

High Performance Indirect Current Control Scheme for BLDC Motor using Four Quadrant Converters

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Abstract— In the recent trends of railway traction, Four Quadrant Converters are mainly used. To describe the four quadrant using DC output to inverter control brushless dc (BLDC) motor drive for various applications. Brushless DC motor drives are becoming more popular in industrial & traction applications. In addition to Indirect current control (ICC) is also an alternative in high power, low switching frequency applications. For effective operation of the developed system, a novel indirect current controlled pulse width modulation scheme is designed and implemented to produce the desired static and dynamic speed-torque characteristics. This project demonstrates the BLDC motor is modeled as star connected with isolated neutral and the voltages supplied are line-line but current commutation is controlled by solid state switches. The commutation instant is determined by the rotor position. The BLDC motor drive system along with the control system for speed and current has been present using MATLAB.

Key words: BLDC Motor, Inverter, Four Quadrant Converter

I. INTRODUCTION

High power AC/DC/AC traction drive systems fed from single-phase AC power supplies are widely used in railway applications [1], [2]. A typical structure of such a system is shown in Fig. 1. Four quadrant converters (4QCs) are commonly applied as front end to provide bi-directional power flow, controllable power factor and Electromagnetic Interference is required. [2]-[5],[12].

The performance of four quadrant energy conversion mainly depends on the control of active and reactive current. For megawatt-level traction drives, switching frequency is limited to several hundred hertz, typically 500 Hz or lower [1]. Control methods based on direct current can still be applicable for 4QC [6], [7]. As a result, control scheme with a fast current circle inside a slow voltage circle are not effective. [8]. In a Phase and Amplitude Control, Fourier analysis, transformation of reference frame, and small-signal linearization sets-the steady-state solution, various active transfer functions, and the harmonic components-are obtained from the three models [10].

In Indirect Current Control (ICC), AC current is indirectly forced by the magnitude and phase of the voltage phasor at AC side of 4QC. AC current is basically open-looped and its conversion from one steady state to another is determined by the natural response of AC side circuit. The time constant of AC side line impedance is usually as long as several fundamental periods, which leads to long-lasting DC offset and significant exceed current in dynamic process. These drawbacks can affect the stability of

4QC [10]. Therefore, dynamic performance of ICC does not be improved [9],[10]. In a Modified ICC method effectively improves the dynamic performance but fast current response is demanded, the compensator may output a big value of control voltage, which draws the 4QC into over-modulation operation becomes invalid[13],[14].

In the case of designing DC voltage controller, small-signal model is generally adopted since the state equations are nonlinear [17]. However, small-signal modeling is quite complex. state-equations of the power converter is applicable to both the two-level and three-level H-bridge topologies. So classical control design techniques can be used. To overcome the above drawbacks, separate steady-state and linearized small-signal explanations. The steady-state model aids design of the converter power circuit. The small-signal form provides a basis for quantitative control design. The power converter is essentially a two-input two-output system with cross-coupling between the inputs and output [10]. Firstly, to achieve independent control of active/reactive power and improve the dynamic response of AC current, a transient-free method of ICC is proposed. By this method, AC current can directly shift from initial steady state to the demanded one without transient process. Line-current harmonics and grid stability are major concerns for the control of a traction vehicle line-side converter. To achieve best dynamic performance the resonant circuit taking up the single-phase power pulsation has to be considered [6]. At last, parameter sensitivity as well as weak grid adaptability of the proposed current control scheme is proved.

II. PROPOSED SYSTEM CONFIGURATION

The figure 1 shows circuit diagram. It consists of four quadrant converter, L-C filter, Inverter and BLDC motor. Here we are using high efficient Ac to Ac converter for traction purpose. Here we are converting 1phase ac to dc then to 3phase ac supply. Adjusting moments of active and reactive current are specified and grid current can immediately get into expected steady state operation without transient process, successfully getting rid of DC offset and overshoot in AC current response. We are using 3 phase inverter for the single phase dc to 3 phase AC supply.

