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Engineering

DESIGN AND IMPLEMENTATION OF SOLAR POWERED BLDC PUMP FOR WATER PURIFICATION

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ABSTRACT Any equipment without power is an idle bunch of components. It is prominent with those dependable upon the non-renewable sources. It is a proactive approach to shift our source of energy to renewable source. This paper details the design and implementation of solar powered BLDC pump with a water purifying system. The integrated system consists of solar panel, charge controllers, batteries, BLDC motor and a water purifying system. Here we are using MPPT technique for optimizing the PV generated power. The designing of the whole system depends upon the application for which it shall be used and accordingly the components are being chosen starting from motor to solar modules. In order to optimize the solar Photovoltaic generated power using a maximum power point tracking (MPPT) technique, a DC-DC conversion stage is usually required in solar PV fed water pumping which is driven by a brushless DC (BLDC) motor. This power conversion stage leads to an increased cost, size, complexity and reduced efficiency. Here addresses a single stage solar PV energy conversion system feeding a BLDC motor – pump, which eliminates the DC-DC conversion stage. The suitability of proposed system is validated through its performance and evaluation using MATLAB/ Simulink based simulated results.

KEYWORDS : MPPT, Solar PV array, BLDC motor, Water pump, VSI, UV filter

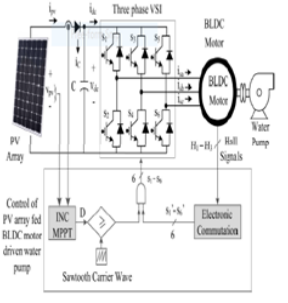
INTRODUCTION

Among the various applications of solar PV energy, a standalone PV powered water pumping system seems to be the most promising and attractive in various areas such as Water purification and rural farm irrigation. The motors comprise more than 40% of overall electric power expenditure . Therefore, a motor plays prominent role to realize a solar PV based energy efficient and cost-effective water pumping. An efficient motor drastically minimizes the number of solar modules for a given power demand and hence its capital cost. The DC motors are mostly used in a low power solar PV water pumping . The DC motor with brushes possesses a low efficiency, and it requires regular maintenance due to the sliding brush contacts and the commutator. An induction motor based PV pumping system is reliable, rugged and maintenance-free with better efficiency and offers more flexibilities for control in comparison to DC motors . The brushless DC (BLDC) motor is identified as a better substitute of the DC motor and an induction motor for PV fed water pumping. This motor is compact, rugged and efficient in comparison to an AC motor. Moreover, a BLDC motor possesses several merits such as reliability, least maintenance requirement, a wide range of speed, easy-to-drive and simple control . Therefore, this motor has received increased attention for water pumping in the last decade owing to its various merits which constitute the attractive features particularly for this application. Ultraviolet water purification is the most effective method of disinfecting bacteria from the water .Ultraviolet (UV) rays penetrate harmful pathogens in our home's water and destroy illness-causing microorganisms by attacking their genetic core(DNA). This is extremely efficient in eliminating their ability to reproduce.Disinfecting our water with Ultrviolet light is exceptionally simple, effective and environmentally safe.UV systems destroy 99.99% of harmful microorganisms without adding chemicals or changing our water's taste or odor.

METHODOLOGY

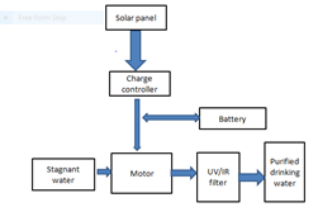
Conventional Topology

The following figure present the schematics of the conventional brushless DC motor drives for PV-water pumping .As shown in Fig the maximum power point tracking (MPPT) is performed by a DC-DC converter. Two phase currents are required to be sensed for motor control . A DC-DC converter, as usual, is deployed to optimize the operating power of a PV array. The solar PV array is directly connected to a VSI which feeds the BLDC motor-pump. A diode in series with the PV array prevents the flow of reverse current. A small DC link capacitor is connected to enable a power transfer from PV array to the BLDC motor-pump.An incremental conductance (INC) MPPT technique is adopted for optimum utilization of solar PV array. This technique uses PV voltage and current as the feedback signals to generate an optimum duty ratio, corresponding to the maximum power of solar PV array.



