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Suitability and Comparison of Electrical Motors for Water Pump Application

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ABSTRACT: Water resources play an important role in world's economy. They are not only essential for satisfying human needs, protecting health, food production, and the restoration of ecosystems but also for economic and social development. There is a great and urgent need to supply sound technology for the provision of drinking water. Water pumping systems are a key component in meeting this need. This paper presents comparison of conventional DC motor, Induction motor and BLDC motor to determine which type of electric motor can be best suited choice for water pump application. These motors are used in areas like homes, vehicles or in wells, where we can probably find a water pump to help them draw water from the ground or to fit their vehicle. The motors that power most pumps can be the focus of many best practices. This paper presents a comparison between different motors used for water pump application. It is clear from the MATLAB/ SIMULINK results that BLDC motor gives better performance, energy saving and also it is cost effective as compared to the present machines and hence is a better alternative for domestic applications, in view of energy conservation.

KEYWORDS: Affinity law; Comparison; Motors; Water pump

I. INTRODUCTION

In recent years interest has grown dramatically in the development of electrical motors to replace conventional hydraulic and mechanical equipment. Now a day's all accessory systems present are candidates for electrical conversion. An electric water pump is selected as the target accessory. The energy is needed to transport water through pipes also to compensate differences in level between the start and the end of a pipe. Electric machines are a means of converting energy. Motors are used to convert mechanical energy from electrical energy. Electric motors are used to power thousands of devices we use in everyday life. This paper is a combination of different motors that are mostly used for water pump application, presently the conventional DC motor and two phase induction motor are widely used but a growing attention towards BLDC motor has been discussed in this paper. Within all these categories, each offering unique abilities that suits them well for water pumping system.

II. DC MOTOR DRIVE

Conventional motor like DC motoris useful for noncritical loads such as water pump application. The simplest and least expensive method to convert solar energy into mechanical energy is to supply a dc motor from a photovoltaic generator [1]. It is typically used, as it need not operate continuously and water output can be easily stored. This arrangement is commonly used for water pumping in rural villages all over the world where there is no existence of grid electricity. With the increased use of these systems, more attention is paid to their design and utilization in order to achieve the most reliable and economical operation. As cost of PV generator is high enough, the system designer is interested in maximum power operation. The system consists of the PV generator and the dc motor as shown in figure 1.

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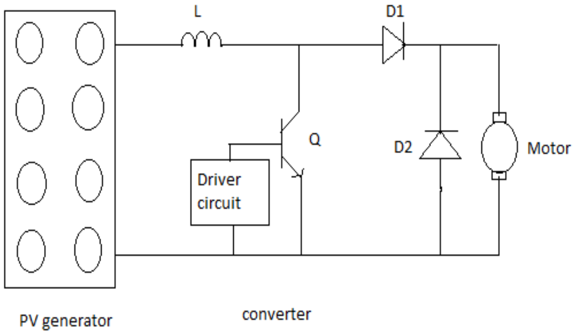

Fig 1: Step up converter with motor circuit

III. SINGLE PHASE INDUCTION MOTOR DRIVE

Single phase induction motor is normally used because of its low cost, availability in local market and low maintenance. This motor has an adequate solution for drinking water supplies in rural areas as well as Grid connected areas. There is a huge demand for single phase motors due to the easy availability of the single-phase Power supply. Capacitor start capacitor run type of single phase induction motor is used mostly for water pump application. This motor contains both a starting and running capacitor. The starting capacitor is connected in series with the centrifugal switch, while the running capacitor is not; the starting capacitor optimizes starting-torque during the starting period, while the running capacitor optimizes the motor's current flow leading to better energy efficiency when operating at running speed.

As shown in figure 2, the output of PV panel is connected to the boost type DC to DC converter. It increases the output voltage level of solar panel and DC link capacitor maintains it at constant DC level. This constant DC voltage acts as an input voltage for single phase bridge inverter. Inverter converts fixed DC voltage to AC voltage of variable magnitude and variable frequency. The outputof the inverter fed to the single phase capacitor start induction motor[3].

