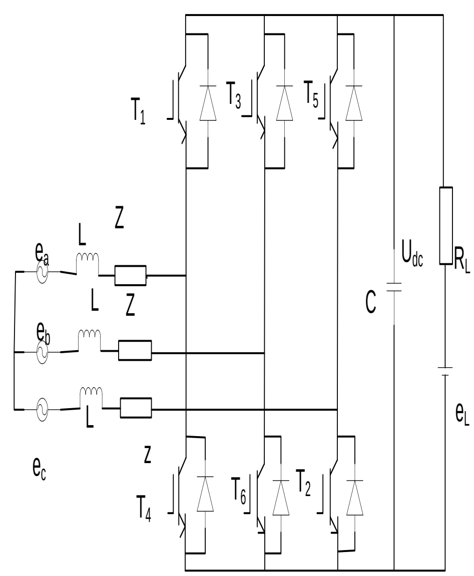

Fig.1 The structure of PWM rectifier

Figure 2 shows the block diagram unity power factor control of the PWM rectifier. This controller uses double closed loop PI control, inner PI loop control the three phase input current method controller by unity power factor control and the output DC voltage is controlled by outer PI loop [3].

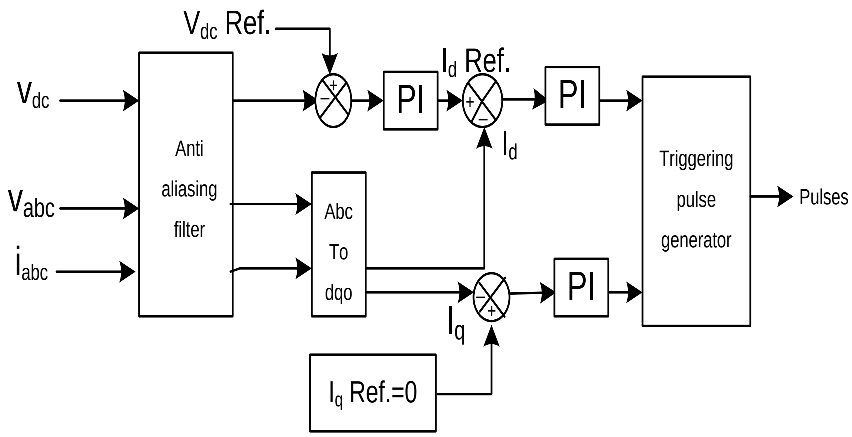

Fig.2 The unity power factor control method of PWM rectifier

3. VECTOR CONTROL OF INDUCTION MOTOR

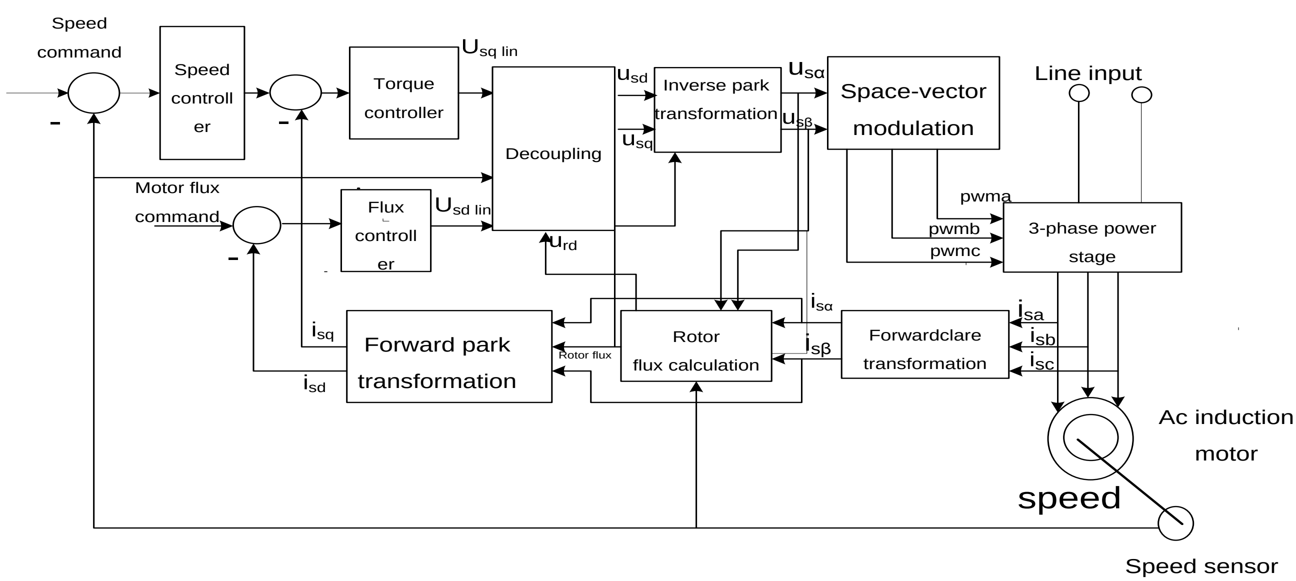

Fig. 3 Block Diagram of Vector controlled Induction Motor

It is the most popular control technique of ac induction motor. In this technique stator current of the induction machine are separated into dq co ordinate system. The direct axis (d) is aligned with the rotor flux space vector .The q-axis component of the rotor flux space vector is always zero.

$$\psi_{rp} = 0 and \frac{d}{dt}\psi_{rq} \qquad \text{……..(1)}$$

3.1 Block Diagram of Vector Control

Figure 3 shows basic structure of the vector control AC induction motor. The procedure for performing vector control is as follows [4].

- Measuring motor quantities (phase voltages and current)
- Covert them to 2-phase system (α,β) using Clarke transformation

- Calculation of rotor flux space vector magnitude and position angle
- Transform stator currents to dq system using parks transformation
- The stator currents i_{sd}, i_{sq} which will produce flux and torque respectively are controlled separately
- By using a decoupling block output stator voltage space vector is calculated
- Transform output stator voltage space vector to dq system using inverse park transformation
- By using a space vector modulation output three phase voltages is generated.

3.2 Forward and Inverse Clarke Transformation

