FUZZY LOGIC CONTROL BASED DIRECT TORQUE CONTROL SCHEME FOR A FOUR SWITCH INVERTER-FED INDUCTION MOTOR DRIVE

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ABSTRACT- Direct Torque Control of induction motor fed drives has become popular and widely used in industries due to fast and good torque response. Induction motors (IM) are simple in construction and are less sensitive to the motor parameters compared to other vector control methods. A new torque and flux control scheme called the direct torque control (DTC) has been introduced for induction motors. In DTC the torque and flux of an induction motor can be controlled directly by applying a suitable voltage vector to the stator of an induction motor. This paper proposes a novel direct torque control (DTC) strategy for induction motor (IM) drives fed by a four switch three-phase inverter (FSTPI). The introduced strategy is based on the emulation of the operation of the conventional six switch three-phase inverter (SSTPI). Using the fuzzy controller for a nonlinear system allows for a reduction of uncertain effects in the system control and improve the efficiency. A method to achieve fastest dynamic performance by modifying the two leg inverter fed DTC of induction motor based on Fuzzy Logic Concept is used here. This has been achieved thanks to a suitable combination of the four unbalanced voltage vectors intrinsically generated by the FSTPI, leading to the synthesis of the six balanced voltage vectors of the SSTPI. Due to the usage of the Fuzzy logic concept, the reliability, efficiency and performance of ac drive increases. Initial torque peak and torque ripple are minimized in the four switch three-phase inverter based DTC using Fuzzy Logic. By using the simulation results we can analyze the proposed method.

INTRODUCTION

Different techniques of induction machine drive have been introduced in order to ensure speed control at variable frequency. In this paper, a controller based on fuzzy logic is designed to improve the performance of DTC and reduce the torque and flux ripple. The major focused features are the uncontrolled switching frequency of the inverter and the high torque ripple resulting from the use of flux and torque hysteresis controllers. DTC is an efficient control technique used in AC drive systems to achieve high performance torque control and flux control.

Currently and more than two decades of investigation, several DTC strategies have been proposed so far [2]–[5]. These could be classified within four major categories: 1) strategies considering variable hysteresis band controllers [6]; 2) strategies with space vector modulation (SVM)-based control of the switching frequency [7], [8]; 3) strategies using predictive control schemes [9]–[11]; and 4) strategies built around intelligent control approaches. Commonly, the voltage source inverter (VSI) feeding IM under DTC is the six-switch three-phase inverter (SSTPI). This said, some applications such as electric and hybrid propulsion systems should be as reliable as possible. Within this requirement, the reconfiguration of the SSTPI into a four-switch three phase inverter (FSTPI), in case of a switch/leg failure, is currently given an increasing attention. A DTC strategy dedicated to FSTPI-fed IM drives has been proposed in [17]. In spite of its simplicity, this strategy is penalized by the low dynamic and the high ripple of the torque.

This paper proposes a new Fuzzy logic into DTC strategy with a Four switch inverter fed to an induction motor. Fuzzy logic improves the overall performance of DTC controlled system [2]. Using an appropriate vector selection table and emulation of six switch inverter [1] an efficient method is implanted.
controllers, torque and flux estimator and a switching table. The basic concept of DTC is to control directly both the stator flux linkage (or rotor flux linkage, or magnetizing flux linkage) and electromagnetic torque of machine simultaneously by the selection of optimum inverter switching modes. The use of a switching table for voltage vector selection provides fast torque response, low inverter switching frequency and low harmonic losses without the complex field orientation by restricting the flux and torque errors within respective flux and torque hysteresis bands with the optimum selection being made.

This paper proposes a new DTC strategy dedicated to FSTPI fed IM drives. It is based on the emulation of the SSTPI operation thanks to the synthesis of an appropriate vector selection table, which is addressed by hysteresis controllers.

The conventional DTC is based on flux and torque hysteresis controllers. Induction motor is fed from a Four Switch Inverter generating the voltage vectors of the Six Switch Inverter by reconfiguration. Applying the most optimized voltage vector that produce fastest dynamic torque response during transient states. Fuzzy logic concept is a most efficient artificial intelligence method which has high application in electric motor drives. A method to achieve fastest dynamic performance by modifying the two leg inverter fed DTC of induction motor based on Fuzzy Logic Concept is used here.

