

# SOLAR PANEL FED BLDC MOTOR FOR WATER PUMPING

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**Abstract** - Solar Energy is becoming the latest and pollution free source nowadays. The use of solar energy is increasing day by day. As per the benefit of solar energy like no pollution, cost effective offers a benefit over the water pump for the irrigation purpose where power transmission is either impossible or uneconomical if possible. By considering various advantages of Brushless DC Motor (BLDC), by using solar energy BLDC motor will be operated. By considering the various advantages of Solar Energy and BLDC Motor like high efficiency, less cost water pumping has the best attractive application of solar energy. No additional control is used for the speed control of BLDC Motor. By using the DC link, we eliminate the DC-DC conversion stage so that it minimizes the cost, size and complexity of the circuit. by using the Voltage Source Inverter, the BLDC Motor is rotated by giving the signal which is received by the PIC controller. PIC controller Eliminates phase current sensors.

**Key Words:** Solar Panels, Voltage Source Inverter (VSI), BLDC Motor, PIC Controller.

## 1. INTRODUCTION

The use of solar energy is increased day by day[2]. In the rural areas power transmission is very difficult or sometimes it is impossible. For the irrigation purpose the water pumping is the most important purpose but due to lack of electricity it creates some problems[1]. Solar power is a 100% clean energy source. It is pollution free and causes no greenhouse gases to be emitted after installation. It can reduce the use of fossil fuels like coal and gas for the generation of electricity which produces air, land, and water pollution.

Water pumping is one of the most useful applications of solar energy[1]. Solar energy is generated anywhere so that in rural areas where electricity is not possible to transmit in that sector easily available the electricity of using solar panels[3]. The initial cost of solar energy is high but this cost is overcome in hardly 5 to 10 years and after that we can use the sun's energy free of cost. This probably reduces the cost of electricity and also, we can sell the remaining energy after use. The BLDC Motor is operated by using Solar Power[2]. The induction motor is also operated by solar energy due its benefits like reliability, ruggedness. But the controlling operation of the Induction motor is difficult so it is simple to operate the BLDC Motor on the solar energy[3,4]. Also, the various

advantages of the BLDC motor are small size, rugged and more efficient noiseless operation, less cost etc [1,3].

By using the DC link the size, cost and complexity of the project is reduced. By using the PIC controller, the control signal to the VSI is operated. Voltage Source Inverter (VSI) is used to give signal to the BLDC motor. VSI consist of MOSFET for the switching operation. Gate pulse is required for control the conduction of MOSFETs in the inverter. It decides the conduction period which gives variable output voltage. We are using the PWM technique to generate gate pulse for the MOSFETs. Pulse Width Modulation (PWM) wave can be used to control the speed of the motor. In this project we use BLDC motors for the water pumping. The operation of the BLDC motor is depending on the attraction and repulsion of the poles.

## 2. SOLAR WATER PUMPING

Fig-1 states the block diagram of PV fed BLDC motor driven water pumping systems. In this the water pump is driven by BLDC Motor. BLDC motor is an Electronically commutated motor, it takes power from the solar PV array. The Solar PV array directly fed to the VSI without the use of DC-DC converter. A diode prevents the flow of reverse current and DC link capacitor used for power transfer from PV array to the motor pump. Eliminating the DC-DC conversion stage. The solar PV array is operating at its peak power by using the same VSI used for the motor.

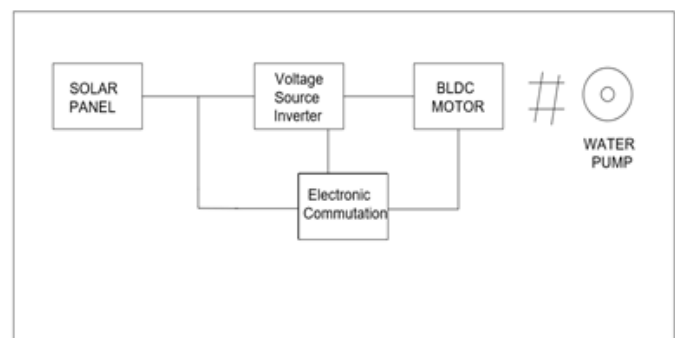


Fig -1: Block Diagram

## 3. OPERATION OF THE SYSTEM

As shown in Fig-2, the solar PV array generates the Electrical energy and feeds the Voltage Source Inverter (VSI). The MOSFET switch of the VSI is operated such that the operation of the solar PV array is optimized and the BLDC motor has a soft starting. VSI supplies the power to

the BLDC motor which is coupled with a water pump. Switching sequence for the VSI is provided by the electronic commutation of the BLDC motor.

