SIMULINK MODEL AND ANALYSIS OF ADJUSTABLE INDUCTION MOTOR DRIVE SYSTEM USING TWO PARALLEL SPWM RECTIFIERS

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ABSTRACT

This paper presents the development of design, modelling and simulation of Single-Phase to Three-Phase Induction Motor Drive System Using Two Parallel Sinusoidal PWM Rectifiers. These are simulated through computer software tool using MATLAB/SIMULINK. This presents the development of design, modelling and simulation for achieving voltage balancing to the output drive. The proposed method uses the same hardware structure which consists of a converter and inverter sections, In between the Converter and inverter two parallel switching device be connected through inductor and capacitor where used to produce balanced output to the motor drive. The proposed method with an advanced switching technique gives a better output with fewer harmonics. A filter is also used in the output side to further reduce the harmonic values. The output is compared between the conventional and proposed methods. The output waveforms are presented.

Keywords: Pulse Width modulation (PWM), Voltage Source Inverter (VSI), Total Harmonic Distortion (THD), Weighted Total Harmonic Distortion (WTHD) Source, Fault Identification System (FIS).

1. INTRODUCTION

A single phase to three phases Driver system includes Rectifier and Inverter. Rectifier is an electrical device that converts alternative current (AC), which periodically reverses direction, to direct current (DC) which flows in only one direction. The process is known as rectification. Three phase inverters are used for variable frequency drive applications and for high power applications such as HVDC power transmission. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminal [1]. For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform [3]. The six-step waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated as described above. When carrier-based PWM techniques are applied to six-step waveforms, the basic overall shape, or envelope, of the waveform is retained so that the 3rd harmonic and its multiples are cancelled [3].
2. CIRCUIT DESCRIPTION OF THE PROPOSED SYSTEM

Figure shows a block diagram representation of a power conditioning stage, where the input is a low frequency ac source which is converted to DC by an AC to DC converter (rectifier) stage. The DC voltage obtained is again converted to single phase or three phase AC voltage of required magnitude and frequency in a DC to AC converter (inverter) stage. The DC link in any AC-DC-AC converter is normally equipped with an electrolytic capacitor which provides decoupling between the rectifier and the inverter [4]. However, the DC link capacitor is a large, heavy, and expensive component. Moreover, the DC bus capacitor is the prime factor of degradation of the system reliability. For space power distribution systems, factors cited above pose even more critical problems.

The system is composed of grid, input inductors (\(L_a\), \(L_a\), \(L_b\), and \(L_b\)), rectifiers (A and B), capacitor bank at the dc link, inverter, and induction machine. Rectifiers A and B are constituted of switches \(q_{a1}\), \(q_{a1}\), \(q_{a2}\), and \(q_{a2}\), and \(q_{b1}\), \(q_{b1}\), \(q_{b2}\), and \(q_{b2}\), respectively. The inverter is constituted of switches \(q_{s1}\), \(q_{s1}\), \(q_{s2}\), \(q_{s2}\), \(q_{s3}\), and \(q_{s3}\). The conduction state of the switches is represented by variable \(sq_{a1}\) to \(sq_{s3}\), where \(sq = 1\) indicates a closed switch while \(sq = 0\) an open one.
3. SINUSOIDAL PWM STRATEGY

In order to control the power factor of the utility interface to the unity, the PWM rectifier is commonly used. The PWM rectifier must control the active and reactive powers to regulate a dc voltage. In a three phase PWM rectifier, these powers can be controlled on the instantaneous basis by using the p-q theory. On the contrary, in a single-phase PWM rectifier, since it is difficult to apply the p-q theory, the active and reactive powers are controlled on the average basis. In addition, these powers fluctuate inherently at the twice line frequency. As a result, a dc voltage is controlled non-linearly, and it is quite difficult to analyse and improve the stability and response of the dc voltage regulation [6].