DTC OF FSTPI-FED IM DRIVES: BACKGROUND

A. DTC Basis

The conventional DTC drive employs two level flux hysteresis controller and three level torque hysteresis controller and its outputs are flux error and torque error respectively. DTC strategies allow a direct control of the motor variables through an appropriate selection of the inverter control signals, in order to fulfill the requirements as whether the stator flux and torque need to be increased, decreased, or maintained. These decisions are achieved according to the output $c_\phi$ of the flux hysteresis controller, the output $c_t$ of the torque hysteresis controller, and the angular displacement $\theta_s$ of the stator flux vector $\Phi_s$ in the Clarke (ab) plane.

The dynamic of $\Phi_s$ is governed by the stator voltage equation expressed in the stationary reference frame, as follows:

$$\frac{d}{dt} \Phi_s = V_s - r_s I_s$$

(1)

Where $V_s$, $I_s$, and $r_s$ are the stator voltage vector, current vector, and resistance, respectively. Neglecting the voltage drop $r_s I_s$ across the stator resistance, and taking into account that the voltage vector is constant in each sampling period $T_s$, the variation of the stator flux vector turns to be proportional to the applied voltage vector. Maintaining the stator flux constant, the variation of the electromagnetic torque $T_m$ depends on the direction of the applied voltage vector, such that:

$$T_m = N_p \frac{M}{r_s} ||\Phi_s|| ||\Phi_r|| \sin \delta$$

(2)

where $\Phi_r$ is the rotor flux vector referred to the stator, $\delta$ is the angular shift between the stator and rotor fluxes, $N_p$ is the pole pair number, and $I_s$, $I_r$, and $M$ are the stator self-inductance, the rotor self-inductance, and the mutual inductance, respectively.

The implementation scheme of the DTC strategy dedicated to a FSTPI-fed IM, shown in Fig. 1, has the same layout as the one of the basic DTC strategy initially proposed.

1) the SSTPI inverter is reconfigured to a FSTPI. Such a reconfiguration is carried out by adding to the former three extra TRIACs with three fast acting fuses.

2) the three-level hysteresis controller in the torque loop is substituted by a two-level hysteresis controller. As will be depicted in Section III, this substitution is motivated by the fact that no zero voltage vector is involved in the proposed DTC scheme.

### TABLE I

<table>
<thead>
<tr>
<th>Switching States, Stator Phase VOLTAGES, THEIR Clarke COMPONENTS AND CORRESPONDING VOLTAGE VECTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(S_1, S_2)$</td>
</tr>
<tr>
<td>(0 0)</td>
</tr>
<tr>
<td>(1 0)</td>
</tr>
<tr>
<td>(1 1)</td>
</tr>
<tr>
<td>(0 1)</td>
</tr>
</tbody>
</table>

B. Intrinsic Voltage Vectors of the FSTPI

The FSTPI topology consists of a two-leg inverter as illustrated in Fig. 1. Two among the three phases of the motor are connected to the FSTPI legs, while the third one is connected to the middle point of the dc-bus voltage.

Let us assume that the states of the four insulated-gate bipolar transistors (IGBTs) of the FSTPI are denoted by the binary variables $S_1$ to $S_4$, where the binary “1” corresponds to an ON state and the binary “0” indicates an OFF state. The IM stator voltages are expressed in terms of the states ($S_1$ and $S_2$) of the upper IGBTs, as follows:

$$\begin{bmatrix}
V_{as} \\
V_{bs} \\
V_{cs}
\end{bmatrix} = \frac{V_{dc}}{6} \begin{bmatrix}
4 & -2 & -1 \\
-2 & 4 & -1 \\
-2 & -2 & 2
\end{bmatrix} \begin{bmatrix}
S_1 \\
S_2 \\
1
\end{bmatrix}$$

(3)
The Clarke transform applied to the stator voltages yields:

\[
\begin{bmatrix}
V_{as} \\
V_{bs}
\end{bmatrix} = \sqrt{2} \begin{bmatrix}
\frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\
0 & \sqrt{2} & -\sqrt{2}
\end{bmatrix} \begin{bmatrix}
V_{as} \\
V_{bs} \\
V_{cs}
\end{bmatrix}
\]

(4)

Four combinations of the states of the upper IGBTs are characterized by four active voltage vectors (V1 to V4) in the \(a\beta\) plane, which are given in Table I.

