Induction Motor Control With Small Dc-Link Capacitor Inverter Fed By Three-Phase Diode Front-End Rectifiers

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Abstract- *This proposed work presents a small film capacitor inverter based induction motor control approach to enhance with reliability and power density of three-phase variable speed drive applications. The object of this work is a robust hybrid motor controller is developed to prevent performance degradation caused by the electrolytic capacitor-less inverter fed by front-end diode rectifiers.*

The structure of the controller combines a model-based controller (MBC) and a hexagon voltage manipulating controller (HVC). The MBC determines the command output voltage with the intersection of the torque and rotor flux linkage command. In the HVC mode, the command voltage vector is determined simply by the torque command and the hexagon-shaped inverter voltage boundary. Successful application of the control approach is corroborated by a graphical and analytical means that naturally lead to a single voltage selection rule. This proposed work also examines the operation sensitivity under motor parameter drifts to determine how to decouple its effect using a voltage disturbance state-filter design. The proposed system is simulated by using MATLAB/SIMULINK.

Keywords- Hexagon voltage manipulating controller(HVC), model based controller(MBC), small film capacitor inverter, Front-end diode rectifiers

I. INTRODUCTION

In low-cost three-phase variable speed drive applications, such as heating-ventilating-air-conditioning (HVAC) systems, diode rectifiers are commonly used as the front-end circuit for non-regenerative ac–dc conversion because of their lower cost and higher reliability [1]. In these types of low-cost ac drive systems, aluminum electrolytic capacitors are commonly used to balance the difference between the instantaneous input and output power as well as suppress the voltage spikes caused by leakage inductance and switching operations, as shown in Fig. 1 [2], [3]. On the other hand, the dc-bus capacitor is not only bulky and heavy but it is also one of the least reliable components on various power electronic topologies. Furthermore, the parasitic lead inductance can cause voltage spikes, which are a major factor in the failure of power electronic devices.

A failure survey of switch mode power supplies reported that electrolytic capacitors are responsible for more than half of the breakdowns of an inverter [4]. Therefore, there is increasing interest in the monitoring lifetime of electrolytic capacitors for reliable and safe operation [4]–[7]. On the other hand, offline monitoring techniques [4], [5] require additional measurements as well as a prior data for the reference model, which makes monitoring process complicated and difficult. A previously reported online method [6] for estimating the capacitance cannot be applied to inverters fed by diode rectifiers. In this regard, a range of regenerative converters and control methods have been proposed in order to minimize or reduce these passive components on a dc bus. The focus of most studies has been on how to reduce the dc-bus capacitor of three-phase pulse width modulation (PWM) rectifiers and single-phase diode rectifiers [7]–[11]. All previous studies were equipped with a conventional closed-loop current controller to regulate the air-gap torque and flux linkage of ac motors.

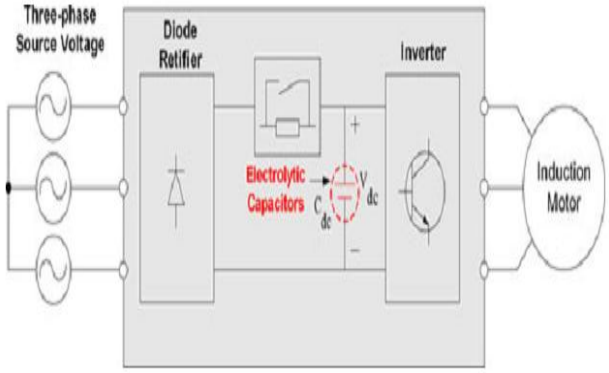

Fig. 1. Three-phase diode rectifier and PWM inverter for IM drive

However, instantaneous current control in a small dc-bus capacitor inverter with the diode rectifier front-end is not straightforward because the dc-link voltage and output power to the motor decrease periodically due to the absence of energy storage. This rapid dc voltage reduction drives the motor to be operated frequently in the field-weakening region below a based speed. Therefore, the current control strategy becomes more complicated under voltage-limited conditions because multiple objective sub-controllers, such as field-weakening, anti-windup control, and overmodulation scheme, should be designed carefully based on the complex tradeoff between the sub-control actions and current control dynamics . Furthermore, realization of the maximum voltage utilization fails because a circular voltage limit is considered an operation boundary instead of a hexagonal limit .

This proposed work presents a position sensor-less vector-controlled induction motor (IM) drive system integrated into HVAC applications. The motor power is supplied by a small dc-link film capacitor inverter fed by a three-phase diode front-end rectifier. A PI motor-current-regulator-free control strategy is proposed to meet the aforementioned challenges by combininga model-based controller (MBC) and a hexagon voltage manipulating controller (HVC). The MBC finds the command output voltage with the intersection of the torque and rotor flux linkage command. In the HVC mode, the command voltage vector can be determined simply by the torque command and the hexagon voltage boundary. The MBC is performed under non-limited conditions and motor control is handed automatically over to the proposed HVC in the voltage shortage region. These voltage selection rules allow for the choice of an objective voltage vector in the absence of PI control gains, sub-controllers, and observers for closed-loop control. The control strategy was implemented on a 1.5-kW IM drive that was equipped with a 20-μFfilm capacitor to confirm its feasibility. In the proposed work effort has been made made to overcome all these disadvantages.