In the practical system The inverter can be commanded by using an adequate pulse width modulation (PWM) strategy for three-phase voltage source inverter (VSI), so that it will not be discussed here. In this section, the PWM strategy for the rectifier will be presented [7]. The rectifier pole voltages $v_{a10}$, $v_{a20}$, $v_{b10}$, and $v_{b20}$ depend on the conduction states of the power switches,

$$v_{a10} - v_{a20} = e_y - (r_a + l_o)p_i a_s - (r'_a + l'_o)p'_a$$
$$v_{a10} - v_{a20} = e_y - (r_a + l_o)p_i b_s - (r'_a + l'_o)p'_a$$
$$v_{b10} - v_{b20} = (r'_a + l'_o)p'_b - (r_a + l_o)p_i b_s$$
$$i_i = i_s$$

4. PI CONTROLLER SYSTEM

Control (VOC) for three-phase system. This is obtained via blocks $Ge-ig$, based on a PLL scheme. The reference currents $i^*_{a}$ and $i^*_{b}$ are obtained by making $i^*_{a} = i^*_{b} = i^*_{g} / 2$, which means that each rectifier receives half of the grid current. The control of the rectifier currents is implemented using the controllers indicated by blocks $R_a$ and $R_b$ [5].

These controllers can be implemented using linear or nonlinear techniques. In this, the current control law is the same as that used in the two sequences synchronous controller described in.
These current controllers define the input reference voltages $v^*_{a}$ and $v^*_{b}$. The homo polar current is measured ($i_o$) and compared to its reference ($i^*_{o} = 0$). The error is the input of PI controller $R_o$, that determines the voltage $v^*_{o}$. The calculation of voltage $v^*_{x}$ is given from a function of $\mu$, selected. The motor three-phase voltages are supplied from the inverter (VSI). Block VSI-Control indicates the inverter and its control. The control system is composed of the PWM command and a torque/flux control strategy (e.g., field-oriented control or volts/hertz control) [10].

The harmonic distortion of the converter voltages has been evaluated by using the weighted THD (WTHD). It is computed by:

$$WTHD(x) = \frac{100}{a_{1}} \sqrt{\sum_{i=2}^{p} \left( \frac{a_{i}}{a_{1}} \right)^2}$$

Where $a_{1}$ is the amplitude of the fundamental voltage, $a_{i}$ is the amplitude of $i^{th}$ harmonic and $p$ is the number of harmonics taken into consideration. The WTHD of voltages generated by rectifiers [$v_{ab} = (v_{a} + v_{b})/2$ for the proposed configuration and $v_{g} = v_{g10} - v_{g20}$ for the conventional one] at rated grid voltage as a function of $\mu$. Note that the parameter $\mu$ determines $v^*_{x}$. The resultant voltage $v_{ab}$ generated by rectifier is responsible to control $i_{g}$, which means that this voltage is used to regulate the harmonic distortion of the utility grid.

![Fig: 4.2 WTHD of rectifier voltage ($v_{ab}$ for proposed configuration and $v_{g}$ for Standard configuration) as a function of $\mu$.](image)

When the single-carrier PWM is used, the behaviour of WTHD of the proposed system is similar to that of conventional one for all $\mu$, as observed in Figure. When the double-carrier PWM is used with $\mu = 0.5$, the WTHD is also the same for both configurations. However, for the other values of $\mu$ the WTHD of the proposed system is lower than that of the conventional one [2]. The WTHD of the proposed topology (double-carrier with $\mu = 0$ or $\mu = 1$) is close to 63% of that of the conventional topology (with $\mu = 0.5$). The study has also shown that it is possible to reduce the switching frequency of the proposed system in 60% and still have the same WTHD of the standard configuration. The WTHD behaviour in Figure depicts the pole voltages ($v_{a10}$, $v_{a20}$, $v_{b10}$, $v_{b20}$) and their references ($v^*_{a10}$, $v^*_{a20}$, $v^*_{b10}$, $v^*_{b20}$), the triangular carrier signals.
(vt1, vt2), the resultant rectifier voltage (v_{ab}) and the circulating voltage (v_o). Besides the total harmonic distortion (THD) of the grid current i_g, associated to the WTHD of the voltage v_{ab}, the harmonic distortion analysis must also consider the currents in the rectifiers. This is an important issue due to losses of the converter. The harmonic distortion of the rectifier currents (i_a, i'_a, i_b, and i'_b) with double-carrier is higher than that of the grid current i_g [8]. When the parallel rectifier with double-carrier is used, the THD of all these currents are reduced for μ = 0 or μ = 1 and increased for μ = 0.5. On the other hand, the THD of the circulating current is also smaller with μ = 0 or μ = 1. Currents i_a, i'_a, and i_o for double-carrier with μ = 1 and μ = 0.5. It can be seen that the mean values of the ripples of all currents are smaller when μ = 1 is selected.