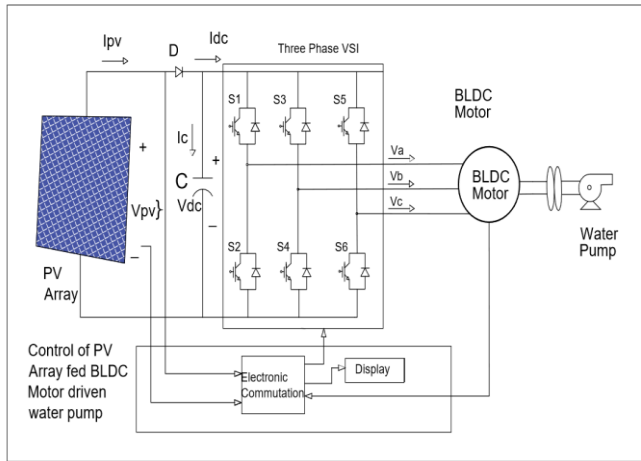


Fig -2: Circuit Diagram

### 3.1 PV Array Modelling

Fig-3 shows the equivalent circuit model of PV cells. To obtain the fixed output voltage and power the circuit model of PV cells is connected in series and parallel combination. The circuit consists of current source 'IL' in parallel with diode. The values of resistance depend upon the number of PV cells connected in parallel and series.

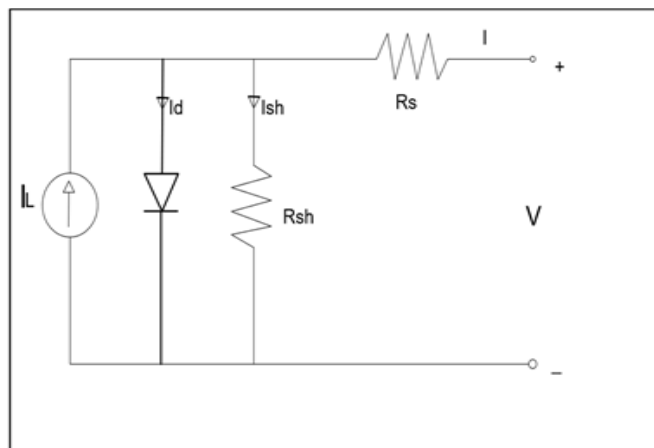


Fig -3: PV Array

The MPP power of PV array,  $P_{mp} = (N_s * W_{mpp})$  Where,  $N_s$  = Number of panels connected in series.  $W_{mpp} = 330 \text{ W}$ ,  $N_s = 3$ . So,  $P_{max} = (3 * 330) \text{ W}$ .  $P_{max} = 990 \text{ W}$

### 3.1.1 Electrical rating of single PV array

Table -1: Electrical ratings of single PV array

Characteristics	Specification
Rated Peak Power ( $P_{max}$ )	330.00 W
Rated Voltage ( $V_{mp}$ )	36.90 V
Rated Current ( $I_{mp}$ )	9.10 A
Open Circuit Voltage ( $V_{oc}$ )	45.60V
Short Circuit Current ( $I_{sc}$ )	9.55 A

The I-V curve of the solar panel is plotted with open-circuit voltage of 45.60V and short circuit current of 9.55A. PV curve of solar panel is plotted. The maximum power of 110.7 W is obtained.

