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NUMERICAL ANALYSIS TECHNIQUE OF BLDC MOTOR DRIVE FOR MINIMUM PULSATING TORQUE

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Abstract -Development of low cost pumping system using a PMBLDC (permanent magnet brushless dc motor) drive coupled to pump load. The controller is designed and developed without current and position sensors therefore reducing to a large extent overall cost of drive system. DC-DC converters are used to maintain the required output in case of low solar insolation during winter and in case of reduced solar output due to increase in cell temperature. A simple filter circuit is introduced inverter to reduce ripples which increases efficiency system. The inverter drives PMBLDC to pump water to tank. The input from the water level sensors attached to tank indicates water level to controller and thereby automates pumping system.

INTRODUCTION

The global energy crisis that is being experienced has lead to need for more energy efficientsystems. Solar energy is ideal form of energy with features of being environment friendly and substituteof dwindling energy resources. It is clean, non-exhaustible all over the world with varyingintensity. Silicon - main material used for manufacturing of solar cells - is the second-most plentiful elementavailable on the earth. Thus, there is no problem for resource availability.The main advantages of the ECM (electronically commutated motor) over brushed motors are lessmaintenance requirements, reduced environmental effects and less electromagnetic radiation I-2]. Withinlast three decades, several improved magnetic materials are developed for high-performance PM motors. Features of high operating efficiency, brushless construction, maintenance-free operation and increasingawareness about energy conservation have demand of the PMBLDC motor in waterpumping application operated by PV-array, particularly remote villages where electric supply is notavailable.Specially designed low-inertia motors fed by MOSFET-based current-controlled voltage-sourceinverter (CC-VSI), provide desirable features such as high power-to weight ratio, high torque-to-current ratio,response and above all high operating efficiency.Automation plays vital role when these systems are installed rural unattended zones and areaswhere scarcity of water prevails in summer. Water resource utilized effectively without wastageand this improves efficiency of the system. Simple probe sensors are used to determine water level which isalso of low cost.

In the sophistication of complicated electronic systems, the DC-to-DC converters will become more and more popular, DC-DC converters have been widely used in industrial applications forDC motor drives, computer systems and communication equipment [1]. Compared to linear regulators, DC-DC regulators achieve better performance in terms of power dissipation, output voltage capability and current capability, but suffer in terms of output noise, line regulation and load regulation. DC-DC regulators ideally efficiency of 100% and practical designs demonstrate efficiency of about 80-90% [2].

Digital implementation of power controllers has gainedmore popularity. This is due their several advantages compared to the analog controller. Digital power control has made the implementation of complex algorithms easier [3-4]. These algorithms help in improving the performance of power converters. Digital power control can be implemented more easily and the component variables and aging effects are negligible compared to the analog controllers [3-4]. The dynamic response is an important factor that determines the performance of the power converter [5]. The design of controller with better dynamic performance is desired. Conventional controllers have some limitations that limit the dynamic performance. These include, fixed bandwidth, fixed phase margin and gain margin. The controller must satisfy the mentioned criteria during steady state in order to have a stable steady state performance. However, during dynamic transient operation, the bandwidth can be increased [6].

In this paper to elaborate and to provides a method to increase the closed-loop bandwidth during the dynamic operation of the controller. The conventional PID controller is usually designed such that it satisfies the phase margin and gain margin requirements using either bode plot or root locus methods. Usually, the bandwidth is limited to 10-25 percent of the switching frequency. The design performances are determined by the values of the proportional constant (*Kp*), integral constant (*Ki*) and derivative constant (*Kd).*

In this paper, in order to overcome limitation of conventional PID controller the fuzzy logic control is studied, proposed and implemented with high frequency for positive output converter with high efficiency. To proposes a control strategy that results in reduction in the overshoot/undershoot and the settling time for the power converter output voltage during dynamic transients. The proposed control method does not require sensing element and any additional parameters and is relatively simple to realize. Simulation and experimental results are provided to validate the solution.