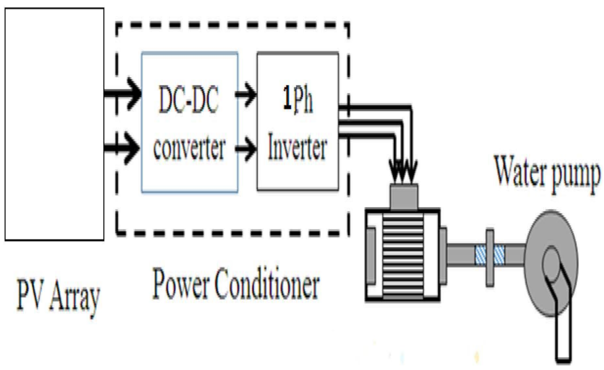

Fig.2. Single phase AC drive for isolated solar photovoltaic system

The speed of induction motors can be controlled by varying the supply frequency. But the terminal voltage is proportional to the product of frequency and flux. If the voltage is maintained fixed at its rated value and thefrequency is reduced below its rated value, the flux will increase. This would cause saturation of the air-gap flux. At low frequency, the reactance will start to decrease and the motor current may be too high. In order to avoid saturation and tominimize losses, motor is operated at rated air-gap flux by varying terminal voltage with frequency so as to maintain the ratio of voltage to frequency nearly constant or to maintain the breakdown torque constant[4].The efficiency of a single phase induction motor in normal working conditions varies from 50% to 70% depending on the rating, starting from 70W to 750W.

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IV. BLDC MOTOR DRIVE

In recent years, BLDC motor is attracting growing attention for automotive applications. Because the brush/commentator assembly is totally eliminated, this reduces audible noise. Moreover, BLDC motor has a number of advantages such as high efficiency,better speed torque characteristics, higher speed ranges and low maintenance cost. Among them, the efficiency is the main reason for electric water pumps. BLDC motor drive is a promising solution to the problem of the bad environmental impacts of water pumps which are based on induction motor. Due to the low efficiency of the current residential water pumps a high energy cost is paid by every household. For reducing energy consumption, improved efficiency and reduced volume and weight, mechanical water pumps are replaced by electrical water pumps [5].

In BLDC motor, structurally the stator assembly surrounds the rotor, embedded into the side of the rotor are permanent magnets. Hall-effect sensors are used to provide positional and rotational information. BLDC motors usually come in fixed voltage types, most common ones in use being the 12V type. When the rated voltage is applied to the motor it will rotate with its maximum speed, but by changing this applied voltage the motor speed can be controlled. The stator is normally 3-phase star connected. Each commutation sequence has one of the windings energized to positive power and the second winding energized to negative power and third winding non-energized. Torque is produced by the interaction of the magnetic field produced by the stator windings and the permanent magnets.

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. For proper rotation of the BLDC motor, the stator windings should be energized in a sequence. It is important to know the rotor position for understanding which winding will be energized following the energizing sequence. Rotor position is sensed using Hall Effect sensors located into the stator. Most BLDC motors have three Hall Effect sensors embedded into the stator as shown in figure 5. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined [6].

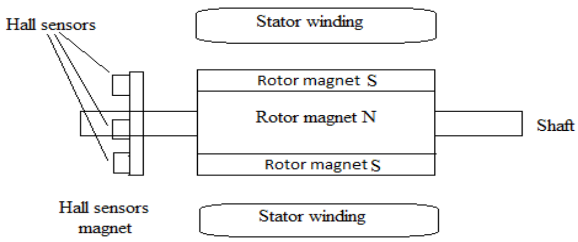

Fig 5: Rotor and hall sensors of BLDC

The speed control input unit provides motor speed to the control system. This input can be analog or digital. The actual motor speed is fed back to the closed-loop controller as shown in figure 6 [6]. The PI controller can be used as the closed-loop control to track the actual motor speed.Based on speed control input, present and past errors (proportional and integral values), the closed-loop control either increases or decreases the PWM duty cycle, which in turn controls the speed of the motor.