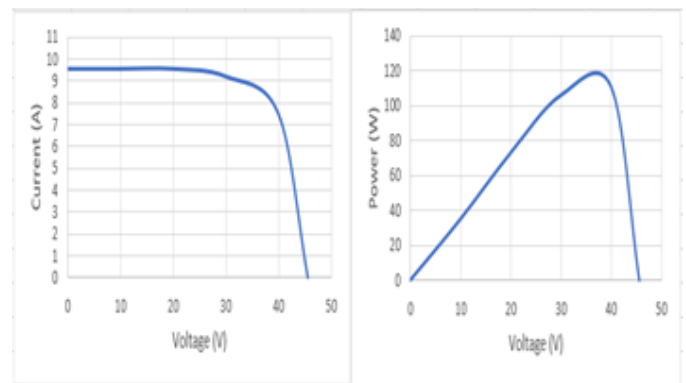


Fig -4: Characteristics of Solar Panel

In this system three solar panels are used. For increasing the solar power capacity, the solar panels connected together are a simple and effective way. The solar panels can connect with each other in three ways by considering the purpose. For large output voltage the three solar panels are connected in series, for large output current the solar panels are connected in parallel and for producing higher output wattage the solar panels are connected in both series and parallel combination. In this system according to purpose three panels are connected in series. Due to series connection of solar panels the output voltage is increased. For connection the positive terminal to negative terminal of each panel and at the end one positive and one negative terminal is remaining. In a series connected solar panel the output voltage of each panel is added up with each panel as shown in below Fig-5.

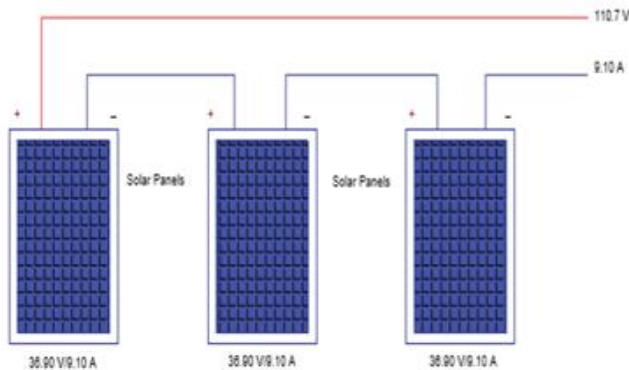


Fig -5: Series Connected Solar Panel

### 3.1.2 Electrical Ratings of Three Series Connected Solar Panel

Table -2: Electrical ratings of Three Series Connected Solar Panel

Characteristics	Specification
Rated Peak Power (Pmax)	990.00 W
Rated Voltage (Vmp)	110.7 V
Rated Current (Imp)	9.10 A

### 3.2 Design of DC link Capacitor

The capacitor connected across the PV array is the DC Link Capacitor of Voltage source inverter. It is a small capacitor it carries the ripple current and it is given by,

$$I_c = I_{pv} - I_{dc}$$

Where,  $I_{pv}$  is the PV array current and  $I_{dc}$  is the dc link current of the VSI. DC link Current  $I_{dc}$  is taken as a constant to calculate the ripple current in the capacitor.

That is,  $I_c = I_{cmax} = I_{pv}$

Where  $I_{pv} = 9.10$  A, which is the PV array Current at MPP. So,  $I_c = I_{cmax} = I_{pv} = 9.10$  A

### 3.3 Design of Water Pump

A water pump is coupled to the shaft of the BLDC motor. In this we use a submersible pump which is submerged in the oil. Due to being submerged in oil the pump prevents the cavitation and it is the advantage of this pump using. Also, it is better than the jet pumps. Pumps consist of stages. Each stage lifts the water of about 5mtr. Use 12 stages pumps.  $12 \times 5$  mtr = 60mtr Water is lifted by 60mtr height.

### 3.3.1 Specification of Pump

Table -3: Specification of Pump

HP	1HP
Efficiency	69%
Output Power	750 W

### 3.4 Brushless DC Motor (BLDC)

For the water pumping we use BLDC Motor. The various advantages of BLDC motors are lightweight, simple construction, less maintenance due to absence of brushes, less noisy than the brushed DC motor with the same output. The rotor of the motor is a permanent magnet and the stator is made by coil arrangement. The BLDC motor is operated by attraction and repulsion between stator and rotor. We use a star connected BLDC motor where the neutral point is not connected.

The advantages of BLDC motor over the other motors are,

- High efficiency and reliability
- Lighter in weight
- The dynamic response is less
- speed range is high
- Life is long etc.

### 3.4.1 Specification of BLDC Motor

Table -4: Specification of BLDC Motor

Power (Input)	990Watt
(Output)	750 Watt
RPM	2850rpm
Pole	6 poles

### 3.5 VSI Switching Pulse Generation

Voltage Source Inverter (VSI) is used for the Switching operation for the BLDC motor. By using the VSI switching operation we can rotate BLDC motors in either direction of clockwise or anti-clockwise. MOSFET is used as switches in the VSI. The output of the solar panel is directly connected to the VSI and the signal is achieved by the PIC controller. It is nothing but a simple 3, single phase inverter. The inverter switches each have a ratio of 50% and switching occurs after every  $T/6$  of time T (60degree interval). We refer to 120degree conduction mode. Therefore, at any instant only two devices are conducting because each device conducts only 120 degrees.

