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DIGITALIZED ELECTRONICALLY COMMUTATED MOTORS FOR E-BIKE

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Abstract: **Now a day, environments get polluted due to more vehicle emission and having lack of source to a vehicle. To build less polluted environment and to reduce fuel cost for a vehicle, move to use E-bike. In today's, market E-bike is available with controller, which triggers switches without sensing the hall sensor output .Due to insensible operation of controller, motor getting transient damages. In addition to this, controller supplied by high power range battery connected in series. Due to this, weight and cost of the overall e-bike**

To overcome this limitation, move to use of digital electronic commutation controller with dual boost controller. Because, the digital controller having precision control and high efficient outputs with low cost. This paper shows the implementation of 3-phase BLDC motor drive by digital commutator with double boost controller as a source. The method shown utilizes the HALL sensors in the motor to determine the motors rotor position and effect commutation. Finally, the proposed topology is simulated by MATLAB/SIMULINK and verified by using hardware. Main goal of this paper is increase the life span and efficiency of motor with low cost.

***Index Terms*—Brushless dc (BLDC) motor drives, electronically commutator unit (DECU), inverters, dual boost converters.**

I. I.INTRODUCTION

Permanent magnet dc motors with trapezoidal and sinusoidal back EMF have several advantages over other dc motor types. As compared to dc motors, they are lower maintenance and they have a high-power density due to the elimination of the mechanical commutation which makes them for high-torque-to weight ratio [1]. Compared to induction motor, they have lower inertia and allowing for faster dynamic response.

Also, they are more efficient due to the permanent magnets which results in virtually zero rotor losses [2]. The major disadvantage with permanent magnet motors is their higher cost and relatively higher complexity introduced by the power electronic converter used to drive them. The added complexity is evident in the development of a torque/speed regulator. Using the d − q transformation to ease the complexity of analyzing three phase machines may serve to design an adequate controller. However, development of a controller based on the transformation of the a − b − c equations to the d − q variables is only advantages for permanent magnet motors with sinusoidal back EMF. Applying the d − q transformation to a trapezoidal back EMF motor does not eliminate the angle dependent phase inductances [3]. The author in [1] applied the d − q transformation to a brushless dc (BLDC) motor by fixing the synchronous reference frame to the instantaneous rotor flux linkage instead to the rotor geometric axis. However, this method is cumbersome since the instantaneous rotor flux linkage must be found experimentally and programmed into a digital signal processor (DSP). Sliding mode control techniques have proved to be computationally extensive when adaptive parameter estimation is used to estimate load parameters [4], [5].

Hysteresis current control and pulse width-modulation (PWM) control coupled with continuous control theory produce the most widely used BLDC motor control techniques [6], [7]. Hysteresis current control is essential toward achieving ad equate servo performance [8], namely instantaneously torque response yielding faster speed response compared to PWM control. For most applications, a proportional-integral current and speed compensators are sufficient to establish a well-regulated speed/torque controller. In other cases, a state feedback control is needed to achieve more precise control of the BLDC motor.[1] Classic control theory and linear system theory are well understood, but are highly complex and require extensive control systems knowledge to develop a well-designed controller.[15] Novel digital controller proposed different states of motor with comparator. But it is not sufficient for high speed and torque application.

Discrete control theory allows for such controllers to be digitally implemented with microcontrollers, microprocessors, or DSPs. Digitizing analog controllers serves to add complexity to the overall design procedure. It is important to note that digital implementation of a continuous control technique does not produce a pure digital controller. Instead, what results is a digitally implemented non digital control technique. This paper proposes a digital electronic controller that treats the BLDC motor drive like a digital system. The BLDC system may only operate at a few predefined states that produce constant predefined motor speeds. Speed regulation is achieved by alternating states done by PWM technic during operation, which makes the concept of the controller extremely simple for design and implementation purposes. And also using dual boost controller as a source. This concept will help reduce the cost and complexity of the motor control hardware. That, in turn, can boost the acceptance level of BLDC motors for commercial mass production applications, successfully fulfilling the promises of energy savings associated with adjustable speed drives. simulations were used for proof-of-concept by using MATLAB/SIMULINK and implementation of the digital Electronic controller was carried out with real-time system(e-bike) .

