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Review of Four Switch Three-Phase Inverter Fed Induction Motor Drives

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ABSTRACT: Inverters designed using reduced active semiconductor devices can be of interest to the industry because of their lower cost and enhanced reliability linked to their less complex gating and control circuitries. This paper review of four switch three phase inverter for the grid connected application in an effort to reduce the cost of the inverter is investigated. Admittedly, this topology warrants higher voltage ratings of the semiconductor devices used and the dc-link split capacitors used with respect to a conventional six-switch three-phase inverter for a specific set of grid voltages. In this paper, application of four power semiconductor switch based three phase inverter has been studied for renewable energy based generalized three phase micro grid interconnection. A simple sinusoidal pulse width modulation (SPWM) is used to control the switching of the four switches. Main advantage of this converter is that it needs only four switches.

KEYWORDS: Four switch inverter, Sinusoidal pulse width modulation, Micro grid.

I. INTRODUCTION

A multilevel inverter (MLI) scheme is proposed for four-pole (4-pole), three-phase (3-phase) induction motor (IM) drives with improved dc bus utilization as well as reduced device count. MLI is realized with three-switch inverter legs (3-SIL) and a single dc source. In the proposed MLI, each 3-SIL is utilized for exciting the two identical voltage profile coils/phase of the four-pole (4-pole) stator winding, which means each leg has to be modulated with two references. These two independent references/leg will limit the modulation index (M.I) of 3-SIL-based proposed MLI. This lower M.I will result in a requirement of the higher magnitude of dc-link voltage to achieve the rated load voltage requirement. In general, the two IVPCs of each phase winding are connected in series, these two IVPCs are separated and excited with conventional two-switch inverter legs without disturbing the flux per pole and other machine parameters. The 18 IVPCs of four-pole nine-phase induction motor (IM) are excited with 18 two-switch inverter legs and fed by the same dc source. Each two-switch inverter leg generates the two-level voltage across each IVPC winding, i.e., the resultant voltage seen by the phase winding is a three-level voltage waveform.

The converter consisting of a single-phase half-bridge rectifier and four-switch three-phase inverter is a low-cost power converter with complicated operating constraints. In the outer loop, a proportional-integral controller is designed to regulate the dc-link voltage, capacitor voltage balancing, and the speed and flux of induction motors (IM). Also, in the inner loop, the finite set model predictive control is employed to control the ac input current and stator currents of the IM. The major advantages of the control strategy include: (i) easy to deal with complicated constraints and manage multiple control targets; (ii) without the need of modulators; (iii) good dynamic response. Pulse width modulation (PWM) variable speed drives are increasingly applied in many industrial applications that require superior performance. The carrier-based PWM strategy can be improved by adding different zero sequence signals to the reference sinusoidal phase voltages. This paper presents a comparative evaluation of five carrier-based PWM techniques with zero-sequence signal injection for a six-switch three-phase inverter (B6) fed an open-loop induction motor (IM) drives over the linear modulation and over modulation ranges. Four-switch three-phase inverter-fed induction motor drive is very attractive because it can be utilized in fault-to-lerant control to solve the open/short-circuit fault of the six-switch three-phase inverter without redundant power switches. However, the balanced three-phase current collapses due to fluctuation of the dc-link capacitor. Allowing constraints included, the predictive torque control (PTC) can be utilized for high performance close-loop control of four-switch three-phase inverter-fed induction motor drive.

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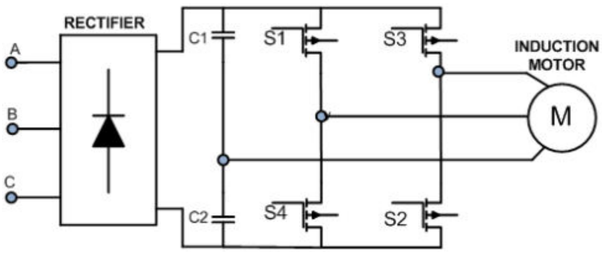

Figure 1: Basic Four Switch Three-Phase Inverter

The four-switch three-phase (B4) inverter, having a lower number of switches, was first presented for the possibility of reducing the inverter cost, and it became very attractive as it can be utilized in fault-tolerant control to solve the open/short-circuit fault of the six-switch three-phase (B6) inverter. However, the balance among the phase currents collapses due to the fluctuation of the two dc-link capacitor voltages; therefore, its application is limited. This paper proposes a predictive torque control (PTC) scheme for the B4 inverter-fed induction motor (IM) with the dc-link voltage offset suppression.