**Table -5:** VSI Switching Pulse Generation

Rotor Position	T 1	T 2	T3	T 4	T 5	T 6
0-60	1	0	0	0	0	1
60-120	1	1	0	0	0	0
120-180	0	1	1	0	0	0
180-240	0	0	1	1	0	0
240-300	0	0	0	1	1	0
300-360	0	0	0	0	1	1

### 3.6 Pulse Width Modulation

Gate Pulse is required for control of the conduction of MOSFETs in the Inverter. The output voltage is varied by the gate pulse. We are using the PWM technique to generate the gate pulse for the MOSFET. The speed of the motor can be controlled by the use of PWM waves. The various advantages of the PWM technique are,

- 1) The whole control system is digital so there is no need for digital to analog converters.
- 2) The susceptibility of the circuit to interference will be reduced by using the digital control lines.
- 3) If the motor is controlled with PWM then the motor may be operated at lower speeds.
- 4) Along with the output voltage control by using PWM method the lower order harmonics are reduced or eliminated.

There is various classification of Pulse Width Modulation to vary the inverter gain.

- 1) Single Pulse Width Modulation
- 2) Multiple Pulse Width Modulation
- 3) Sinusoidal Pulse Width Modulation
- 4) Trapezoidal Pulse Width Modulation
- 5) Staircase Pulse Width Modulation

In this system the Sinusoidal Pulse Width Modulation is used. By comparing a sinusoidal reference signal with a triangular carrier wave of frequency the gate signals are generated.

### 3.7 PIC Controller

Peripheral Interface Controller (PIC) is an IC. It is the world's smallest microcontroller that can be programmed to carry out a large range of tasks. In our project we use PIC16F886. It is 28 pin IC. The 5V

supply is given to the PIC controller by the Solar panel through IC0785. It generates PWM signals for the MOSFET switches in the Inverter. It also monitors the condition and status of the BLDC motor. It also detects the level of the water and on that basis, it controls the operation of the drive.

#### 3.7.1 Features of the PIC16F886

**Table -6:** Features of PIC16F886

CPU	8-bit
Total pins	28
Programmable pins	24
Operating voltage	2.0V to 5.5V
RAM	368Bytes
EEPROM	256Bytes
CPU speed	1MIPS@1MHZ
PWM Channels	4

### 4. CONTROL OF PROPOSED SYSTEM

The control of the proposed SPV array sustained VSI-BLDC motor for water pumping system is grouped into three sections.

### 5. SIMULATION

#### 5.1 Ideal Performance

The ideal performance of the PV array is as shown in Fig -6. The performance shows the PV voltage (V<sub>pv</sub>) in volts, PV current (I<sub>pv</sub>) in Amp and Power (P<sub>pv</sub>) in Watt.