Fig. 2 shows the four active voltage vectors represented in the \(a\beta\) plane. These vectors have unbalanced amplitudes and are shifted by an angle of \(\frac{\pi}{2}\). Indeed, vectors V1 and V3 have an amplitude of \(V_{dc}/\sqrt{6}\), while vectors V2 and V4 have an amplitude of \(V_{dc}/\sqrt{2}\).

**TABLE II**

VECTOR SELECTION TABLE OF THE BASIC DTC STRATEGY

| \(c_{\phi}\) | +1 | +1 | −1 | −1 |
| \(c_{\tau}\) | +1 | −1 | +1 | −1 |

| Sector I | V3 | V2 | V4 | V1 |
| Sector II | V4 | V3 | V1 | V2 |
| Sector III | V1 | V4 | V2 | V3 |
| Sector IV | V2 | V1 | V3 | V4 |

C. Limitations of the Basic DTC of a FSTPI-Fed IM

The basic DTC of an IM fed by the FSTPI is based on the subdivision of the \(a\beta\) plane into four sectors [17], limited by the four active voltage vectors as shown in Fig. 2.

The vector selection table corresponding to the basic strategy is presented in Table II.

Accounting for the symmetry of the four sectors, the following analysis of the torque and flux variations, will be limited to sector I, considering two cases:

1) the initial stator flux vector \(\Phi_{s1}\) is held by vector V2 ;

2) the initial stator flux vector \(\Phi_{s1}\) is held by vector V3 .

Equation (1) could be rewritten as follows:

\[
\phi_{s2} = \phi_{s1} + (V_i - r_i l_i)T_i
\]

Where \(V_i (1 \leq i \leq 4)\) is the voltage vector generated by the FSTPI.

The vector selection table corresponding to the basic strategy is presented in Table II.

Fig. 3 shows different phasor diagrams of (5), considering both cases previously cited with four scenarios selected from the vector selection table, for each. One can notice the following remarks which deal with the torque dynamic.

1) The application of voltage vectors V1 or V3 leads to a low torque dynamic if:
(a) $\Phi_{s1}$ is close to vector $V_2$ due to the low amplitude of $V_1$ and $V_3$ [see Fig. 3(a1) and (a3)];
(b) $\Phi_{s1}$ is close to vector $V_3$ due to the low angular shift of the flux vector.

Concerning the flux dynamic, one can notice the following:

1) High flux variations leading to overshoots or undershoots outside the flux hysteresis band with:
   (a) the application of voltage vectors $V_1$ or $V_3$ if $\Phi_{s1}$ is close to vector $V_3$ [see Fig. 3(b1) and (b3)];
   (b) the application of voltage vectors $V_2$ or $V_4$ if $\Phi_{s1}$ is close to vector $V_2$ [see Fig. 3(a2) and (a4)].
2) The flux command $c\phi$ is not achieved with the application of:
   (a) vector $V_1$ in sector IV corresponding to the control combination ($c\phi = +1$, $c\tau = -1$) as illustrated in Fig. 3(a1);
   (b) vector $V_2$ in sector I corresponding to the control combination ($c\phi = +1$, $c\tau = -1$) as illustrated in Fig. 3(b2);
   (c) vector $V_3$ in sector I corresponding to the control combination ($c\phi = +1$, $c\tau = +1$) as illustrated in Fig. 3(a3);
   (d) vector $V_4$ in sector II corresponding to the control combination ($c\phi = +1$, $c\tau = +1$) as illustrated in Fig. 3(b4).

From the previous analysis, one can clearly notice that the basic DTC strategy presents different limitations. These could be eradicated considering the introduced DTC strategy which will be developed in the following section.