I. ANALYSIS OF PROPOSED SYSTEM

In novel approach, it is possible to find two main branches of control techniques in DC-DC regulators: voltage feedback control technique and current feedback control technique. The voltage feedback is shown in figure 1 and it can be applied with Pulse-Width-Modulation (PWM) and Pulse-Frequency-Modulation (PFM) techniques. It permits for better load regulation, a lower ripple and to easily filter the electromagnetic interference. Furthermore this control technique simplifies design of control loop, because no compensation is needed to guarantee stability [7].

The current feedback is shown in figure 2 and, it allows a better efficiency when low output current is needed, a limited maximum output current switch, lower current consumption and a feed forward path that speeds up the regulation loop and a current control with a PFM technique is considered to be the most appropriate.

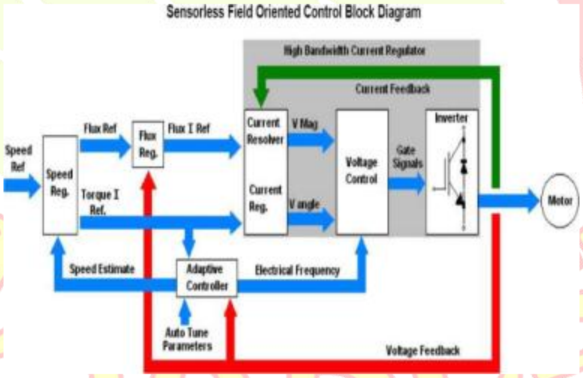

Fig. 1 Proposed Block Diagram

The proposed DC-DC converter with fuzzy logic controller block diagram is shown in the figure 4, the system can be divided in to four blocks:input source; control loop; feedback path and power stage.

As discussed above DC input is fed in to a positive lift converter module, the soft switches in the converter is controlled by a high frequency and efficient fuzzy logic controller with set of rules frame for regulated output set as the reference voltage with the variation of load with reduced ripples and overcoming of overshoot voltage, the results are simulated in matlab/Simulink and output are efficient compared to PID controller and shown in the figure

Fuzzy control can be used to improve controller systems extra layer of intelligence to the current control method. The process of converting input value to fuzzy value is called "fuzzification".

The DC/DC converter used in this boost converter, which is chosen based on ratings of array and inverter voltage. Boost converter configuration steps up the PV outputvoltage to the voltage required by the inverter. Irrespective variations in output voltage, boostconverter output voltage is kept constant by control circuit which incorporates PIC controller. A switchingfrequency of 1 kHz is chosen for the design and MOSFET of appropriate rating IRF250 is selected as theswitch.

$$L \geq Vi * D * T / (2 * \Delta I)$$

$$C = D * Io * TS / \Delta Vo$$

Here Ts and D are switching time period and duty cycle switch S used in the converter. Viis theoutput voltage of PV array and Vo is inverter input voltage. A value of 12MH of inductor and 10 MFDcapacitor was designed for this work based on above equation.

II. PWM BASED MOSFET DRIVER CIRCUIT

PWM signals are given from PIC microcontroller .MOSFET drive circuit consists transistorsBC547 which are npn and pnp transistor respectively. When BC547 is low input it is in offstate and so BC557 base input making it to be in off state .during this condition MOSFET receiveslow input and remains in off state. When input to BC 547 is high it moves to on state and 12v supplyis grounded. The low input to BC 557 which turns it on .during this period MOSFET receives a highsignal and switches to on state.

In a conventional DC motor, current polarity is altered by commutator and brushes. In brushlessDC motor, polarity reversal is performed power transistor switching in synchronization with rotorposition. To accomplish this, input of PMBLDC motor is connected inverter. Inverter is designed in sucha way that, its output frequency is function of instantaneous rotor speed and phase control will correspondto actual rotor position. A BLDC motor is driven by 3 phase inverter with six step commutation [8]. Here conducting interval of each phase is 120° electrical angle. In order to produce maximum torque,inverter commutated every 60°, so current is in phase with back EMF. Commutation timing isdetermined by back EMF method and sequence of commutation is retained in proper order so that theinverter performs the function of brush and commutator in conventional DC motor to generate a rotationalstator flux.