Assume a-axis and α axis in same direction

There

$$i_{s\alpha} = k[i_{s\alpha} - \frac{1}{2} i_{sb} - \frac{1}{2} i_{sc}]$$

$$i_{s\beta} = k\frac{\sqrt{3}}{2}(i_{sb} - i_{sc}) \quad \text{.... (2)}$$

Where

i_{sa} =actual current of the motor phase A [A]

i_{sb} =actual current of the motor phase B [A]

$i_{s\alpha,\beta}$ =actual current of the motor phase C [A]

For non power invariant Transformation K=2/3

The inverse Clarke Transformation for the value of K=2/3 Is given by

$$i_{s\alpha} = i_{sa}$$

$$i_{s\beta} = \frac{1}{\sqrt{3}} i_{sa} + \frac{2}{\sqrt{3}} i_{sb} \quad \text{... (3)}$$

$$i_{sa} = i_{s\alpha}$$

$$i_{sb} = -\frac{1}{2} i_{s\alpha} + \frac{\sqrt{3}}{2} i_{s\beta}$$

$$i_{sc} = -\frac{1}{2} i_{s\alpha} - \frac{\sqrt{3}}{2} i_{s\beta} \quad \text{... (4)}$$

3.3 Forward and Inverse Park Transformation

Because the control process is not possible in stator reference frame these are shifted to dq reference frame

$$i_{sd} = i_{s\alpha} \cos\theta_{filed} + i_{s\beta} \sin\theta_{filed}$$

$$i_{sq} = -i_{s\alpha} \sin\theta_{field} + i_{s\beta} \cos\theta_{flied} \quad \text{...... (5)}$$

Where

$$\sin\theta_{fleld} = \frac{\psi_{r\beta}}{\psi_{rd}}$$

$$\cos\theta_{flied} = \frac{\psi_{r\alpha}}{\psi_{rd}} \quad \text{..... (6)}$$

$$\psi_{rd} = \sqrt{\psi_{r\alpha}^2 + \psi_{r\beta}^2} \quad \text{...... (7)}$$

Inverse park transformation is given by

$$i_{s\alpha} = i_{sd} \cos\theta_{flied} - i_{sq} \sin\theta_{flied}$$

$$i_{s\beta} = i_{sd} \sin\theta_{flied} + i_{sq} \cos\theta_{flied} \quad \text{..... (8)}$$

3.4 Rotor Flux Model

In AC induction motor vector control magnitude of rotor flux space vector place a vital role. To obtain rotor magnetic flux space vector here the process of monitoring rotor speed, stator voltage. And currents are utilized.