**PROPOSED DTC STRATEGY**

**A. Approach to Generate Balanced Voltages by the FSTPI**

The proposed DTC strategy is based on the emulation of SSTPI operation by the FSTPI. This has been achieved through the generation of six balanced voltage vectors using the four intrinsic ones of the FSTPI. The generated vectors have the same amplitude and angular shift as those of the SSTPI. Basically, the active voltage vectors $V_k$, with $1 \leq k \leq 6$, yielded by the SSTPI have an amplitude $V_k$ equal to $\sqrt{3}/3 V_{dc}$, where $V_{dc}$ is the dc-bus voltage. For the same value of $V_{dc}$, the voltage vectors $V_i$, with $1 \leq i \leq 4$, generated by the FSTPI, present unbalanced amplitudes $V_i$, such that:

$$
\begin{align*}
V_1 = V_3 &= \frac{V_{dc}}{\sqrt{3}} = \frac{1}{2} V_k \\
V_2 = V_4 &= \frac{V_{dc}}{\sqrt{2}} = \frac{\sqrt{3}}{2} V_k 
\end{align*}
$$

Therefore, a dual application of the voltage vector $V_1$ (respectively, $V_3$) of the FSTPI leads to the generation of the voltage vector $V_{11}$ (respectively, $V_{33}$), as shown in Fig. 4. It is to be noted that $V_{11}$ and $V_{33}$ are identical to two vectors among the six generated by the SSTPI. Now, let us call $V_{ij}$ the voltage vectors resulting from the sums of successive voltage vectors $V_i$ and $V_j$, with $1 \leq i \leq 4$ and $1 \leq j \leq 4$. As far as the angular shift between two successive voltage vectors is equal to $\frac{\pi}{2}$, the amplitude $V_{ij}$ of vectors $V_{ij}$ can be expressed as follows:

$$
V_{ij} = \sqrt{V_i^2 + V_j^2} = \sqrt{\frac{1}{2} + \frac{1}{2} V_{dc}} = \sqrt{\frac{2}{3} V_{dc}} = V_k \quad (6)
$$

![Fig. 4. Generation of the SSTPI active voltage vectors using the four unbalanced voltage ones of the FSTPI.](image)

One can notice that the voltage vectors $V_{ij}$ have the same amplitude as the ones generated by the SSTPI. Beyond the amplitude, the four generated vectors, named $V_{12, 23, 34,}$ and $V_{41}$, as shown in Fig. 4, share the same phases with the four remaining active voltage vectors of the SSTPI. Table III summarizes the Clarke components of the six voltage vectors generated by the FSTPI considering the previously described approach.

**TABLE III**

**Clarke COMPONENTS OF THE GENERATED VOLTAGE VECTORS**

<table>
<thead>
<tr>
<th>$V_{ij}$</th>
<th>$V_{23}$</th>
<th>$V_{33}$</th>
<th>$V_{34}$</th>
<th>$V_{41}$</th>
<th>$V_{11}$</th>
<th>$V_{12}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{12}$</td>
<td>$\sqrt{3} V_{dc}/\sqrt{6}$</td>
<td>$-V_{dc}/\sqrt{6}$</td>
<td>$-\sqrt{3} V_{dc}/\sqrt{6}$</td>
<td>$-V_{dc}/\sqrt{6}$</td>
<td>$V_{dc}/\sqrt{6}$</td>
<td></td>
</tr>
<tr>
<td>$V_{33}$</td>
<td>$0$</td>
<td>$V_{dc}/\sqrt{2}$</td>
<td>$0$</td>
<td>$-V_{dc}/\sqrt{2}$</td>
<td>$-V_{dc}/\sqrt{2}$</td>
<td></td>
</tr>
</tbody>
</table>

Following the generation of six balanced active voltage vectors ($V_{23, 33, 34, 41, 11,}$ and $V_{12}$), the $ab$ plane turns to be subdivided into six symmetric sectors as illustrated in Fig. 4. Moreover, zero voltage vectors can be achieved through the application of two opposite intrinsic ones. The previously described approach represents a great
control benefit so far as several DTC strategies implemented in SSTPI fed IM drives could be applied to FSTPI-fed IM ones.

B. Vector Selection Table of the Proposed DTC Strategy

The synthesis of the vector selection table of the proposed DTC strategy is based on the approach described in the previous paragraph. Reaching this advanced step, one can wonder: how the control combinations \(c_\phi = j1, c_\tau = j1\) could be achieved applying the generated balanced voltage vectors? To answer this question, the following approach has been adopted.