II. II. DIGITALIZED ELECTRONICAL COMMUTATOR

The proposed digital electronic commutation controller treats the driver of BLDC motor like a Digital system. In this proposed circuit , Double boost converter used in source to convert low voltage to high voltage which is adequate to run BLDC motor by switching operation in double boost converter .Three phase inverter used to converter dc supply to ac supply, to energize the stator poles of BLDC motor by alternating phase energisation. hall sensor used to sense the rotor position. These positions are used to start and run BLDC motor in very efficient manner and reduce transient damages.

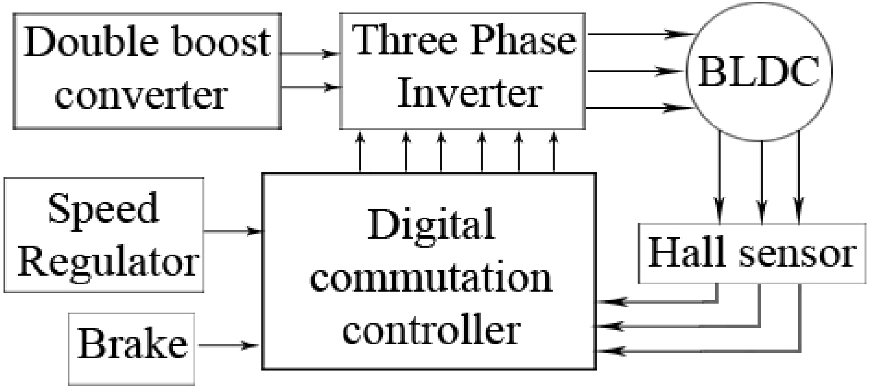

Fig. 1. Fig1: Block Diagram of Proposed circuit

PWM technique is used in Digital Commutation controller to trigger on the switches present in the inverter on based on hall sensor output. Basically, Digital Commutation controller operates in six states to complete one full revolution. States are consists of hall sensor output state with corresponding switches to turn ON to produce different phase energisation. Speed regulator is used to control wide range of speed by varying the duty cycle of PWM Pulses. Duty cycle variation is between 0% to 80%. This will achieve the fastest speed response considering all practical limitations. In our application , brake used to stop the bike.

This paper covers the design and experimental verification of Proposed circuit operation. The design procedure for method is derived and computer simulations are provided..

III. III. DOUBLE BOOST CONTROLLER

The Boost converter circuit operating in continuous conduction mode is popular choice for medium and high power application. This is because the continuous nature of the boost converter’s input current results in low conducted electromagnetic interference (EMI) compared to other active topologies such as buck-boost and buck converters.

The half-bridge boost converter is an adequate topology to obtain high DC voltages in ac-dc converters. The fig.2 shows the circuit diagram of the half-bridge boost converter topology with power factor correction, which is able to provide a power factor varying from -1.0 to +1.0, as the voltage across each semiconductor device is equal to twice the output voltage.

This paper presents a soft switched half-bridge double boost converter in order to obtain higher output voltages, as low voltages across the semiconductor devices are achieved. Fig.2.shows half-bridge double boost topology, which has prominent advantages. The voltage across each semiconductor is V0 and the voltage ripple across the capacitors C and C1 is reduced. Moreover control circuit employed in this in this topology is rather simple, since the same Gate signal can be applied to MOSFET's (M amd M1). Due to the advantages previously mentioned, Which improves the overall performance of the PMDC drive.

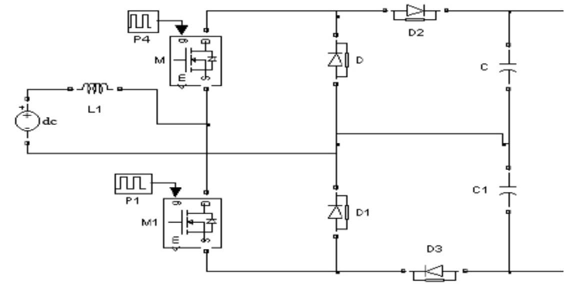

Fig. 2. . double boost converter

The simulation results clearly shows that, for the same input voltage of 100V, the Double boost converter produce double the voltage as that of the input applied voltage. Moreover the speed response of the PMDC drive shows superior performance with double boost converter.