II. RELATED WORK

P. R. Bhimireddy et al., [1] an effective phase reconfiguring concept is proposed for reducing the dc-link voltage requirement of the proposed MLI. In addition, all the possibilities of phase reconfiguring details for proposed MLI-fed 9-phase IM drive are also presented. A three-phase carrier-based space vector pulsewidth modulation is implemented for improving the linear modulation range of proposed MLI configuration further. In contrast with existing 9-phase three-level inverters, like NPC and FC, the proposed MLI configuration requires only one dc link (with half of the magnitude) and lesser number of semiconductor devices.

B. P. Reddy et al.,[2] As compared to conventional nine-phase neutral point and flying capacitor multilevel inverters (MLIs), the requirement of the dc-link magnitude for the proposed topology is reduced by 50%. The nine-phase PPMIM drive is modulated with the carrier-based three-phase space vector pulsewidth modulation in order to enhance the linear modulation range (LMR). The inverter legs associated with two IVPCs per phase in 9-phase 4-pole (9PH-4PO) mode and six IVPCs per phase in 3-phase 12-pole (3PH-12PO) mode are modulated with the same reference wave and phase-displaced triangular waves.

B. Prathap Reddy et al.,[3] This multilevel voltage will improve the torque ripple profile of the motor drive. In addition, the proposed MLI scheme along with phase grouping will enrich the linear modulation range of the pole-phase-modulated induction motor (PPMIM) drive in nine-phase four-pole (9PH-4PO) mode. The switches used to generate a multilevel voltage in 3PH-12PO mode are effectively utilized for blocking the flow of circulating currents. As compared with other conventional nine-phase five-level inverters the proposed five-level inverter requires only 30 switches and it does not require extra clamping diodes/capacitors and extra bidirectional switches for isolating neutrals in 9PH-4PO operation.

S. Shi et al.,[4] It is difficult to control by the conventional strategies. This study proposes a hybrid predictive control strategy with dual loops for this converter. The simulation and experimental results indicate that the proposed method can guarantee the stable operation and good performance.

Z. M. Elbarbary et al.,[5] proposed a fuzzy logic controller (FLC) to mitigate the negative effects of motor parameter variation influence on indirect rotor field oriented control (IRFOC) without proposing a tuning method. However, neither rotor nor magnetizing inductances were investigated. Instead, the variation in stator resistance and load inertia-which have less effect on the orientation algorithm-is demonstrated. This correspondence introduces a typical system model with similar simulation platform and parameters. With identical tests, two errors to the original paper have been found. First, the reported speed which is in rev/min should be in rad/s. Second, the motor speed response to increasing inertia is opposite. The obtained results from the evaluation model confirm the claimed issues which conflict with the interpretations of the commented paper results.

M. S. Zaky et al.,[6] The complete IFOC scheme incorporating the FLC for IM drives fed by the proposed FSTP inverter is built in MATLAB/Simulink, and it is also experimentally implemented in real time using a DSP-DS1103 control board for a prototype 1.1-kW IM. The dynamic performance, robustness, and insensitivity of the proposed FLC with the FSTP inverter-fed IM drive is examined and compared to a traditional proportional-integral (PI) controller under speed tracking, load disturbances, and parameters variation, particularly at low speeds. It is found that the proposed FLC is more robust than the PI controller under load disturbances, and parameters variation.

I. N. El Badsi et al.,[7] The carrier-based PWM strategies under consideration are tested and are verified by experiments using a test bench. Several experimental results are presented to validate this study. The characteristics of the PWM methods are analyzed and compared based on four criteria such as the variation of the root mean square values of stator voltages and currents, mechanical speed and slip versus the stator frequency using the open-loop scalar control.

D. Zhou et al.,[8] However, the control performance of PTC depends on a two weighting factors obtained through a nontrival process and this process is inefficient to be used online. To avoid this process, a fuzzy online tunning of weighting factors based on Sugeno method is presented in this paper. This method can be used for online tuning of more than one weighting factors. A program in MATLAB has been developed to verify the effectiveness of the method.