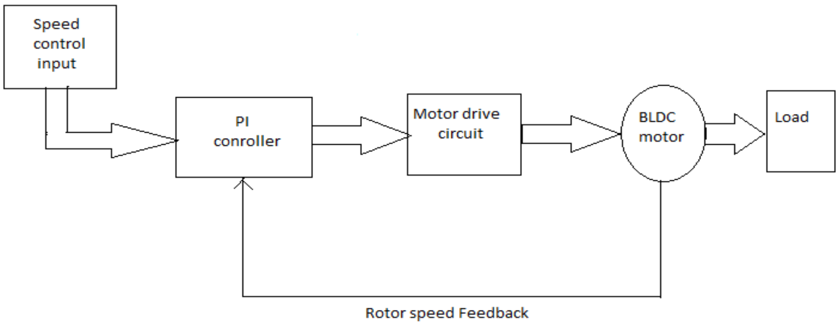

Fig 6: Basic block diagram of BLDC motor drive

The permanent magnet BLDC motors have many advantages over the dc motor and induction motor [7]. They have better torque-speed characteristics due to the elimination of brush friction at higher speeds and improve the useful torque output. Its operating life is high and maintenance is low. The permanent magnet rotors have low inertia, which improves the dynamic response of the motor. In addition, the ratio of torque developed to the size of the motor is higher, making it useful in applications where space and weight are critical factors. The use of permanent magnet rotor eliminates the copper losses and provides considerable improvement in thermal characteristics.
MATLAB simulation is carried out for the BLDC motor drive and the speed and the rotor torque waveforms are obtained.