Proposed Topology

Here we are using solar panel to power the BLDC motor .The solar PV array is directly fed to the VSI without using a DC-DC converter ,since DC-DC converter has many disadvantages we are using a single stage solar energy conversion system which is demonstrated through its steady state, starting and dynamic functionalities using MATLAB based simulation. Maximum power point tracking is used to generate optimum duty ratio and also helps in optimizing the PV generated power.The charge controller circuit controls the voltage generated from the solar panel.The voltage will be stored in the battery.By using the power from the pv array the motor is turned on and the pump takes the stagnant water from the desired location and then it is passed through the uv filter so that all the bacterias and other disease causing organisms are destroyed.After this filter the water can be used as portable drinking water can be stored in containers.



BLDC MOTOR MODEL

In this paper a 3 phases, 4 poles, Y connected trapezoidal back-EMF type BLDC is modeled. Trapezoidal back-EMF is referring that mutual inductance between stator and rotor has trapezoidal shape [3]. Therefore abc phase variable model is more applicable than d-q axis. With the intention of simplifying equations and overall model the following assumptions are made:

- Magnetic circuit saturation is ignored.
- Stator resistance, self and mutual inductance of all phases are equal and constant.
- Hysteresis and eddy current losses are eliminated.
- All semiconductor switches are ideal.

The electrical and mechanical mathematical equations of BLDC are:

$$V_a = Ri_a + (L-M)\frac{di_a}{dt} + E_a \quad (1)$$

$$V_b = Ri_b + (L-M)\frac{di_b}{dt} + E_b \quad (2)$$

$$V_c = Ri_c + (L-M)\frac{di_c}{dt} + E_c \quad (3)$$

$$\begin{cases} E_a = K_e \omega_m F(\theta_e) \\ E_b = K_e \omega_m F(\theta_e - \frac{2\pi}{3}) \\ E_c = K_e \omega_m F(\theta_e + \frac{2\pi}{3}) \end{cases} \quad (4)$$

$$\begin{cases} T_a = K_t i_a F(\theta_e) \\ T_b = K_t i_b F(\theta_e - \frac{2\pi}{3}) \\ T_c = K_t i_c F(\theta_e + \frac{2\pi}{3}) \end{cases} \quad (5)$$

$$T_e = T_a + T_b + T_c \quad (6)$$

$$T_e - T_l = J\frac{d^2\theta_m}{dt^2} + \beta\frac{d\theta_m}{dt} \quad (7)$$

$$\theta_e = \frac{P}{2}\theta_m \quad (8)$$

$$\omega_m = \frac{d\theta_m}{dt} \quad (9)$$

Where k= a, b, c

V_k : k_{th} Phase voltage applied from inverter to BLDC

i_k : k_{th} Phase current

R : Resistance of each phase of BLDC

L : Inductance of each phase of BLDC

M : Mutual inductance

E_k : k_{th} Phase back - EMF

T_k : Electric torque produced by k_{th} phase

T_e : Electric torque produced by BLDC

K_e : Back - EMF constant

K_t : Torque constant

ω_m : Angular speed of rotor

θ_m : Mechanical angle of rotor

θ_e : Electrical angle of rotor

$F(\theta_e)$: Back - EMF reference as function of rotor position

MATLAB code is written to produce Ideal Back-EMF of BLDC as function of rotor position. Simulation result of Ideal back-EMF reference waveforms of all phases versus electrical angle are shown in Fig. 3.

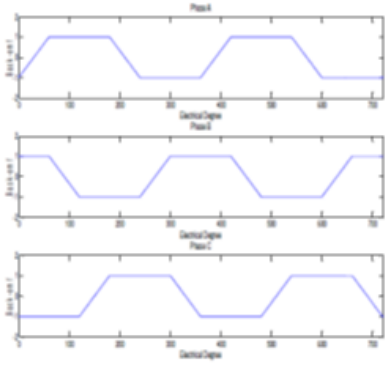


Fig. 3 Ideal back-EMF reference waveforms of all three phases

For convenient implementation of equation in MATLAB / SIMULINK, most of references [3-5] are used state space equations.State space form of equations (1), (2), (3) and (7) can be derived as:

$$V_{ab} = R(i_a - i_b) + (L-M)\frac{d}{dt}(i_a - i_b) + E_{ab} \quad (10)$$

$$V_{bc} = R(i_b - i_c) + (L-M)\frac{d}{dt}(i_b - i_c) + E_{bc} \quad (11)$$

Where $i_a + i_b + i_c = 0$, therefore after modifying equations (10) and (11) and neglecting mutual inductance,

$$\frac{di_a}{dt} = -\frac{R}{L}i_a + \frac{2}{3L}(V_{ab} - E_{ab}) + \frac{1}{3L}(V_{bc} - E_{bc}) \quad (12)$$

$$\frac{di_b}{dt} = -\frac{R}{L}i_b - \frac{1}{3L}(V_{ab} - E_{ab}) + \frac{1}{3L}(V_{bc} - E_{bc}) \quad (13)$$