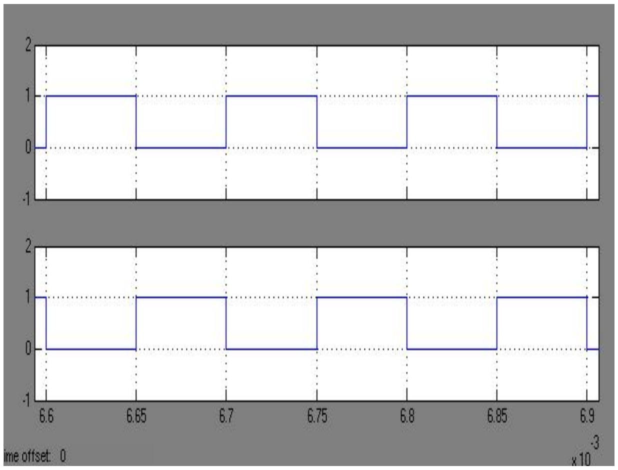

Fig. 3. Driving pulses for m1 and m2 (15khz)

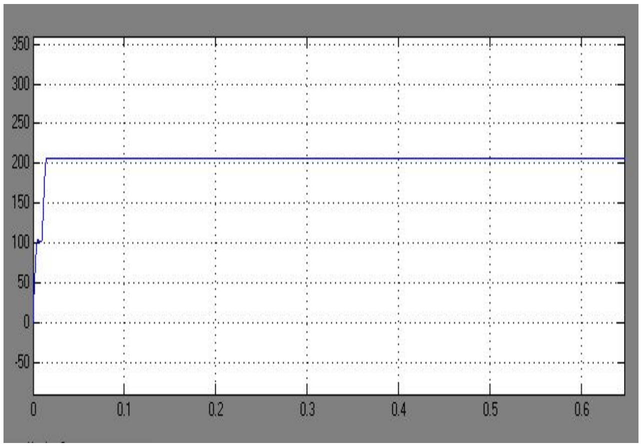

Fig. 4. Double Boost Converter output voltage.

IV. DIGITAL COMMUTATION CONTROLLER

The Three Phase bldc motor is operated in a two-phase-on fashion, i.e. the two phase that produce the highest torque are energized while the third phase is off. Which two phases are energized depends on the rotor position. The signals from their position sensors produce a three digit number that changes every 60 degree (electrical degrees) as shown in figure 4

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Fig 4 shows a cross section of a three- Phase star-connected motor along with its phase energizing sequence. Each interval starts with the rotor and stator field lines 120 degree apart and ends when they are 60 degree apart. Maximum torque is reached when the field lines are perpendicular. Table shows the switching sequence, the current direction and the position sensor signals.

We have seen that the principle of the BLDC motor is, at all times, to energize the phase pair which can produce the highest torque. To optimize this effect the Back EMF shape is trapezoidal. The combination of a DC current with a trapezoidal Back EMF makes it theoretically possible to produce a constant torque. In practice, the current cannot be established instantaneously in a motor phase; as a consequence the torque ripple is present at each 60 degree phase commutation.