By solving the following equation, rotor flux space vector can be obtained

$$\left[(1-\sigma)\ T_s + T_r\right]\frac{d\psi_{r\alpha}}{dt} = \frac{L_m}{R_s} u_{s\alpha} - \psi_{r\alpha} - \omega T_r \psi_{r\beta} - \sigma L_m T_s \frac{di_{s\alpha}}{dt} \quad \text{....... (9)}$$

$$\left[(1-\sigma)\ T_s + T_r\right]\frac{d\psi_{r\beta}}{dt} = \frac{L_m}{R_s} u_{s\beta} - \psi_{r\beta} - \omega T_r \psi_{r\alpha} - \sigma L_m T_s \frac{di_{s\beta}}{dt} \quad \text{...... (10)}$$

Where

Ls=self-inductance of the stator [H]

Lr =self-inductance of the rotor [H]

Lm=magnetizing inductance [H]

Rs=Resistance of a stator phase winding [Ohm]

Rr =Resistance of a rotor phase winding [Ohm]

ω = Angular Rotor speed [rad. s-1]

pp = Number of motor pole pairs

$T_r = \frac{L_r}{R_r}$ = Rotor Time constant [s]

$T_s = \frac{L_s}{L_r}$ = Stator Time Constant [s]

$\sigma = 1 - \frac{L_m^2}{L_s L_r} =$ Resultant Leakage Constant [-]

3.5 Decoupling Circuit

The Purposes of rotor flux –oriented vector controls, the direct axis stator current and quadrature axis stator current must be controlled independently. The stator currents are decoupled control and stator voltages are not considered. The stator voltage decoupled and stator current components isd and Isq are indirectly controlling of terminal voltage of induction

- linear components $u_{sd}^{lin}, u_{sq}^{lin}$
- Decoupling components $u_{sd}^{decouple}, u_{sq}^{decouple}$

The equations are decoupled as follow:

$$u_{sd} = u_{sd}^{lin} + u_{sd}^{decouple} = [k_R i_{sd} + k_L \frac{d}{dt} i_{sd}] - [\omega_s k_L i_{sq} + \frac{\psi_{rd} l_m}{l_r t_r}]$$
………. (11)

$$u_{sq} = u_{sd}^{lin} + u_{sd}^{decouple} = [k_r i_{sq} + k_l \frac{d}{dt} i_{sd}] + [\omega_s k_l i_{sd} + \frac{l_m}{l_r} \omega \psi_{rd}]$$
……. (12)

Where

$$K_R = R_S + \frac{L_m^2}{L_r^2} R_r$$
……. (13)

$$K_L = L_S - \frac{L_m^2}{L_r}$$
….. (14)

$$u_{sd}^{lin} = K_R i_{sd} + K_L \frac{d}{dt} i_{sd}$$
…… (15)

$$u_{sq}^{lin} = K_R i_{sq} + K_L \frac{d}{dt} i_{sq}$$
…… (16)

The decoupling components

$$u_{sd}^{decouple} = -(\omega_s K_L i_{sq} + \frac{L_m}{L_r T_r} \psi_{rd})$$
…. (17)

$$u_{sq}^{decouple} = (\omega_s K_L i_{sd} + \frac{L_m}{L_r} \omega \psi_{rd})$$
….. (18)

3.6. Space Vector Modulation

It can directly transform the stator voltage vectors α, β- coordinate system to pulse width modulation signals. It is more valid for transformation from α, β- coordinate system, this technique are good results. In the basic principle of standard space vector modulation explained d with the help of power stage schematic diagram

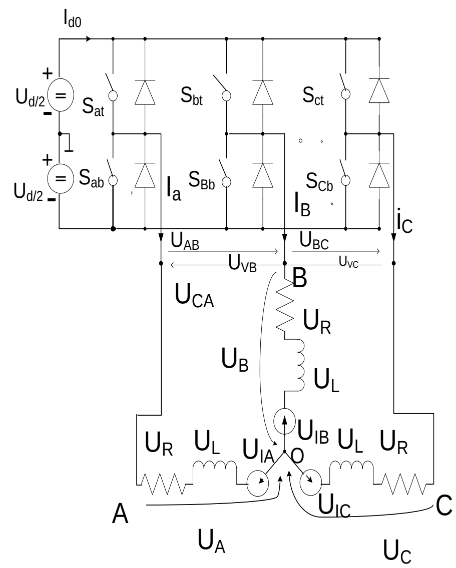

Fig.4 power stage schematic diagram

Table1 is there are six non-zero vectors UO, U60, U120, U180, U240, U300 and two zero vectors O000 andO111, defined in α, β coordination. The combination of ON/OFF states of power state switches for each voltage vector by the three digital numbers is parenthesis.

