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DESIGN AND DEVELOPMENT OF SMC BASED SPEED CONTROL OF PERMANENT MAGNET DC MOTOR DRIVE FOR EV APPLICATIONS

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Abstract--- The main aim of the paper is to design and develop a Sliding mode Controller which can control the speed of Permanent Magnet DC motor drive for EV Applications which represents a novel approach for controlling the speed of a Permanent Magnet DC motor, which is a critical component of an Electric Vehicle (EV). The proposed technique is based on Sliding Mode Control (SMC) and is capable of controlling the speed of the motor accurately and efficiently. The paper begins by providing an overview of the requirements for an EV motor drive system and the existing control methods. It then explains the SMC technique and its advantages over other control methods. Overall, the paper presents a significant contribution to the field of EV motor drive systems, and the proposed SMC-based speed control system has the potential to improve the performance and efficiency of EVs.

Index Terms **– Permanent Magnet, DC Motor, Sliding Mode Controller, SMC, Electric Vehicle**

I. INTRODUCTION

Electric vehicles (EVs) have gained significant attention in recent years due to their potential to reduce greenhouse gas emissions and improve energy efficiency. Permanent Magnet DC (PMDC) motors are commonly used in EV applications due to their high efficiency, low cost, and simple control structure. However, the speed control of PMDC motors is a critical task that requires robust and precise control to ensure efficient and reliable operation of the motor. Sliding Mode Control (SMC) is a robust and nonlinear control technique that can be used for the speed control of PMDC motors used in EV applications. SMC-based control provides accurate speed tracking, fast transient response, and smooth control action, making it an ideal choice for EV applications. The SMC-based control technique is designed to make the system insensitive to parameter variations, disturbances, and modeling uncertainties. The SMC-based controller generates the control signal for the motor driver circuit based on the feedback from the sensors, which in turn controls the speed and direction of the motor. The experimental results of the SMC-based speed control of PMDC motor drive have shown promising performance in terms of speed tracking accuracy, robustness, fast transient response, and improved energy efficiency. Permanent Magnet (PM) motors are by far the biggest user of permanent magnet materials capturing 60 percent of the PM market. The explosive rate of growth of PM motor market, exceeding 25% annually in the last decade, not only relied on discovery of high energy PM materials like NdFeB motor drive technologies. These include high frequency high power semiconductor switches like IGBTs and MOSFETs and microelectronic data processing hardware like microcontrollers.

II. MATHEMATICAL MODEL

The system model including a PMDC motor with a sliding mode control is shown in the block diagram. The mathematical description of the system in state space is represented by the following state equations:

$$\dot{x} = Ax + Bu + Fw \ , \quad x(0) = 0$$

$$x = [x_1, x_2, x_3]^T = \left[\int (\omega_{ref} - \omega_r)dt, \omega_r, i_a\right]^T \tag{1}$$

where x is the state vector, with x1(integral of speed error), x2(ωr : speed), and x3 (ia : motor armature current) as states; u is the control signal; ωref is the motor speed reference input (speed command), ωre is speed deviation and L T is load torque. The motor armature voltage, Va , is used as the control signal. System parameters are motor friction coefficient, f; motor inertia coefficient, J; motor torque constant, Km; armature resistance Ra and armature inductance La.

III. SLIDING MODE CONTROL

The motor control system behavior in transient condition consists of two modes of operation. One is the reaching mode in which the state trajectory moves from the initial conditions towards the switching surface. The other one is the sliding modein which the state trajectory slides on the switching surface towards the steady state condition. Therefore,designing the controller consists of two steps; selecting a proper switching surface, and determining an adequate control signal.