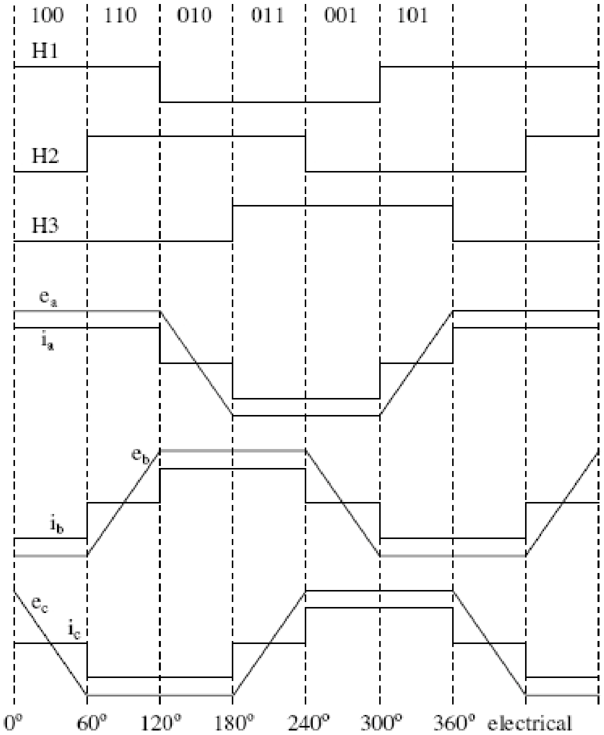

Fig. 7. Hall sensor output with corresponding phase current

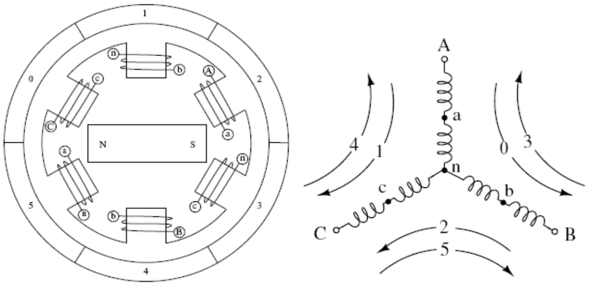

Fig. 5. Cross section of motor and phase sequence

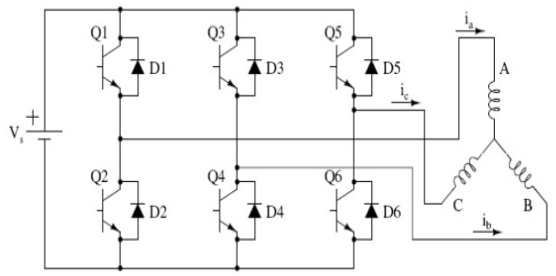

Fig. 6. Voltage source three phase inverter

Brushless DC electric motors to detect the position of the permanent magnet. In the pictured wheel with two equally spaced magnets, the voltage from the sensor will peak twice for each revolution. This arrangement is commonly used to regulate the speed of disk drives. , a Hall sensor is combined with circuitry that allows the device to act in a digital (on/off) mode, and may be called a switch in this configuration. Hall sensor and corresponding phase sequence are shown in below table 1. Hall sensor used in brushless DC electric motors to detect the position of the permanent magnet.

TABLE I.

Switching interval	**Seq. number**	**Pos. sensors**			**Switch closed**		**Phase Current**		
		H1	***H2***	***H3***			***A***	***B***	***C***
0° – 60°	0	1	0	0	Q1	Q4	+	-	off
60° – 120°	1	1	1	0	Q1	Q4	+	off	-
120° – 180°	2	0	1	0	Q3	Q6	off	+	-
180° – 240°	3	0	1	1	Q3	Q2	-	+	off
240° – 300°	4	0	0	1	Q5	Q2	-	off	+
300° – 360°	5	1	0	1	Q5	Q4	off	-	+

V. SIMULATION RESULTS

To carry out simulations, it was necessary to develop a MATLAB/SIMULINK. model that carried out both digital controller implementation methods. The first step was to define a detailed system-level block diagram, which outlined the communication between the controller and the rest of the electric drive system. The controller requires position information from the Hall-effect sensors, as well as monitoring of the three phase currents. From that information, the controller must be able to determine the appropriate firing of the three-phase inverter, so as to implement the conduction-angle digital control.