Then state space model of BLDC motor is:

$$\begin{bmatrix} i_a \\ i_b \\ \omega_m \end{bmatrix} = \begin{bmatrix} -\frac{R}{L} & 0 & 0 \\ 0 & -\frac{R}{L} & 0 \\ 0 & 0 & -\frac{\beta}{J} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ \omega_m \end{bmatrix} + \begin{bmatrix} \frac{2}{3L} & \frac{1}{3L} & 0 \\ -\frac{1}{3L} & \frac{1}{3L} & 0 \\ 0 & 0 & \frac{1}{J} \end{bmatrix} \begin{bmatrix} V_{ab} - E_{ab} \\ V_{bc} - E_{bc} \\ T_e - T_l \end{bmatrix} \quad (14)$$

$$\begin{bmatrix} i_a \\ i_b \\ i_c \\ \omega_m \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -1 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ \omega_m \end{bmatrix} \quad (15)$$

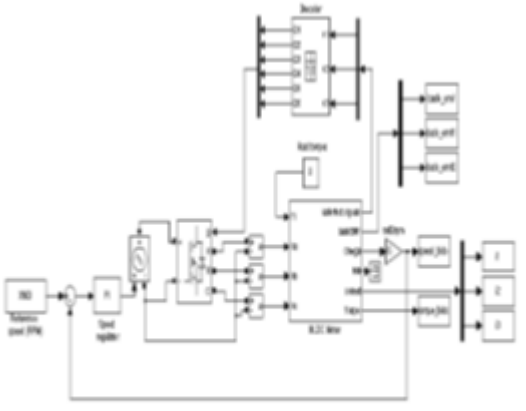


Fig. 5 Overall model of BLDC motor drive

SIMULATION RESULTS

Simulation results of BLDC motor under no load and load conditions are shown. As it can be seen in Fig. 6, dynamic response of BLDC due to its permanent magnet (low inertia) rotor is high. Pulsating torque of BLDC is shown in Fig. 7. Figure 8 shows back-EMF produced in phase A of motor. Hall Effect signals of all three phase are shown in Fig. 9 according to table I. Table II shows BLDC motor specification to investigate performance of advanced model.

TABLE II TECHNICAL SPECIFICATIONS

Parameter	1 HP Pump
Rated Torque (Nm)	2.1 Nm
Input Power (W)	750 W
Rated voltage (V)	24V / 36 V / 48V (Please specify while ordering)
Rated Speed (RPM)	3000
Rated Current (A)	20 A
Peak Current (A)	25 A
Winding Type	3 Phase Star Connected
Insulation Class	Class B
Magnet Temperature (°C)	80°
Hall Effect Angle (electrical angle)	120°
Shaft Rotation Direction	Anti-clockwise
Pipe Size Inlet - Outlet	1 Inch - 1 Inch
Discharge in Liters per hour*	2080 (15 Head)
Pump Section*	Self Priming / Centrifugal (Please specify while ordering)