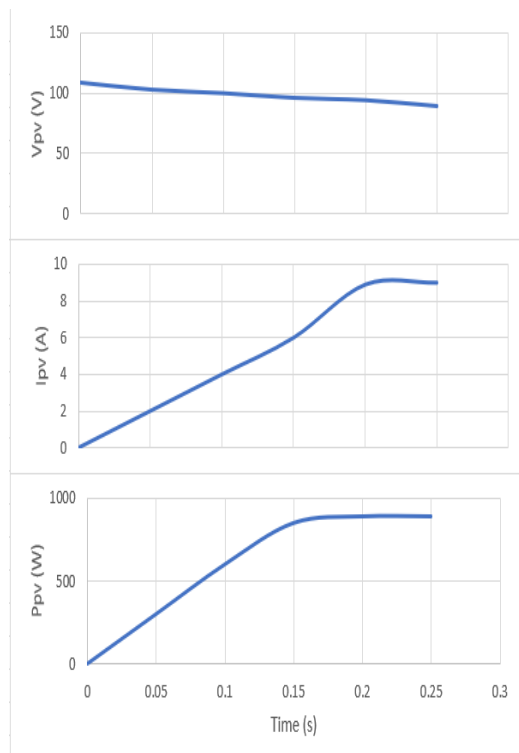


Fig -6: Ideal response of Solar PV Array

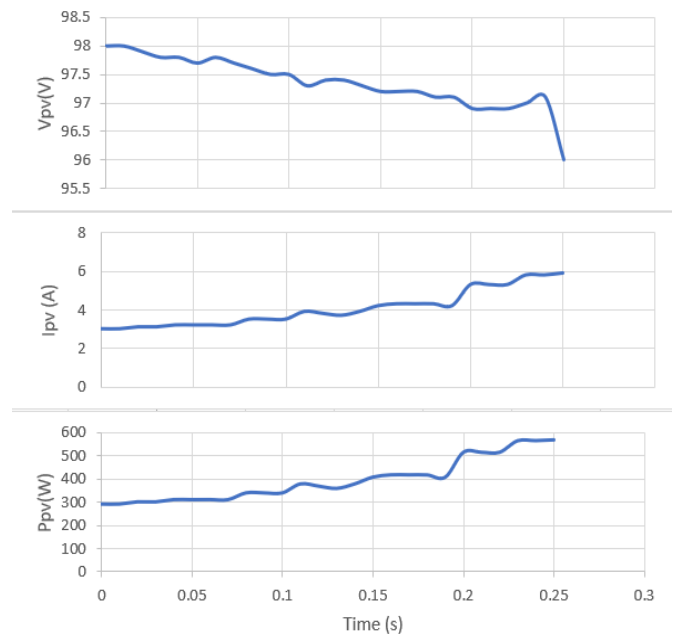


Fig -7: Dynamic performance of PV Array

### 5.2 Dynamic performance

Depending upon the atmospheric condition the voltage ( $V_{pv}$ ), Current ( $I_{pv}$ ) and Power ( $P_{pv}$ ) is varied. Under variable atmospheric condition the result is also variable as shown in Fig -7.

Fig -7 shows the PV array results under variable atmosphere condition. By changing the output PV voltage, the speed, voltage and current of the BLDC motor is also changed which is shown in Fig -8.

Table -7 shows the result of the parameter of PV array and BLDC motor.

Table -7: Result of PV Array and BLDC motor

Vpv (DC) in V	Ipv (DC) in A	Power (Watt)	Nrpm
98	3	294	1490
97.7	3.2	312.64	1580
97.5	3.5	314.25	2030
97.2	4.2	408.24	2310
96.9	5.3	513.57	2311
96	5.9	566.4	2315

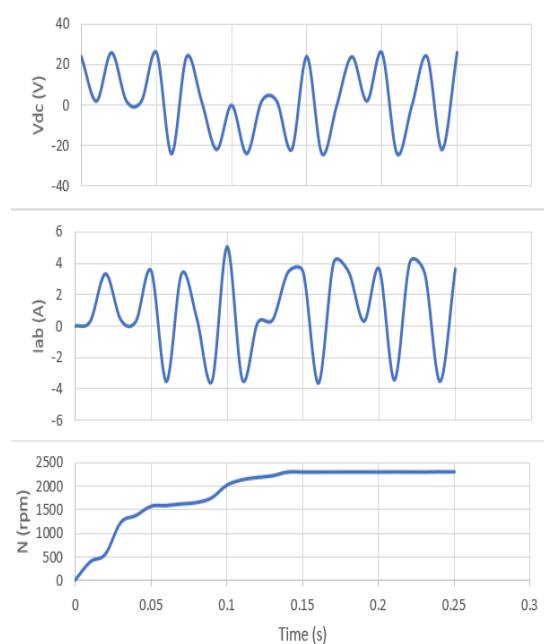


Fig -8: Dynamic Performance of BLDC Motor

### 5.2 Response of Results

Fig -9 shows the response of PV array at steady state condition. It shows the DC voltage of PV array in volt versus Time in Second. The voltage is maintained in the range of 96V-98V. Fig - 10 shows the response of BLDC motor Voltage versus Time in second at steady state condition. Fig -11 and Fig -12 shows the photocopy of response of PV array and BLDC motor under the variable atmospheric condition.