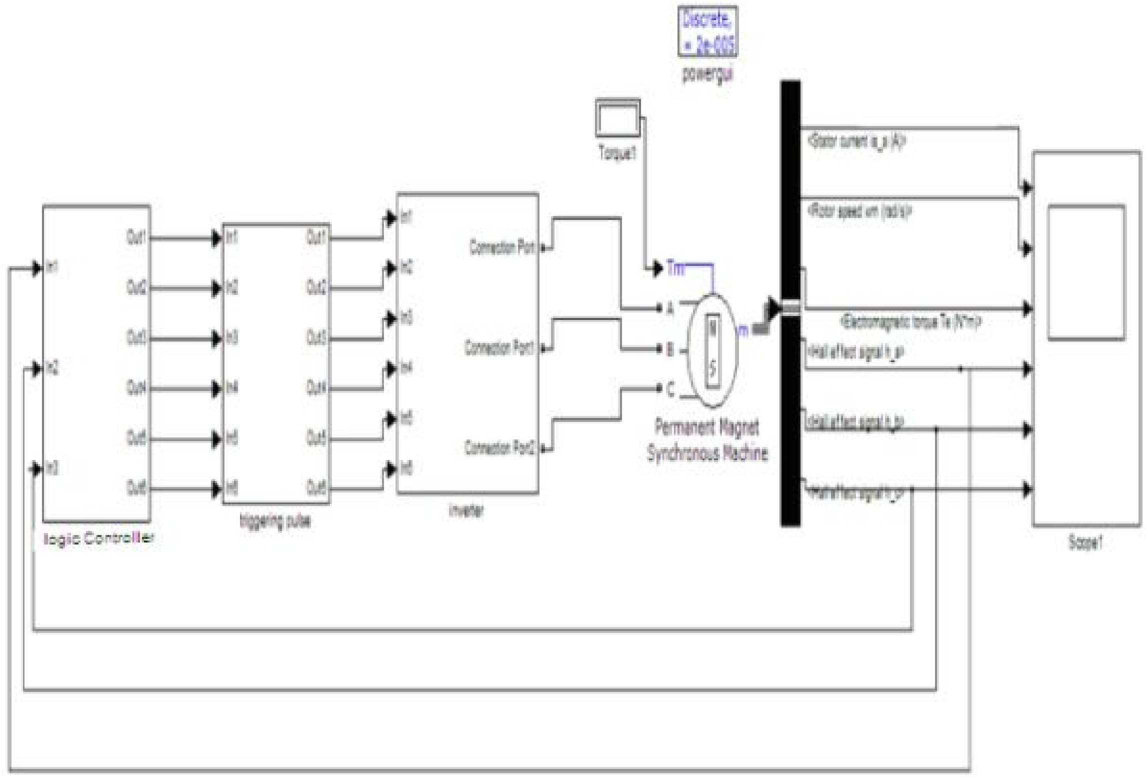

Fig. 8. Overall simulation Block diagram

Essential parameter of motor and inverter are calculated by standard formula .Simulation output calculated and output got in simulation is shown in below tabular.

TABLE II.

Sl.no	Parameters	Calculated voltage	Simulated valve	Units
1	Voltage	48	48	V
2	Power	500	500	W
3	Torque	10	10	n-m
4	Speed	500	500	rpm

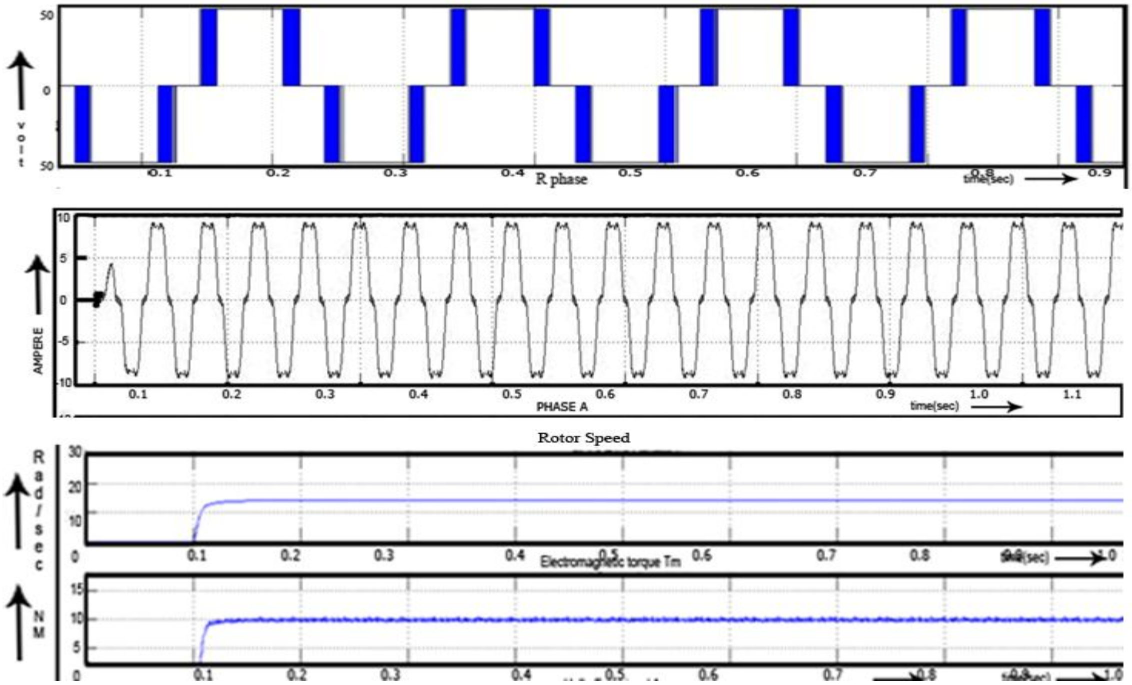

Fig. 9. Output voltage , current , speed and torque

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