II. LITERATURE REVIEW

Below is a literature review of works carried out in last few years by following papers

[1] K. W. Lee, M. Kim, J. Yoon, S. B. Lee, and J. Y. Yoo, "Condition monitoring of dc-link electrolytic capacitors in adjustable-speed drives,"IEEE Trans. Ind. Appl., vol. 44, no. 5, pp. 1606–1613, Sep./Oct. 2008. : In this paper author discussed about a new sensor-less technique for monitoring the condition of inverter dc link aluminum electrolytic capacitors based on equivalent series resistance, ESR, and capacitance, C, estimation is proposed in this paper. The main concept of the proposed method is to estimate ESR and C of the capacitor using the inverter whenever the motor is stopped. The parameters are estimated from the dc link voltage and stator current measurements available in the inverter with the switched dc link voltage applied to the motor stator winding. The temperature of the capacitor can also be estimated under thermal equilibrium based on the stator resistance estimate to take the influence of temperature variation into account. An experimental study on a 250 W permanent magnet synchronous motor performed under accelerated capacitor degradation is presented to verify the proposed technique. It is shown that the proposed method provides a reliable and sensitive indication of capacitor aging without additional hardware requirements.

[2] M. L. Gasperi, "Life prediction modeling of bus capacitors in AC variable frequency drives,"IEEE Trans. Ind. Appl., vol. 41, no. 6, pp. 1430–1435, Nov./Dec. 2005.: This paper explains aboutAluminum electrolytic capacitors are the leading choice for ac variable-frequency drive (VFD) bus filters. Predicting the expected life of these components in this application is complicated by four factors. First, the electrical impedance of aluminum electrolytic capacitors is nonlinear with both frequency and temperature. Second, motor drives produce a spectrally rich ripple current waveform that makes energy loss difficult to compute. Third, the heat transfer characteristic of capacitor banks is dependent on design geometry. Fourth, the expected life of aluminum electrolytic capacitors is extremely sensitive to operating temperature. This paper describes a method for predicting bus capacitor life that addresses these problems by using a multiple component model for capacitor impedance, a motor drive simulation to create ripple current waveforms, a heat transfer model based on bank geometry, and a capacitor life model derived from the device physics of failure. An example is given showing the effect of ac line impedance on the relative expected life.

[3] A. Layhani, P. Venet, G. Grellet, and P. J. Viverge, "Failure prediction of electrolytic capacitors during operation of a switchmode power supply," IEEE Trans. Power Electron., vol. 13, no. 6, pp. 1199–1207, Nov. 1998. : In this paper author discussed aboutElectrolytic filter capacitors are frequently responsible for static converter breakdowns. To predict these faults, a new method to set a predictive maintenance is presented and tested on two types of converters. The best indicator of fault of the output filter capacitors is the increase of ESR (equivalent series resistance). The output-voltage ripple ΔVo of the converter increases with respect to ESR. In order to avoid errors due to load variations, ΔVo is filtered at the switching frequency of the converter. The problem is that this filtered component is not only

dependent on the aging of the capacitors, but also on the ambient temperature, output current, and input voltage of the converter. Thus, to predict the failure of the capacitors, this component is processed with these parameters and the remaining time before failure is deduced. Software was developed to establish predictive maintenance of the converter. The method developed is as follows. First, a reference system including all the converter parameters was built for the converter at its sound state, i.e., using sound electrolytic filter capacitors. Then, all these parameters were processed and compared on line to the reference system, thereby; the lifetime of these capacitors was computed.

[4] A. M. Imam, T. G. Habetler, R. G. Harley, and D. M. Divan, "Real-time condition monitoring of the electrolytic capacitors for power electronics applications," inProc. IEEE Appl. Power Electron.Conf., 2007, pp. 1057–1061.: The objective of this paper is to propose a new low cost method to detect the changes in equivalent series resistor (ESR) and the capacitance value of an electrolytic capacitor in order to realize the real-time condition monitoring of an electrolytic capacitor. Experimental and simulation results are discussed to illustrate the proposed condition monitoring technique. In addition, it is shown that the proposed method can be used for a non-stationary system where waveforms are continuously varying in amplitude, frequency, and phase. The proposed on-line failure prediction method has the merits of low cost and circuit simplicity.