PUMP

Two types of pumps are commonly used for water pumping: positive displacement andcentrifugal. Positive displacement types are used in low-volume pumps and cost-effective. Centrifugal pumpsrelatively high efficiency and are capable of pumping a high volume of water. It is found that energyutilized by centrifugal pump is much higher than volumetric pump [6].The pump used centrifugal type which can be described by aerodynamic load and ischaracterized by the following equation:

$$T = A.\ \omega 2$$

Where A is the pump constant

Pump output or hydraulic horse power (HP) is liquid horsepower delivered by the pump and is calculated by

$$\text{Hydraulic horse power} = (Q * TDH * \rho * g)/1000$$

In (5) Q is the flow rate in m3/s, TDH is the total dynamic head in m, ρ is the density of water in kg/m3, and g isthe acceleration in m/s2.

Probe sensors are used to indicate the water level. When the lowest level is reached PWM signalsare given to BLDC driver which starts the BLDC motor thereby initiating the pumping process. Whenmedium level is reached the duty cycle is reduced to run the drive at a relatively low speed. When highestlevel is reached i.e. when tank is full the controller provides the brake signal to the BLDC motor therebystopping the pumping operation.

PIC microcontroller is the RISC based microcontroller fabricated in CMOS that uses separate bus for instruction and data allowing simultaneous access of programand data memory. The advantage of CMOS and RISC combination is low power consumption resulting ina very small chip size with a small pin count. The advantage of CMOS is that it has immunity to noise thanother fabrication techniques.PIC microcontroller performs following three prime functions:

- It receives solar panel output voltage and boost converter output voltage input and inputs it generates PWM signals to MOSFET (in boost converter).
- It generates PWM signals for MOSFET switches in the inverter.
- It receives input from the water level sensor based on which it automates drive operation.

Consider the interval when phases A and C are conducting and phase B is open as indicated byshaded region. Phase A winding is connected to the positive terminal of the dc supply, phase C to negativeterminal of the dc supply and phase B is open. Therefore, ia= −ic and ib= 0. (shaded region) that back EMF in phases A and C are equal and opposite. The difference of line voltageswaveform is, thus, an inverted representation of the back EMF waveform. Thatduring this interval (shaded portion) the back EMF ebn transits from one polarity to another crossing zero.Therefore, operation Vab − Vbc (Vabbc) enables detection of the zero crossing of phase B EMF. Therefore,zero-crossing instants of the back EMF waveforms may be estimated indirectly from measurements of onlythree terminal voltages of the motor. From the ZCD of all the back EMF in a similar manner we obtain switching sequence. Commutation instances are determined 30°from ZCD [2].

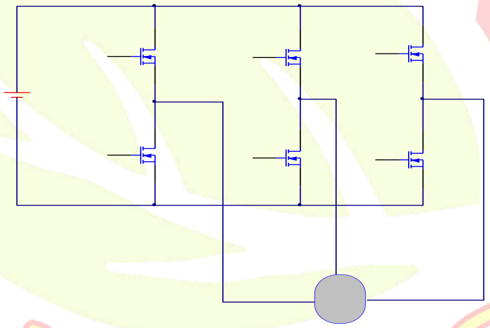

Fig. 2 Proposed Circuit Diagram

Field-oriented control (FOC) is suitable for the high-end application due to its complex design and higher processing requirements. It commutates the motor by calculating voltage and current vectors based on motor current feedback. It maintains high efficiency over a wide operating range and allows for precise dynamic control of speed and torque. The FOC controls the stator currents represented by a space vector. It transforms three-phase stator currents into a flux-generating part and a torque-generating part and controls both quantities separately.The arrangement of the FOC controller resembles a separately excited dc motor.The Clarke transformation converts the three phase sinusoidal system (A, B, and C) into a two-phase time variant system (α, β). A two-coordinate time-invariant system (d, q) is obtained by the Park transformation.