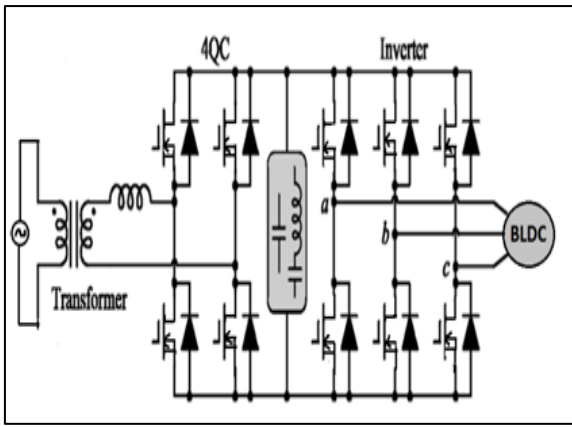


Fig. 1: Typical AC fed BLDC Motor Drive System

The performance of four quadrant energy conversion mainly depends on the control of active and reactive power, i.e. active and reactive current. Four quadrant converters (4QCs) are widely applied as front end to provide bi-directional power flow, controllable power factor and constant voltage.

III. CONTROLLER DESCRIPTION

The interface circuit and the software for control operation are designed with consideration of a short sampling time to achieve a better presentation. In order to make the control algorithm executable in real time, a simple PI (Proportional Integral) control algorithm has been developed. Timer overflow break up has been used instead of polling to help to shorten the calculation time. The implementation of the PI controller has been done by writing the assembly language program. The digital controller parameters were selected purely from the standpoint of the performance and physical realization in the analytical and theoretical sense.

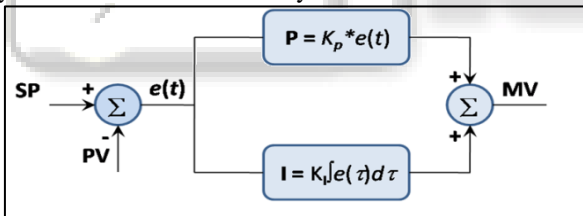


Fig. 2: PI Controller Block Diagram

The output of the PI-controller is V0

$$V_0 = K_p * e(kT) + K_i * u(kT) \dots \dots \dots (1)$$

$$V = K_p * e(kT) + K_i * \{u[(k-1)T] + T e(kT)\} \dots \dots \dots (2)$$

The PI algorithm uses a new tool to generate an analog like output directly from the microcontroller without using any DAC (digital to analog converter). This technique is known as the PWM (Pulse Width Modulation). In PWM a square wave is generated with a constant frequency, and adjust in the On-Time or Off-Time of the square wave. By clamping the duty-cycle speed of change, variation related to the average output current. The following equation shows the relation between duty cycle and average output voltage.

$$V_{av} = V_{in} \frac{T_{on}}{T_{on} + T_{off}} \quad (3)$$

With PI algorithm features, the microcontroller generates PWM with varying duty cycle resulting effective control action signal across the motor

IV. SIMULATION RESULTS

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. MATLAB for further analysis. Simulink, developed by Math Works, is a viable tool for model, simulate and analyze multi-domain dynamic systems. Its primary edge is a graphical block diagramming tool and a customizable set of block libraries. It offers tight combination with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in control assumption and digital signal processing for multi-domain simulation and Model- Based Design. Simulink is a building block diagram environment for multi-domain simulation and Model- Based Design. It supports scheme level design, simulation regular code generation, and continuous test verification of embedded system.

The figure 3 shows the simulation diagram of indirect current control scheme for BLDC motor using four quadrant converters. Four quadrant converters convert single phase AC supply into DC supply. Inverters convert DC supply into three phase AC supply. This is a two stage conversion.

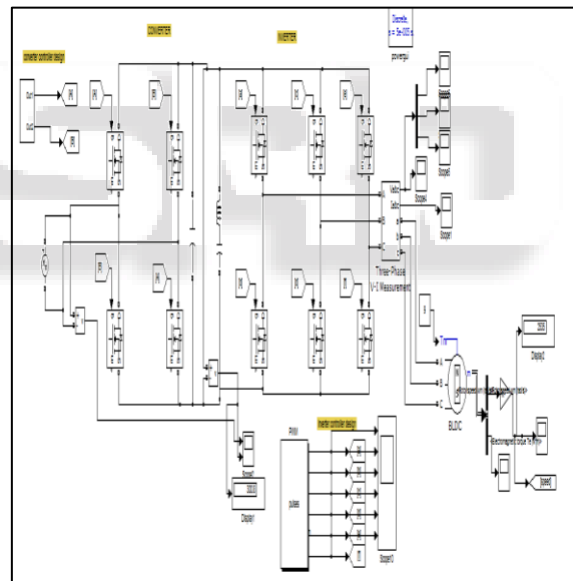


Fig. 3: Simulation Diagram of Indirect Current Control Scheme for BLDC Motor.

By giving the input voltage is 311V. This is the single phase AC input voltage waveform. When the X axis is Time and Y axis is voltage.