[5] A. Yoo, S. K. Sul, H. Kim, and K. S. Kim, "Flux-weakening strategy of an induction machine driven by an electrolytic-capacitor-less inverter,"IEEE Trans. Ind. Appl., vol. 47, no. 3, pp. 1328–1336, May/Jun. 2011. : This paper presentsAnovel flux-weakening strategy for an induction machine driven by an electrolytic-capacitor-less inverter. In the electrolytic-capacitor-less inverter, the dc-link voltage is fluctuating at six times the frequency of the input three-phase source due to its small dc-link capacitance. Hence, the decoupling of the fluctuation and maximum utilization of the dc-link voltage is a major issue in the electrolytic-capacitor-less inverter. In this paper, the cost function is set to increase the voltage utilization of the inverter for the flux-weakening operation of an induction machine. With the proposed flux-weakening strategy, the operating speed of the induction machine is extended above the base speed without any stability problems. The experimental results show the effectiveness of the proposed strategy.**[6] L. Malesani, L. Rossetto, P. Tenti, and P. Tomasin, "AC/DC/AC PWM converter with reduced energy storage in the DC link,"IEEE Trans. Ind. Appl., vol. 31, no. 2, pp. 287–292, Mar./Apr. 1995**. :The paper introduces the family of quasi-direct converters, i.e., forced-commutated AC/DC/AC power converters including small energy storage devices in the DC link. In particular, the case of the three-phase to three-phase quasi-direct power converter is considered. Since energy storage minimization calls for instantaneous input/output power balance, a proper control strategy is needed. The paper describes a simple and effective control technique which also provides high-power factor and small distortion of the supply currents. After a discussion of the general properties of quasi-direct power converters, design criteria of both power and control sections are given, and experimental results of a 2-kVA prototype are reported.

III. PROBLEM STATEMENT

In low-cost three-phase variable speed drive applications, such as heating-ventilating-air-conditioning (HVAC) systems, diode rectifiers are commonly used as the front-end circuit for non-regenerative ac–dc conversion because of their lower cost and higher reliability. The dc-bus capacitor is not only bulky and heavy but it is also one of the least reliable components on various power electronic topologies. The parasitic lead inductance can cause voltage spikes, which are a major factor in the failure of power electronic devices. A failure survey of switch mode power supplies report that electrolytic capacitors are responsible for more than half of the breakdowns of an inverter. The maximum voltage utilization fails because a circular voltage limit is considered an operation boundary instead of a hexagonal limit.

IV. OBJECTIVE

The main objective of this proposed work is a small film capacitor inverter based induction motor control approach to enhance with reliability and power density of three-phase variable speed drive applications. A robust hybrid motor controller is developed to prevent performance degradation caused by the electrolytic capacitor-less inverter fed by front-end diode rectifiers. The structure of the controller combines

- A model-based controller (MBC) .
- A hexagon voltage manipulating controller (HVC).

A. SUB OBJECTIVE OF PROJECT-

Below are the sub objectives to complete project in modular form

a) Study the issues of electrolytic capacitor and its consequences: -This section includes study the issues of electrolytic capacitor and failure causes of that .

b) Design and study the suitable installation of a small film capacitor inverter based induction motor: This section includes design of capacitor inverter based induction motor by replacing electrolytic capacitor with small film DC link capacitor.

c) Detailed study of the proposed model using the structure of the controller combines a model-based controller (MBC) and a hexagon voltage manipulating controller (HVC):- This section includes detailed study of proposed system determine all parameter in the motoring operation the dc-link voltage, flag signal, air-gap torque, and rotor flux linkage are illustrated from top to bottom& design with MATLAB /SIMULINK.

V. SCOPE OF THE PROJECT

A PI motor-current-regulator-free control strategy is proposed to overcome the problems by Electrolytic capacitor by combining a model-based controller (MBC) and a hexagon voltage manipulating controller (HVC). The MBC finds the command output voltage with the intersection of the torque and rotor flux linkage command. In the HVC mode, the command voltage vector can be determined simply by the torque command and the hexagon voltage boundary. The MBC is performed under non-limited conditions and motor control is handed automatically over to the proposed HVC in the voltage shortage region. These voltage selection rules allow for the choice of an objective voltage vector in the absence of PI control gains, sub-controllers, and observers for closed-loop control. The control strategy was implemented on a 1.5-kW IM drive that was equipped with a 20-μFfilm capacitor to confirm its feasibility.

VI. METHODOLOGY

- Collection and detailed analysis of the relevant literature to arrive at central idea of the proposed work.
- Study the issues of electrolytic capacitor and its consequences.
- Design and study the suitable installation of a small film capacitor inverter based induction motor control approach to enhance with reliability and power density of three-phase variable speed drive application
- Detailed study of the proposed model using the structure of the controller combines a model-based controller (MBC) and a hexagon voltage manipulating controller (HVC).
- Design of Motor controller with MATLAB/SIMULINK
- Simulation of entire model in MATLAB/SIMULINK&study the various performance parameters.
- Analysing the simulation results.7.

VII. CONCLUSION

This proposed work of the controller design of a position sensor-less vector-controlled IM drive system supplied from a small dc-link film capacitor inverter fed by a three-phase diode frontend rectifier. The proposed approach focuses on the controller performance when entering or leaving the infeasible voltage domain. The PI motor-current-regulator-free control structure presents a smooth transition from the MBC under the unconstrained voltage region to the HVC when the voltage limit is encountered.

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