IV. BLOCK DIAGRAM FOR PROPOSED SYSTEM

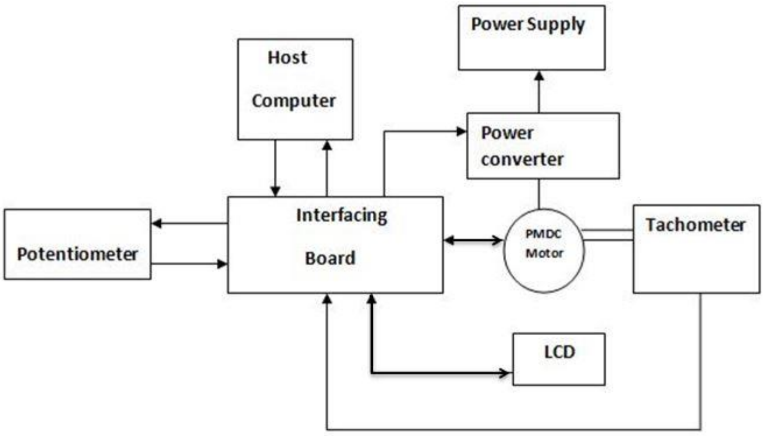

Fig. 1 Block diagram of proposed system

The above block diagram perfoms a systematic procedure which are as follows using the host computer , the program code is dumped into the interfacing board. The dumped code is excuted respectively and performs all the tasks and programs mentioned in the code.The dc power supply is supplied to the buck converter which supplies the required voltage and current to the circuit. Using slide mode control, the actual speed of motor is compared with the reference speed, when actual speed is less than the reference speed, then the voltage and current is increased using potentiometer to increase the speed which will be equal to the reference speed and vice-versa.The actual speed should be equal to reference speed which indicates that the motorcontrol system is stable. Sliding mode control uses a sliding surface which is designed in between the actual speed and reference speed. The speeds are mesured using speed sensor or tachometer which sends data to microcontroller which displays the speed in liquid crystal display. The motor speed responses are compared at load condition and no load condition observed.There are certain parameters which are applied to achieve the desired performance by both hardware and software and the observation are noted respectivel

V. DC-DC BUCK CONVERTER

To overcome the problems like battery life, power dissipation in controlled circuits that occur due to converters and to increase its efficiency the requirement involved is converting the battery voltage to low supply voltage. Low input voltage is best suited for buck converter.

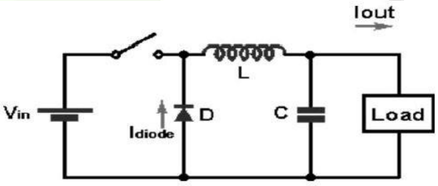

Fig.2 DC-DC Buck Converter

DC/DC Buck power converter parameters are constituted as a capacitor C, input voltage Vin, switch of transistor S, an inductor L, a diode D, and a load resistance RL. Let the current through the converter be iL and voltage across the resistor is VR. Voltage across the resistor VR is in opposite polarity with input voltage Vi. When the converter switch S is turned on the voltage Vi is applied through the inductor L, capacitor C and load resistor RL. When switch is turned off the inductor L acts as source and energy passes through the capacitor C and to load RL

Table.1 Design Specifications for buck converter

Quantity	***Existing***	***Proposed***
R	61 7ohms	61 7
L	118.6mH	11.86mH
C	114.4uF	11.44uF
E	56 V	56

Considering the parametric uncertainties, the simulation results closed-loop of dc/dc Buck power converter fed to dc motor system in the synthesized controller, the nominal values used for the Buck converter parameters mentioned above in the table respectively. The nominal values of GNM5440E dc Engel motor (24V, 95W), connected to a reduced ratio of 14.5:1 gearbox

(G3.1) was used for simulation purpose is as follows ^e⁼12.01 x 10-2N - m/A, La=o. 222 x 10-2H 12.01 x s/rad, 11.82 x 10-2 kgm2^a⁼965 mQ, b 129.6 x 10-3N – ms. Control gains associated to motor and converter is a = 15, < = 2 120. 0.001; 6= 50. The desired angular velocity trajectory or was proposed is given by where tis the time.