![Graphs showing currents i_a, i'_a, and i_o for double-carrier with μ = 1 and μ = 0.5.]

5. FAULT COMPENSATION

The fault compensation is achieved by reconfiguring the power converter topology with the help of isolating devices (fast active fuses—F_j, j = 1 . . . , 7) and connecting devices (back-to-back connected SCRs—t1, t2, t3), as observed in Figure. These devices are used to redefine the post-fault converter topology, which allows continuous operation of the drive after isolation of the faulty power switches in the converter. Presents the block diagram of the fault diagnosis system. In this figure, the block fault identification system (FIS) detects and locates the faulty switches, defining the leg to be isolated. This control system is based on the analysis of the pole voltage error [7].

Fig. 4.3 Currents i_a, i'_a, and i_o for double-carrier With μ = 1 and μ = 0.5.
Fig: 5.1 (a) Configuration highlighting devices of fault-tolerant system.
(b) Block diagram of the fault diagnosis system.

The four possibilities of configurations have been considered in terms of faults:
1) Pre-fault (“healthy”) operation [see Fig. (a)];
2) Post-fault operation with fault at the rectifier B [see Fig. (b)];
3) Post-fault operation with fault at the rectifier A [see Fig. (c)];
4) Post-fault operation with fault at the inverter [see Fig. (d)].

Fig: 5.2 Possibilities of configurations in terms of fault occurrence
(a) Pre-fault system. (b) Post-fault system with fault at rectifier B.
(c) Post-fault system with fault at rectifier A. (d) Post-fault system with fault at the inverter
Double-carrier with $\mu = 0.5$ (D-Ca $\mu = 0.5$); and 3) double carrier with $\mu = 0$ (D-Ca $\mu = 0$). For case 1) the proposed configuration with double-carrier and $\mu = 0$ have its efficiency slightly smaller than that of the conventional one, but with the other PWM strategies its efficiency is clearly inferior. In the other cases, the proposed configuration with double-carrier and $\mu = 0$ presents higher efficiency than the conventional one [9]

6. RESULTS AND DISCUSSION

The simulation is done with a motor load. The output voltage, current, motor currents, carrier signal were simulated and shown below. The harmonic values were also measured through FFT Analysis

![Simulated Circuit for Non Parallel Rectifier Methods](image)

**FIG: 6.1** Simulated Circuit for Non Parallel Rectifier Methods

![Graph of $V_{dc}$ Feedback Output Waveform](image)

**FIG: 6.2** $V_{dc}$ Feedback Output Waveform
TWO PARALLEL RECTIFIER METHOD

Fig: 6.3 Speed Curve of Motor Drive

Fig: 6.4 MATLAB simulation of Two Parallel Rectifier Method

Fig: 6.5 $V_{dc}$ Feedback Output Waveform
7. CONCLUSION

A single-phase to three-phase drive system composed of two parallel single-phase rectifiers, a three-phase inverter and an induction motor was proposed. The system combines two parallel rectifiers without the use of transformers. The system model and the control strategy, including the PWM technique, have been developed in this paper. Compared to the conventional topology, the proposed system permits to reduce the rectifier switch currents, the THD of the grid current with same switching frequency or the switching frequency with same THD of the grid current and to increase the fault tolerance characteristics. In addition, the losses of the proposed system may be lower than that of the conventional counterpart. The experimental results have shown that the system is controlled properly, even with transient and occurrence of faults.
REFERENCES