As a result, the equivalent voltage vectors per sampling period \(T_s\) generated by the FSTPI, considering the adopted approach, can be expressed as:

\[
\begin{align*}
V_{11H} &= \frac{1}{2}V_{11} = V_1 \\
V_{33H} &= \frac{1}{2}V_{33} = V_3 \\
V_{ijH} &= \frac{1}{2}V_{ij}
\end{align*}
\]

where subscript \(H\) indicates the half of the corresponding voltage vector. In what follows, the synthesis of the vector selection table will be limited to sector I \((-\pi/6 \leq \theta_s \leq \pi/6\). In this case and as shown in Fig. 5, the following voltage vectors are applied during a sampling period, according to the corresponding control combinations:

\[
\begin{align*}
V_3 \text{ for } (c_\phi = +1, c_\tau = +1) \\
V_{12} \text{ for } (c_\phi = +1, c_\tau = -1) \\
V_{34} \text{ for } (c_\phi = -1, c_\tau = +1) \\
V_{11} \text{ for } (c_\phi = -1, c_\tau = -1)
\end{align*}
\]

In order to emulate the operation of the SSTPI, each control combination \((c_\phi, c_\tau)\) should be maintained during two sampling periods \(2T_s\), which yields the application of:

\[
\begin{align*}
V_{33} \text{ for } (c_\phi = +1, c_\tau = +1) \rightarrow V_3 \text{ then } V_3 \\
V_{12} \text{ for } (c_\phi = +1, c_\tau = -1) \rightarrow V_1 \text{ then } V_2 \\
V_{34} \text{ for } (c_\phi = -1, c_\tau = +1) \rightarrow V_3 \text{ then } V_2 \\
V_{11} \text{ for } (c_\phi = -1, c_\tau = -1) \rightarrow V_1 \text{ then } V_1
\end{align*}
\]
TABLE V
IMPLEMENTED VECTOR SELECTION

<table>
<thead>
<tr>
<th>$c_0$</th>
<th>$c_r$</th>
<th>$\tau$</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
</tr>
<tr>
<td>+1</td>
<td>-1</td>
<td>-1</td>
<td>+1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Periods $\tau$</th>
<th>$1^{st}$</th>
<th>$2^{nd}$</th>
<th>$1^{st}$</th>
<th>$2^{nd}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_0$</td>
<td>$V_1$</td>
<td>$V_2$</td>
<td>$V_3$</td>
<td>$V_4$</td>
</tr>
</tbody>
</table>

III. FUZZY LOGIC CONTROLLER

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC.

The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani’s, ‘min’ operator. v. Defuzzification using the height method.

Fuzzification

Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big). The Partition of fuzzy subsets and the shape of membership CE(k) E(k) function adapt the shape up to appropriate system. The value of input error and change in error are normalized by an input scaling factor. In this system the input scaling factor has been designed such that input values are between -1 and +1. The triangular shape of the membership function of this arrangement presumes that for any particular E(k) input there is only one dominant fuzzy subset.

The input error for the FLC is given as

$$E(k) = \frac{P_{ph,k} - P_{ph,k-1}}{V_{ph,k} - V_{ph,k-1}}$$

(10)

$$CE(k) = E(k) - E(k-1)$$

(11)

Inference Method: Several composition methods such as Max–Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.

Defuzzification: As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, “height” method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter. In UPQC, the active power, reactive power, terminal voltage of the line and capacitor voltage are required to be maintained. In order to control these parameters, they are sensed and compared with the reference values. To achieve this, the membership functions of FC are: error, change in error and output.

The set of FC rules are derived from

$$u = [aE + (1-a)*C]$$

(12)
Where $\alpha$ is a self-adjustable factor which can regulate the whole operation. $E$ is the error of the system, $C$ is the change in error and $u$ is the control variable.

IV. SIMULATION-BASED INVESTIGATION OF PERFORMANCE OF THE DTC STRATEGY

The ratings and parameters of the induction machine, used in the simulation:

As can be noticed, the stator phase currents are almost balanced, although the stator phase voltage $V_{cs}$ has an amplitude lower than the one of $V_a$. Fig. 7(d)–(f) shows the sector succession, the stator flux, and the electromagnetic torque, respectively. The analysis of Fig. 7(e) with respect to Fig. 7(d) clearly highlights that a demagnetization appears at the beginning of each sector. For instance, if $\Phi_s$ is located in the beginning of sector I, the corresponding control combination ($c_{\phi} = +1$, $c_{\tau} = +1$) is achieved by the application of the voltage vector $V_3$.