C. Ashfak et al.,[9] the proposed scheme with conventional DTC for IM fed from six switch and four switch three phase inverter shows interesting performance. Space vector pulse width modulation (SVPWM) is the best technique in comparison with pulse width modulation (PWM) or sinusoidal pulse width modulation (SPWM) because of its lesser total harmonic distortion, wider linear modulation range, their easier digital realization and better DC bus utilization for obtaining the switching voltage vectors. Simulation results show the validity of the proposed scheme.

D. Zhou et al.,[10] The voltage vectors of the B4 inverter under the fluctuation of the two dc-link capacitor voltages are derived for precise prediction and control of the torque and stator flux. The three-phase currents are forced to stay balance by directly controlling the stator flux. The voltage offset of the two dc-link capacitors is modeled and controlled in the predictive point of view. A lot of simulation and experimental results are presented to validate the proposed control scheme.

K. Spandana et al.,[11] The proposed system also reduces six switches three phase inverter to four switches three phase inverter. This makes system compact which reduces cost and switching losses, line harmonics, improves power factor, reliability and extends the output voltage range. The system is modeled using MATLAB simulink. Simulation studies are done with induction motor. Simulation results are presented.

A. Ouarda et al.,[12] This work is aimed at the development of novel direct torque control (DTC) strategies devoted to induction motor (IM) drives fed by two reduced-structure three-phase inverters, such that (i) the four-switch three-phase inverter (FSTPI) also called B4-inverter and (ii) the three-switch three-phase inverter (TSTPI) also called B3-inverter or delta-inverter. The proposed strategies make it possible the emulation of the operation of the conventional six-switch three-phase inverter (SSTPI), thanks to appropriate combinations of the unbalanced voltage vectors intrinsically-generated by the reduced-structure inverters, leading to the synthesis of the six balanced voltage vectors of the SSTPI.

III. FOUR SWITCH THREE-PHASE INVERTER

Photovoltaic a four switch based three phase inverter is proposed for grid connected applications. The number of power electronic switches needed for a conventional three phase inverter topology is six during the overall operation. To optimize the overall power circuit of the micro grid, a cost effective solution for the power circuit is to replace the traditional six switch based three phase inverter with a four switch based three phase inverter topology.

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The four-switch inverter, having a lower number of switches has been studied for the possibility of reducing the inverter cost. In comparison with conventional three phase inverter with six switches, the main features of this converter are the following:

(i) Reduced number of switches and freewheeling diode
(ii) Low cost
(iii) Less complex gate driving circuitry
(iv) Reduction in conduction losses.

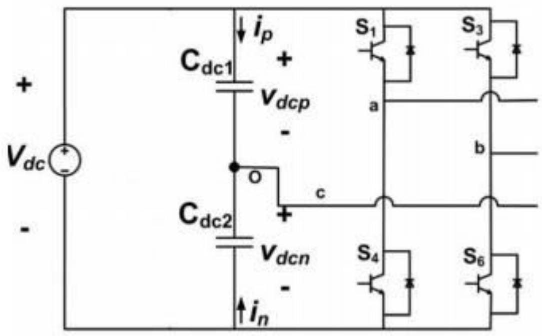

Figure 2: Three Phase Four Switch Inverter

A standard three phase voltage source inverter utilizes three legs with a pair of complementary power switches per phase. A reduced switch count voltage source inverter uses only two legs with four switches as shown in Fig. 2.
The circuit consists of 4 switches S1, S3, S4, S6, and two split capacitors Cdc1 and Cdc2. The dc voltage source Vdc is assumed to be formed by the renewable energy sources. The power circuit is the three phase four switch inverter. Two phases “a” and “b” are connected to the two legs of the inverter, while the third phase “c” is connected to the center point of the dc link capacitors, Cdc1 and Cdc2. The 4 power switches are denoted by the binary variables, where the binary “1” corresponds to an ON state and the binary “0” corresponds to an OFF state. The states of the upper switches (S1, S3) and lower switches (S4, S6) of a leg are complementary that is S4 =1− S1 and S6 =1− S3.

IV. CONCLUSION AND FUTURE WORK

In this paper, application of four power semiconductor switch based three phase inverter has been studied for renewable energy based generalized three phase micro grid interconnection. A simple SPWM is used to control the switching of the four switches. The current control of the inverter ensures proper active and reactive power flow from the grid along with grid current THD control in the presence of the nonlinear load at the grid. The simulation results are evaluated and verified. A three phase four switch inverter uses only four switches. It replaces the two switches with two capacitors and came as a cost effective solution for interfacing renewable sources and micro grid.

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