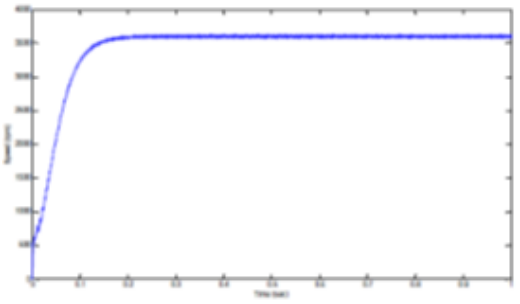


Fig. 6 Speed characteristics under no load condition

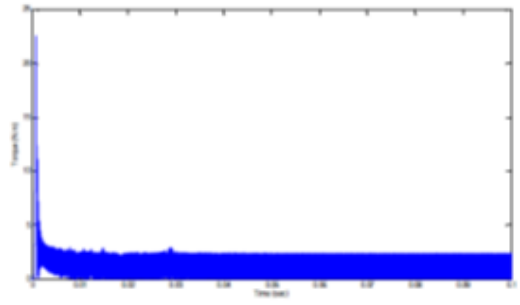


Fig. 7 Torque characteristics under no load condition

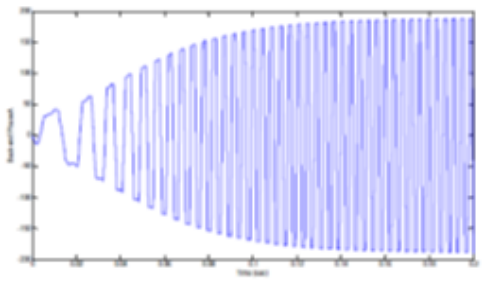


Fig. 8 Back-EMF of phase A

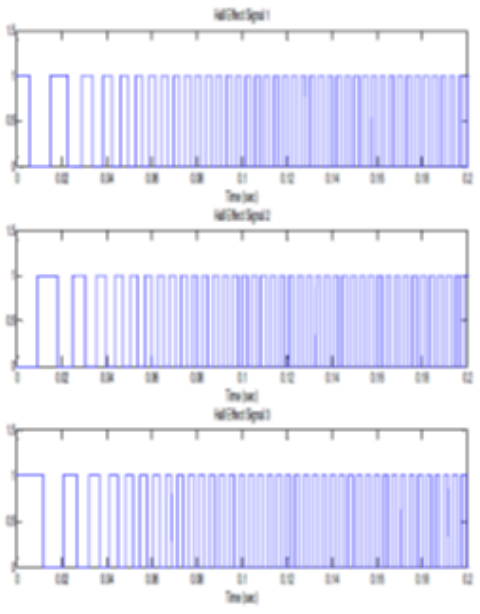


Fig. 9 Hall Effect signals

Simulation also has been done under 10 N.m load torque. BLDC speed characteristic is shown in Fig. 12 under load condition. It can be seen that under load condition time for speed to reach its final value is increased. Current characteristics of phase A of motor under load condition is shown in Fig. 13. Maximum value of current is 40 amps.

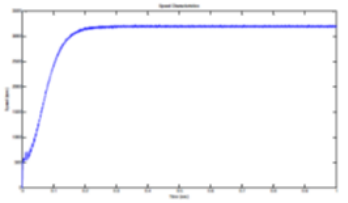


Fig. 12 Speed characteristics under load condition

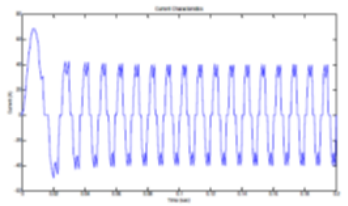


Fig. 13 Current characteristics under load condition

BLDC 360 Watts (0.5 HP) Pump



Figure 14.BLDC Pump

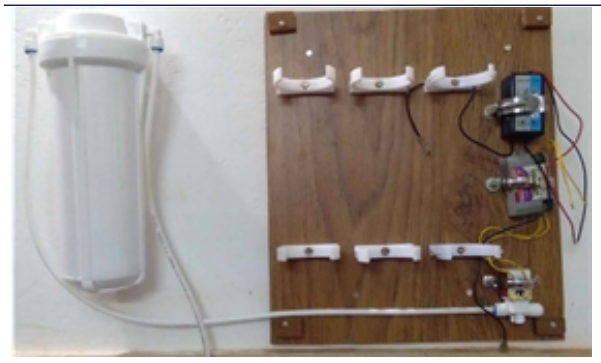
UV FILTRATION

UV systems are an effective means of water dis infection. It is used to destroy E-coli crystosporidium,, giardia or any types of bacteria and viruses in the water. It is not advised to use chlorine to disinfect water due to its toxic by products. It is important to avoid drinking any water that is potentially contaminated from bacteria to protect yourself from any water borne bacterial diseases.

Advantages of UV filtration

- Chemical free: UV purification does not use any chemicals like chlorine or leave any harmful by products.
- Taste &odour free: UV does not add any chemical taste or odour to the water.
- Extremely effective: One of the most effective ways to kill disease causing microbes by destroying 99.99%.
- Requires less energy
- Low maintenance





CONCLUSIONS

A BLDC motor driven water pump is proposed here. The proposed system has been found working effectively. PV panel and BLDC motor is simulated using MATLAB/SIMULINK and corresponding output is obtained. The proposed system has been designed and modelled appropriately to accomplish the desired objectives and validated to examine various performance under no load and loaded conditions. The system under study has shown various desired functions such as MPP extraction of SPV array, fundamental frequency switching of VSI resulting in reduced switching losses, speed control of BLDC motor without any additional control resulting in reduced cost and complexity. The proposed system has been operated successfully even under minimum solar irradiance. The automation of the water pumping system has improved the system performance and also enhanced proper filteration of water by using UV filter. Maintenance of UV system is fairly easy and an effective water treatment tool.SPV array generated electricity is widely used for household application. The proposed system is simple and low cost, because of the elimination of sensors and is widely used for water purification.

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