The obtained results are illustrated in Fig. 8(b) where a decrease of the average value of the flux and an increase of the torque one are noticed. Thus, the desired control combination ($c_{\phi} = -1$, $c_{\tau} = +1$) is achieved by the applied sequence.

A bandwidth of the electromagnetic torque controller is equal to $0.04$ Nm which represents $1.6\%$ of the rated torque. For the sake of a safe operation of the inverter, the dc-bus voltage $V_{dc}$ is limited to $400$ V in both experimental tests and simulation works. Fig. 7 shows some features characterizing the steady-state operation of the IM under the control of the proposed DTC strategy, for a mechanical speed $\Omega = 50$ rad/s and a constant load torque $T_l = 1$ Nm. Fig. 7(a) and (b) illustrates the waveforms of the stator phase voltages $V_a$ and $V_{cs}$, respectively. Fig. 7(c) shows the stator phase currents.

TABLE VII

<table>
<thead>
<tr>
<th>Harmonic</th>
<th>$i_{2nd}$</th>
<th>$i_{3rd}$</th>
<th>$i_{5th}$</th>
<th>$i_{2nd}$</th>
<th>$i_{3rd}$</th>
<th>$i_{5th}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_s = 2.5$ Hz</td>
<td>8%</td>
<td>13.8%</td>
<td>9.5%</td>
<td>11%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f_s = 20$ Hz</td>
<td>12%</td>
<td>13%</td>
<td>12.5%</td>
<td>7%</td>
<td>4%</td>
<td>8.5%</td>
</tr>
</tbody>
</table>

As can be noticed, the stator phase currents are almost balanced, although the stator phase voltage $V_{cs}$ has an amplitude lower than the one of $V_a$. Fig. 7(d)–(f) shows the sector succession, the stator flux, and the electromagnetic torque, respectively. The analysis of Fig. 7(e) with respect to Fig. 7(d) clearly highlights that a demagnetization appears at the beginning of each sector. For instance, if $\Phi_s$ is located in the beginning of sector I, the corresponding control combination ($c_{\phi} = +1$, $c_{\tau} = +1$) is achieved by the application of the voltage vector $V_3$. The obtained results are illustrated in Fig. 8(b) where a decrease of the average value of the flux and an increase of the torque one are noticed. Thus, the desired control combination ($c_{\phi} = -1$, $c_{\tau} = +1$) is achieved by the applied sequence.
This paper deals with the direct torque control of induction motor using fuzzy logic controller. Direct torque control (DTC) is a technique used in a three-phase motor to control the torque and eventually speed. This paper dealt with a new DTC strategy dedicated to FSTPI fed IM drives. DTC is an efficient control technique used in AC drive systems to achieve high performance torque control and flux control. Here we are using the fuzzy controller compared to other controllers i.e. The fuzzy controller is the most suitable for the human decision-making mechanism, providing the operation of an electronic system with decisions of experts. The proposed DTC strategy is based on the emulation of the operation of the conventional SSTPI. Direct Torque Control of induction motor fed drives has become popular and widely used in industries due to fast and good torque response. The proposed scheme is equipped for ripple reduction in torque. The steady state oscillations and unwanted forced oscillations can be eliminated using fuzzy controllers.

REFERENCES

**TABLE VIII**

<table>
<thead>
<tr>
<th>INDUCTION MACHINE RATINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
</tr>
<tr>
<td><strong>Torque</strong></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
</tr>
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</table>

**TABLE IX**

<table>
<thead>
<tr>
<th>INDUCTION MACHINE PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>( r_s )</strong></td>
</tr>
<tr>
<td><strong>( l_s )</strong></td>
</tr>
<tr>
<td><strong>( M )</strong></td>
</tr>
<tr>
<td><strong>( J )</strong></td>
</tr>
<tr>
<td><strong>( r_r )</strong></td>
</tr>
<tr>
<td><strong>( l_r )</strong></td>
</tr>
<tr>
<td><strong>( N_p )</strong></td>
</tr>
<tr>
<td><strong>f</strong></td>
</tr>
</tbody>
</table>

**CONCLUSION**

This paper deals with the direct torque control of induction motor using fuzzy logic controller. Direct torque control (DTC) is a technique


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