Figure 4 as the eight possible switching states are possible and given by combinations of the corresponding power switches the value ONE means upper switch is ON and bottom switches OFF.

The value ZERO means upper switches are OFF and bottom switches are ON. Within the result in output line – to – line voltage, phase voltage, voltage vector

Table1 Switching Patterns and Resulting Instantaneous Line – to-Line and Phase Voltages

abc	Ua	Ub	Uc	Uab	Ubc	Uca
000	0	0	0	0	0	0
100	2Udc/3	-Udc/3	-Udc/3	Udc	0	-Udc

110	Udc/3	Udc/3	2Udc/3	0	Udc	-Udc
010	-Udc/3	2Udc/3	-Udc/3	-Udc	Udc	0
011	2Udc/3	Udc/3	Udc/3	-Udc	0	Udc
001	-Udc/3	-Udc/3	2Udc/3	0	-Udc	Udc
101	Udc/3	-2Udc/3	Udc/3	Udc	-Udc	0
111	0	0	0	0	0	0

It is a technique and direct bridge between vector control and PWM.

1. Sector identification.
2. Space voltage vector decomposition into direction of sector base vector u_x, $u_{x\pm60}$.
3. PWM duty cycle calculation

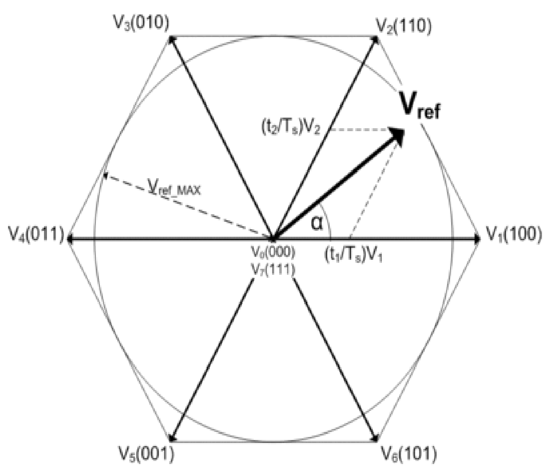

Fig.5 Base Space Vector and Voltage Vector projection

The principle of the SVM

$$T_{PWM}.U_{S[\alpha,\beta]} = T_1.U_X + T_2.U_{X\pm60} + T_0.(O_{000} \vee O_{111}) \quad \text{...... (19)}$$

$$T_{PWM} = T_1 + T_2 + T_0 \quad (20)$$

Where
T0, T1, T2 =Time periods
U s(α,β) =Space voltage vector
The direction of the sector base vector Ux, Ux±60

$$T_{PWM}.U_{SX} = T_1 U_X \quad \text{.. (21)}$$

$$T_{PWM}.U_{S[X\pm60]} = T_2.U_{X\pm60} \quad \text{....(22)}$$

$$T_1 = \frac{|U_{SX}|}{|U_X|} T_{PWM} \quad \text{Vector Ux .... (23)}$$

$$T_2 = \frac{|U_{SX}|}{|U_{X\pm60}|} T_{PWM} \quad \text{Vector ux ±60 ...... (24)}$$

$$T_0 = T_{PWM} - (T_1 + T_2) \quad \text{.... (25)}$$

4. MASTER SLAVE CONTROL TECHNIQUE

This technique is used in the process of synchronization Double motors. The main characteristic is that reference speed given to the master motor produces the corresponding revolving speed and it will acts as a reference speed of slave motor. Any noise or the changes occurred in a master motor will reflected and tracked by the slave motor [5].

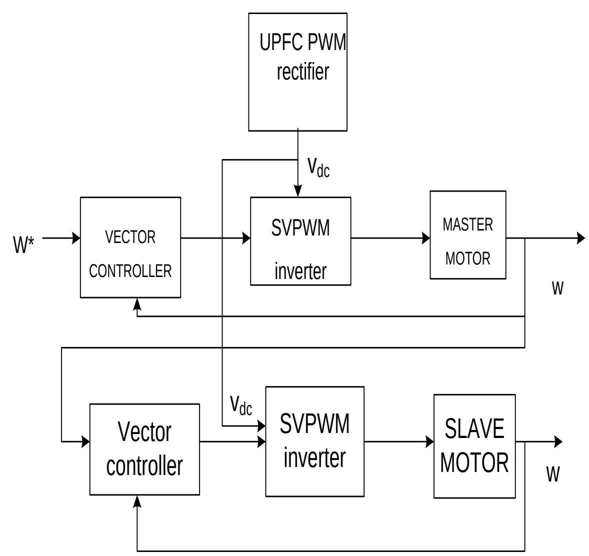

Fig.6 Block diagram of master slave control technique

The indirect vector control reference speed and load torque applied to motor shaft can be selected both switch blocks, in order to either constant value or step function.