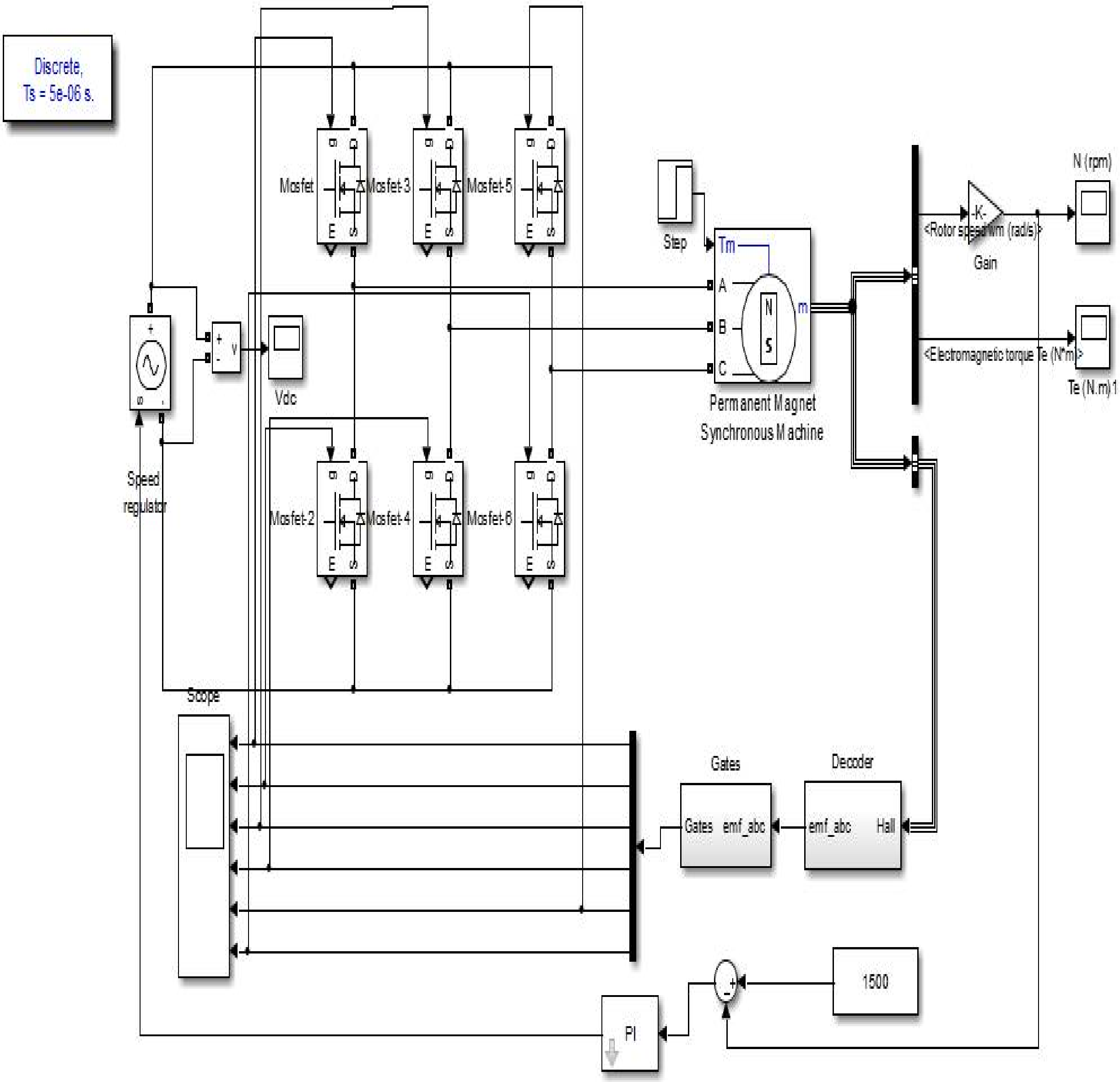

Fig 7: Simulink model of BLDC motor

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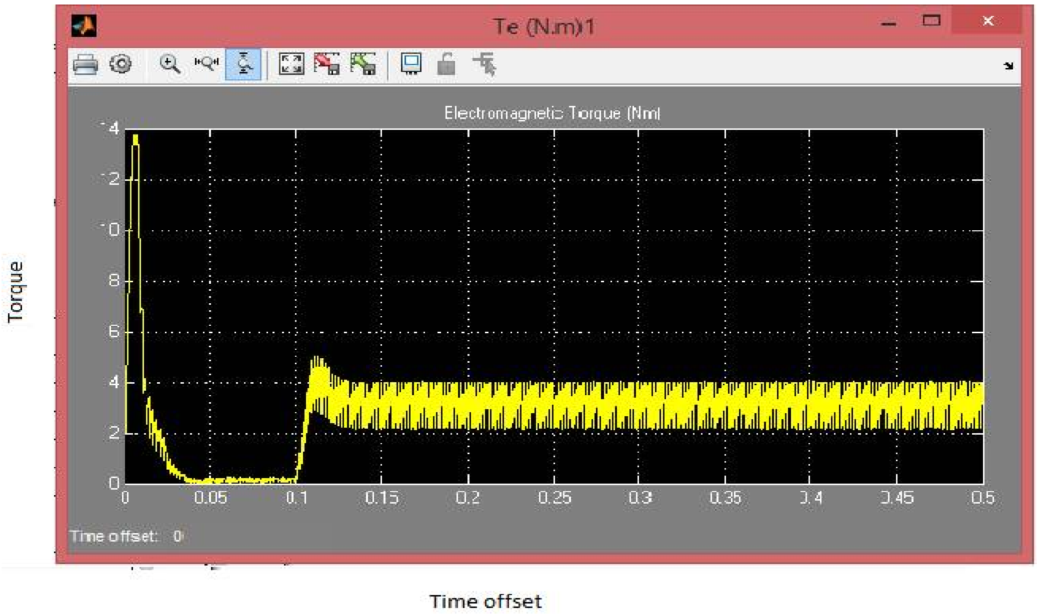