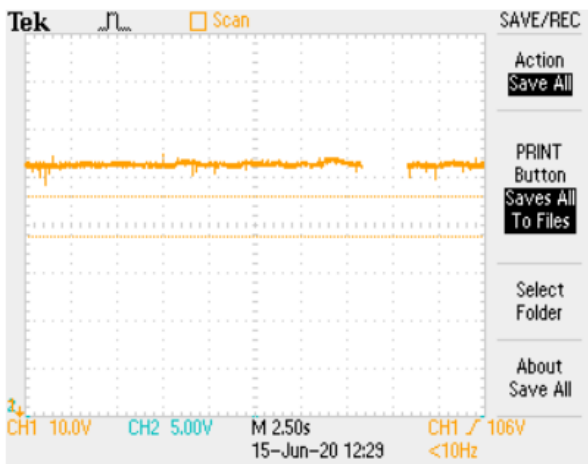


Fig -9: Response of PV Array at steady state condition

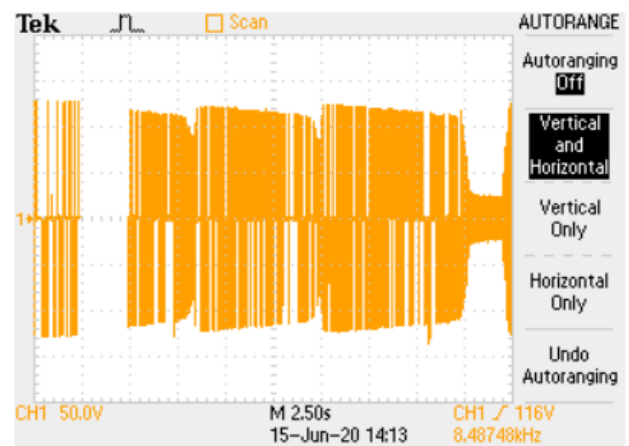


Fig -12: Response of BLDC Motor at variable atmospheric Condition

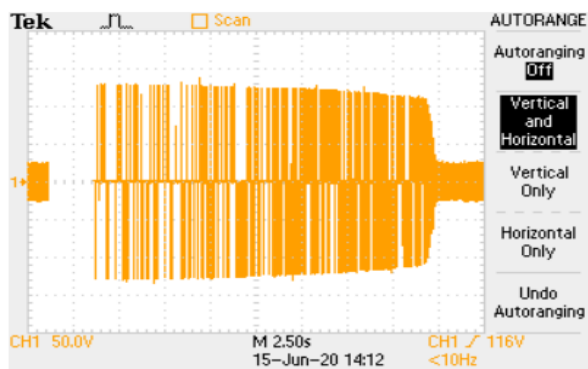


Fig -10: Response of BLDC Motor at steady state condition

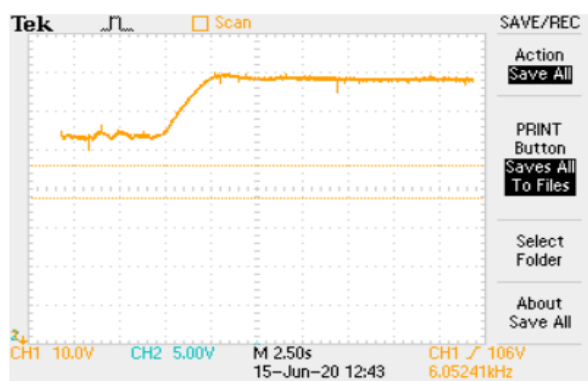


Fig -11: Response of PV Array at variable atmospheric condition

## 6. HARDWARE

Hardware circuit consist of Voltage Source Inverter, PIC Microcontroller, Display. The Solar panels are used to convert the solar energy into electrical energy. Direct Current which is received by solar panels is converted in Alternating Current by using Voltage Source Inverter. VSI consists of MOSFET switches. Gate signals are produced by the PIC controller which is given to the MOSFET switches of the VSI. Pump is coupled to the BLDC motor shaft on the outside.



Fig -13: Hardware

## 7. CONCLUSION

By using a DC link the DC-DC Conversion is removed so that the system is simple, less cost and compact. The efficiency of about 60-70% is achieved by using BLDC Motor. By using solar panels, we can reduce the pollution, and maintenance cost is very less or almost no maintenance. Due to use of the BLDC motor we can achieve maximum efficiency because there is no use of brushes and commutation. No additional control is required for the speed control.

In the villages or where electricity is not possible to transfer or it is not economical if transfer then there is more scope.

## 8. ACKNOWLEDGEMENT

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