5. MODELING AND SIMULATION RESULTS

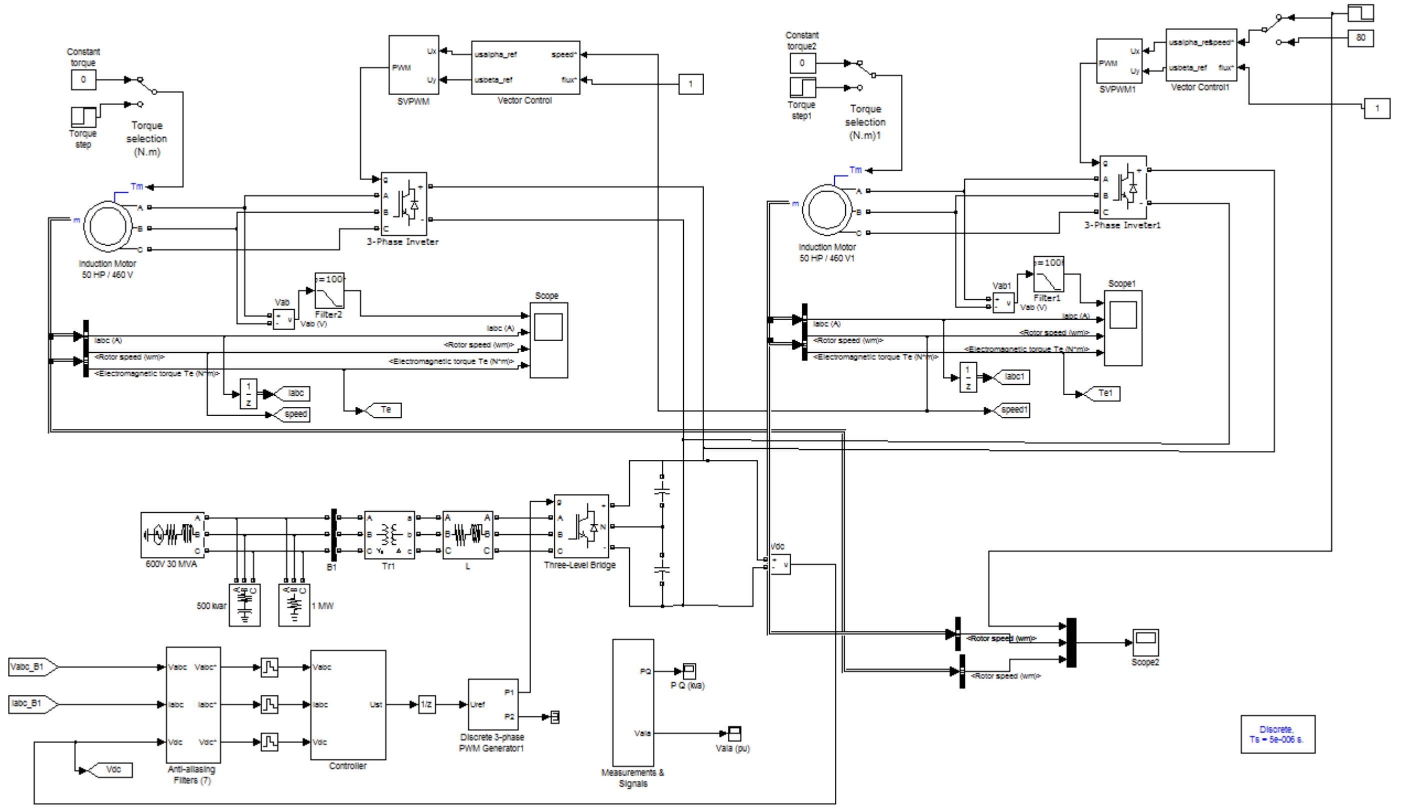

Fig.7 Matlab Simulink model for Master Slave Vector controlled Double induction motor using UPF controlled PWM rectifier

The figure 7 represents the basic building model for a Master Slave vector controlled Double Induction motor fed by a Unity Power Factor Controlled PWM Rectifier.