III. RESULTS

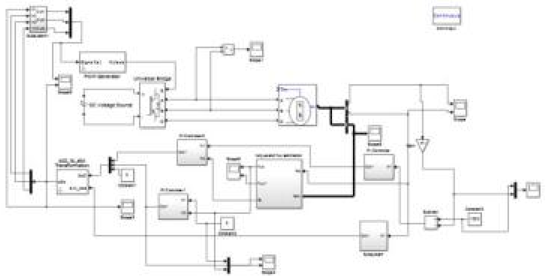

Fig. 3 Proposed Simulink Diagram

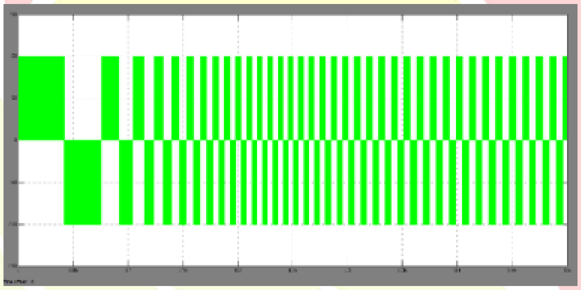

Fig. 4 Input Voltage for BLDC Motor Pumping System

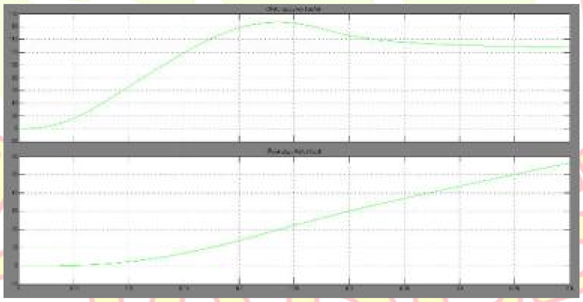

Fig. 5 Rotor Speed and Stator Speed

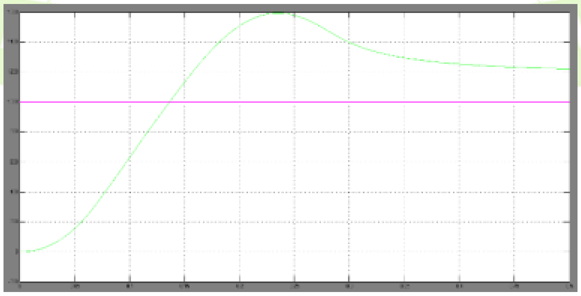

Fig. 6 Output Voltage for BLDC motor

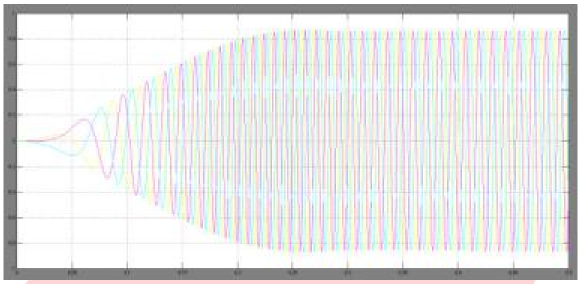

Fig. 7 Output for Active and Reactive Power

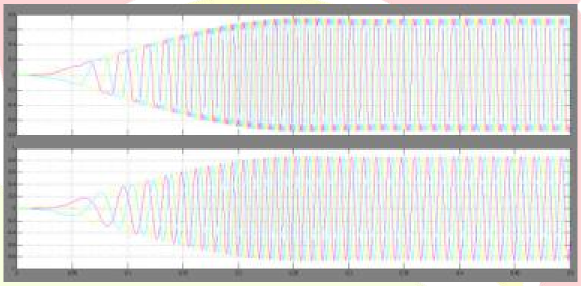

Fig. 8 Active and Reactive Power for Rotor and Stator

IV. CONCLUSION

The proposed system has workingeffectively. The elimination of sensors has reduced thecost to great extent. The position detection using back EMF is easier to implement and worksefficiently. Due to the presence of DC-DC converter system is suitable to work efficiently even inconditions of low power due to poor solar insolation. The automation water pumping system hasimproved system performance and also enhanced proper utilization of water. Owing to improvedperformance, less maintenance requirement, low power requirement, efficient working conditions andeffective use of water resource system is ideal for water pumping especially in isolated areas.

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