VI. RESULTS AND DISCUSSION

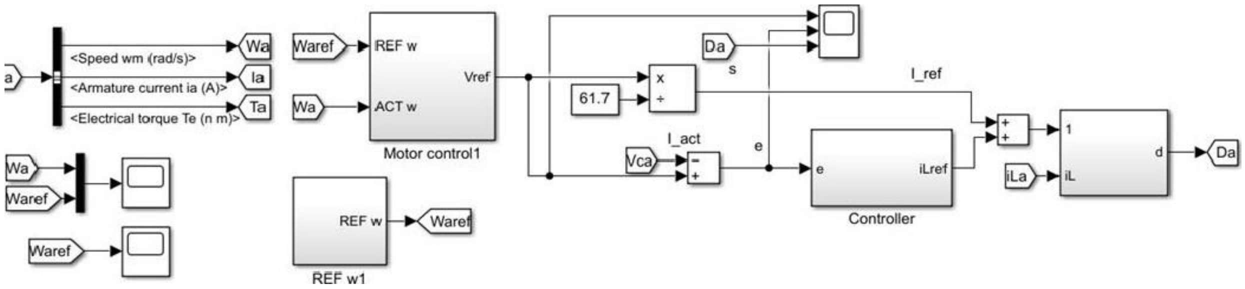

Fig. 3 Simulink model of slide mode control

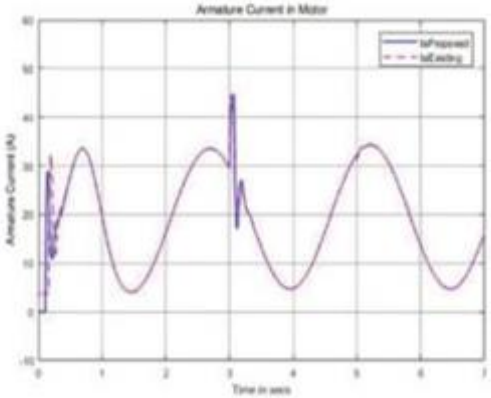

Fig.4 Armature current of motor

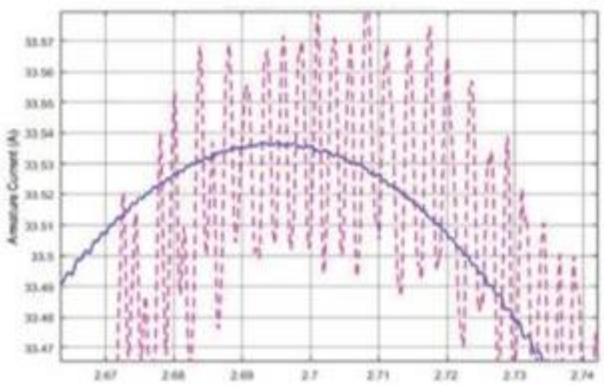

Fig.5 Zoomed view of armature current of motor

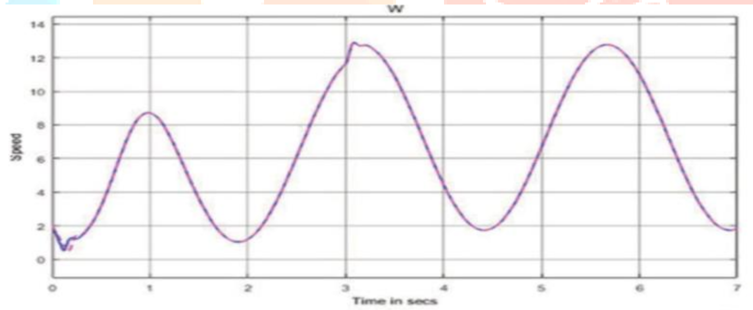

Fig.6 Speed response of motor under SMC

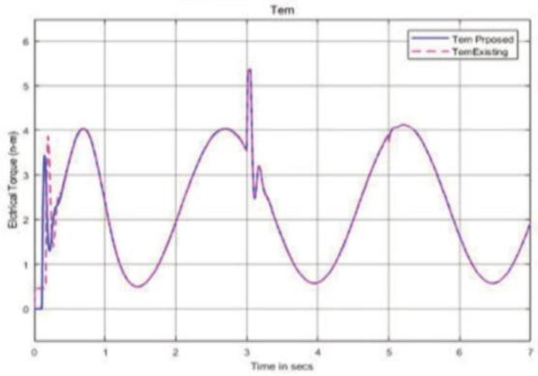

Fig.7 Electrical torque of motor

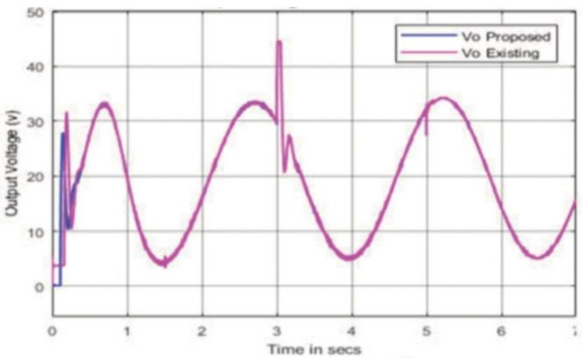

Fig.8 Output voltage of buck converter

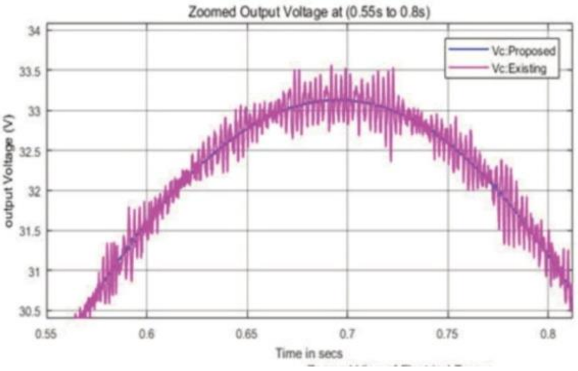

Fig.9 Zoomed view of Output voltage of buck converter

The numerical validation of the proposed control scheme in governing the converter motor system has been performed in a simulated environment using MATLAB/Simulink. The simulation test has been run with sampling time of Ts = 0:001s. The target motor shaft angular velocity has been set to! d = 500 rad/sec. The performance of the considered SMC method has been quantitatively. compared here with that of conventional, ideal PID, with its proportional, integral respectively. The parameters of the simulated plant as well as the tuned observer and controller gains are listed in Table 1. In order to establish a fair base for comparison, PID and SMC were empirically tuned to provide similar control performance in the nominal plant operating conditions (i.e., no load torque disturbance: _L = 0). Both controllers were run with zero initial conditions. The robustness of both tested controllers against unmodeled load torque disturbance (L, 0) has been verified by applying a following user-defined disturbance. The results of the conducted numerical study are gathered in Figs. 4-9. In all the figures, the comparison between conventional PID and proposed SMC is presented systematically.

VII.CONCLUSION

In this work, the problem of controlling a DC-DC buck power converter-DC motor systems has been investigated. The motor shaft angular velocity had to be regulated in spite the influence of unmodeled load torque disturbance. A combination of a special state transformation, load torque observer, and sliding mode controller has been proposed to comprehensively address the problem. The conducted simulation tests showed the effectiveness of the proposed approach in on-line disturbance estimation and rejection. The sliding mode controller provided additional robustness against modeling discrepancies. The entire scheme has also been validated through a dedicated stability proof with stability conditions established.

VIII.FUTURE SCOPE

Future work will revolve around mitigating the chattering effect, while retaining the desired features of the proposed control scheme (i.e., adaptability to different unknown load torques, robustness against plant parametric variations) as well as experimental validation on a laboratory tests.

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