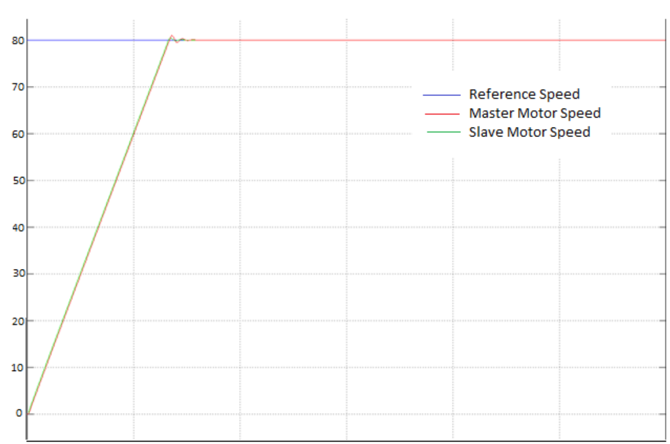

Fig.8 Rotor speed response for a master and slave motors with the constant reference speed

Figure 8 represents the speed response of the master motor and the slave motor with the constant reference speed of 80 rpm.

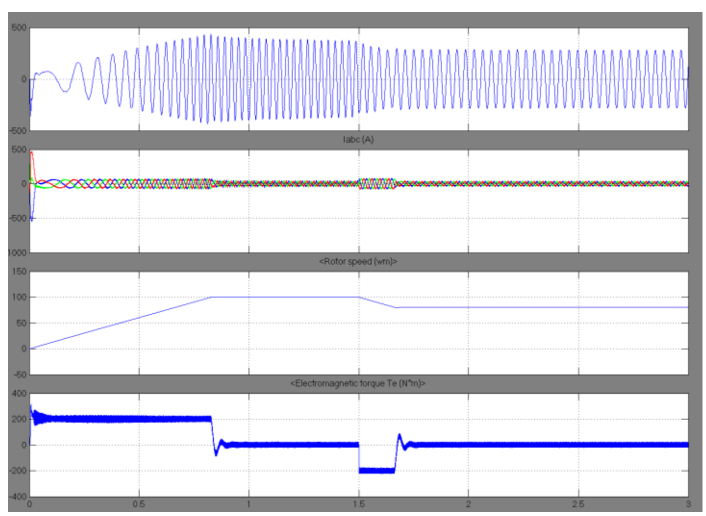

Fig.9 Voltage, Current, Rotor speed and Torque for a Master Motor and Slave motor

Figure 9 represents the voltage, current, Rotor speed and Torque for a Master motor and slave motor for the reference speed changing from 100 rpm to 80 rpm at 1.5 sec

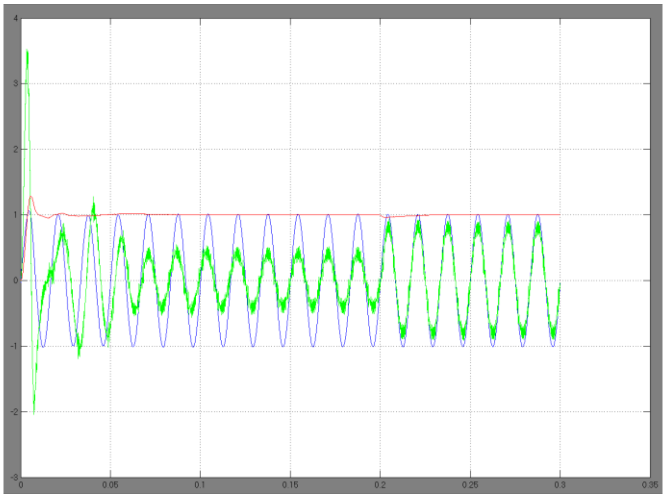

Fig.10 Output voltage, current and dc voltage of Unity Power Factor Control PWM rectifier

Figure 10 describes output voltage, current and dc voltage for a Unity Power Factor Control PWM rectifier. Here at time 0.2 sec the current is in phase with the voltage and maintain unity power factor.

CONCLUSIONS

In this work all the parameters for the master and slave motors are investigated, the technique is well synchronized for double induction motor. In industry applications the synchronization of double induction motors plays a vital role. The master slave double induction motor technique has faster speed response, short settling time, robustness, and less over shoot.

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BIOGRAPHIES

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