Fig 8: Torque of BLDC motor

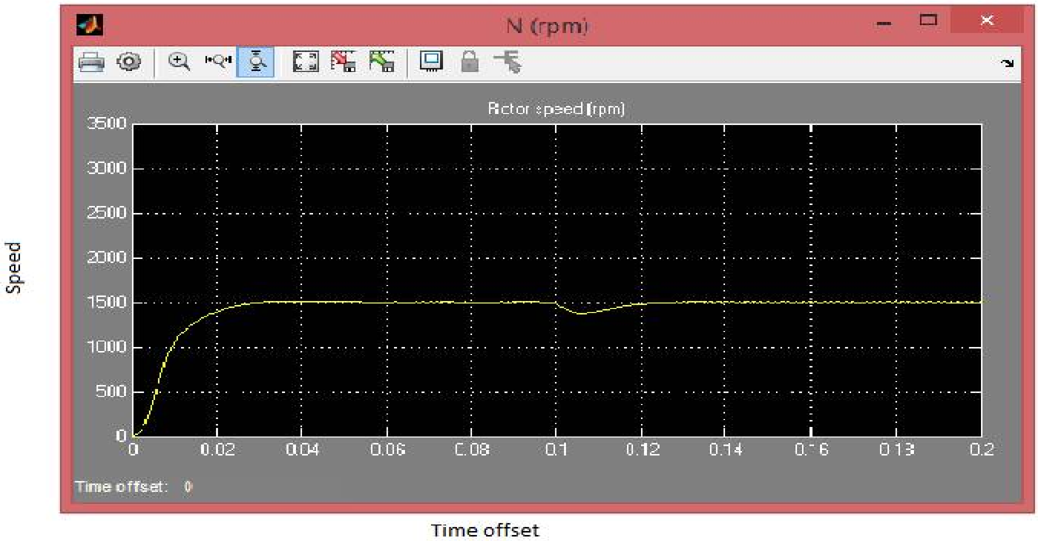

Fig 9: Speed of BLDC motor

Comparing the torque and speed resultsas shown in figure 8-9[8], it is concluded that BLDC motor's performance is better than the other two kinds of motors. BLDC motor can reach stable state much faster than induction motor and DC motor. By comparing the dynamic responses of DC motor, Induction motor and Brushless DC motor, it is determined that BLDC motor is the best choice for high efficiency motor.

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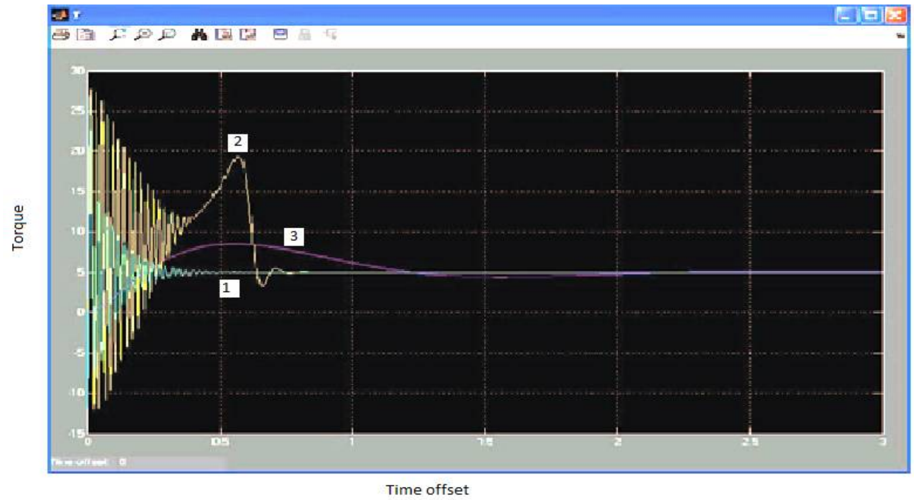

Fig 8: Torque of dc motor, induction motor and BLDC motor

COMPARISON OF ELECTRICAL MOTORS:

FEATURE	CONVENTIONAL DC MOTOR	INDUCTION MOTOR	BRUSHLESS DC MOTOR
Mechanical structure	Field magnets on the rotor and stator are made up of permanent magnet or electromagnet	Stator has windings and AC lines are connected to the stator	Field magnets on the stator and rotor are made up of permanent magnets
Maintenance	Periodic maintenance because of brushes	Low maintenance	Low or no maintenance
Speed torque characteristics	Moderate loss in torque at higher speeds because of losses in brushes	Non linear	Flat- operation at all speeds with rated load
Efficiency	Moderate- losses in the brushes	Low- heat and current losses in both rotor and stator, high efficiency motors are also available (higher cost)	High- no losses in the brushes
Commutation method	Mechanical contact between brushes and commutator	Special starting circuit is required	Using solid state switched
Electrical noise	High- because of brushes	Low	Low
Detecting method of rotors position	Automatically detected by brushes and commutator	NA	Hall sensors, optical encoder
Direction reversal	Reversing the terminal voltage	By reversing any two phase of motor input	Reversing the switching sequence
Control requirement	No controller is required for a fixed speed and it is required for variable speed	No controller is required for a fixed speed and it is required for variable speed	A controller is always required to control the commutation sequence
System cost	Low	Low	High- because external controller requirement

Table 1: Comparison of electrical motors

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V. CONCLUSION

Comparison has given between different types of motors which has been using from past years for water pump application. It has determined that BLDC motor is the best choice for high efficiency. It is concluded that although the induction motors technology is more mature than others, for water pump application the brushless DC motors is more suitable than others.For the operation of a water pump, it is important to consider not only performance but also reliability. In future it would be advantageous if conventional and induction motorsare replaced with brushless dc motor for water pump application.

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