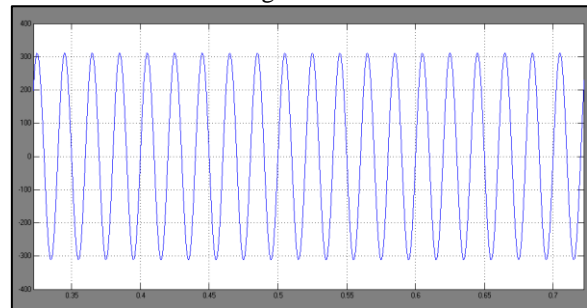


Fig. 4: Waveform of Single Phase AC Input Voltage

This is the three phase output voltage waveform of the inverter. Output voltage range is 290V. Voltage is to be controlled by using PWM techniques.

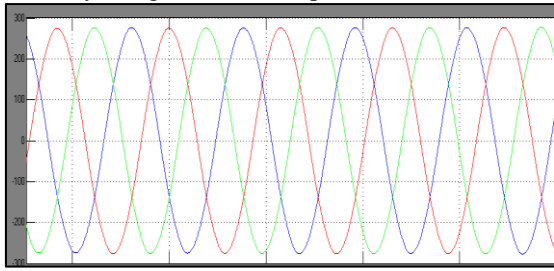


Fig. 5: Waveform of Three Phase Output Voltage

This is the output current waveform of the inverter. AC Current and DC voltage are indirectly controlled. Inverter Output current value is 7A.

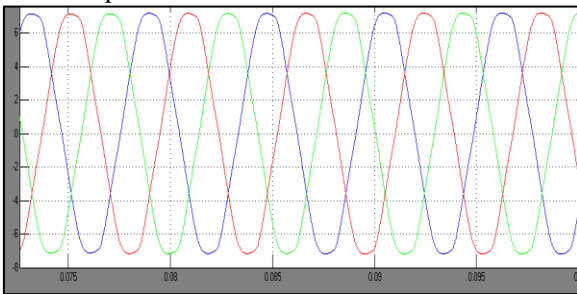


Fig. 6: Waveform of Three Phase Output Current

This is the DC voltage waveform. When the X axis is time and Y axis is voltage. DC voltage range is 300V

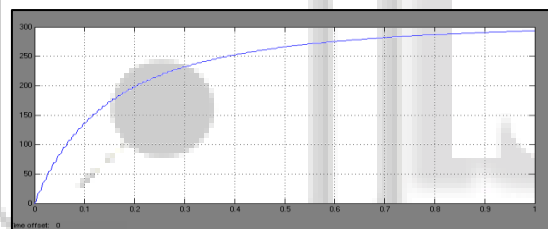


Fig. 7: Waveform of DC Voltage

This is the Inverter phase voltage of one phase. Phase voltage range is 100V.

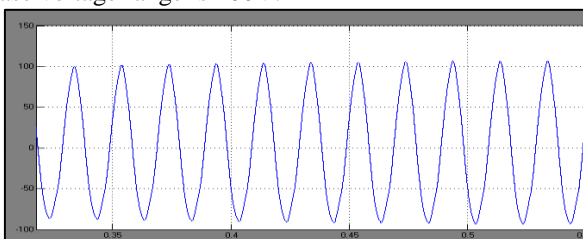


Fig. 8: Waveform of Inverter Phase Voltage

When the load is BLDC motor. Motor speed is to be controlled by using PI controller. Speed range is 2500rpm.

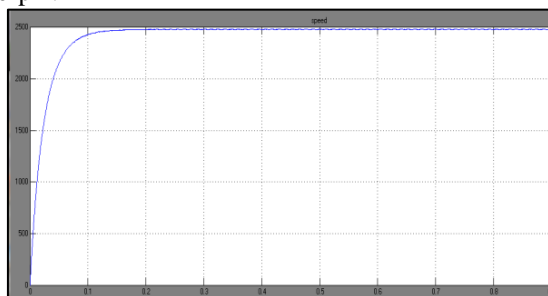


Fig. 9: Waveform of BLDC Motor Speed

V. CONCLUSION

The modeling procedure presented in this project helps in simulation of various operating conditions of BLDC drive system. The performance estimation results show that, such a model is very useful in studying the drive system before taking up the enthusiastic controller design, accounting the relevant active parameters of the motor. The simulation model of the BLDC motor drive system with PI control based four switch three phase inverter on MATLAB/Simulink platform is presented. And also in this paper, the four switch inverter topology is studied to provide a possibility for the realization of low cost and high performance three phase BLDC motor drive system.

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