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Engineering

SOLAR BASED LVDC HVLS FAN FOR INDUSTRIAL AND COMMERCIAL APPLICATIONS

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ABSTRACT Non conventional sources of energy are gaining attention on account of dwindling fossil fuels. Using solar energy in coordination with conventional sources of energy will be more promising .Solar power can be used to supply BLDC motor .A brushless DC MOTOR (BLDC MOTOR) is a synchronous electric motor which runs on the supply of direct current electricity. In these motors there is a linear relationship between current and torque and also in between voltage and rpm of BLDC motor. This paper presents the modeling design and construction of a BLDC ceiling fan which is cost efficient. BLDC HVLS Fan or Brushless DC fan is an advanced technology which offers practically maintenance free & noiseless operations. The whisper silent fan is ideal for any kind of application preferably industries, meditation hall, marriage hall, prayer halls, temples, church, assembly halls etc.

KEYWORDS : BLDC, HVLS, Solar.

INTRODUCTION

Electric power generation is limited in India due to various factors such as the environment and availability of raw materials (fossil fuels etc.). It is clear that residential sector is the one where maximum energy conservation is possible while the other sectors are so commercialized that there is no incentive to propose and sustain any major conservation of energy through other alternate energy efficient appliances in these sectors.

Ceiling fan is a major domestic appliance in most of the tropical and subtropical countries especially India, China, US, Brazil, etc. where the climate is warm. They contribute significantly to the residential electricity consumption. For example, estimated electrical energy consumption by ceiling fan alone was 6% of energy consumed by domestic appliances.

A brushless DC (BLDC) motor is a synchronous electric Motor powered by direct-current (DC) electricity and having an electronic commutation system, rather than a mechanical commutator and brushes. In BLDC motors, current to torque and voltage to rpm have linear relationships.

High Volume Low Speed(HVLS) fans move slowly and distribute large amount of air at low rotational speed. Conventional ceiling fans run on totally opposite principle of low volume high speed.

WHY BLDC?

Today the typical ceiling fan is based on AC motors which are power hungry. Along with this the typical AC motor based fans have the rpm control through the capacitor or resistor based regulators and is not efficient as there is loss in the regulator itself to some extent.

In addition the RPM control is by controlling the voltage and the voltage fluctuations of the mains make it very challenging to have constant RPM based on the AC mains supply. Further, existing AC motor solution, results in power factor (PF) degradation with no improvement for PF and there are other ill effects like harmonics injection to the AC mains, etc. The total amount of air flow or displacement is based on the blade size & rpm and does not change due to any other factor. The proposed solution is to keep the same air flow or displacement with less of energy usage along with improving the PF using the BLDC motor based ceiling fans.

Typical BLDC motor based ceiling fan has much better efficiency and excellent constant RPM control as it operates out of fixed DC voltage.

BLDC MOTOR AND ITS CONTROL

Brushless DC Motor (BLDC)/electronically commutated motor/ synchronous DC motor are synchronous motor. For motor control, it is essential to know the position of the rotor which determines the commutation. Hall Effect sensors are used to detect the position of permanent magnet and the signals from sensors are used to adjust the PWM sequence of 3 phase bridge inverter. BLDC motor are powered with a DC source via an inverter that produces an AC current which drives the each phases of motor.

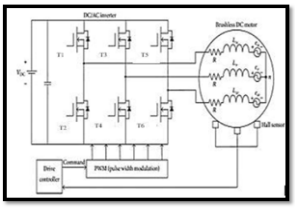


Fig 1

A six step commutation sequence is employed by the system for each electrical revolution. During (motoring mode) both upper arm and lower arm switches are used. During RB (generator mode) lower arm switches (T4, T6, T2) are controlled for the power reversal. The higher arm switches T1, T3, T5 are kept off for all Hall signals.

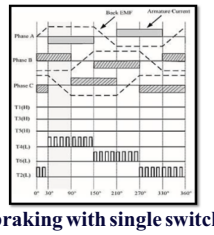


Fig 2: Regenerative braking with single switch

MODELLING OF BLDC MOTOR

The model of BLDC motor is developed considering the following assumptions.

- The stator windings are star connected.
- The supply system is balanced.
- No power losses in the inverter.
- The air gap is uniform.
- The inverter employs a 180 degree six step switching
- The fundamental frequency has a dominant effect on system dynamics.

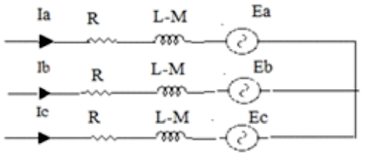


Fig 3: Equivalent circuit of a BLDC motor.

The voltage across the motor winding is expressed as

$$V_a=R_a i_a+L_a\frac{di_a}{dt}+M_{ab}\frac{di_b}{dt}+M_{ac}\frac{di_c}{dt}+E_a$$

$$V_b=R_b i_b+L_b\frac{di_b}{dt}+M_{ba}\frac{di_a}{dt}+M_{bc}\frac{di_c}{dt}+E_b$$

$$V_c=R_c i_c+L_c\frac{di_c}{dt}+M_{ca}\frac{di_a}{dt}+M_{cb}\frac{di_b}{dt}+Ec$$

Va ,Vb, Vc represents stator winding resistances ia, ib, ic are motor phase currents. Self inductance of the motor winding is denoted by La , Lb, Lc and mutual inductances between stator windings are represented as Mab, Mac,Mba, Mbc, Mca, Mcb .The back emf waveforms Ea, Eb ,Ec are functions of angular velocity of the rotor shaft.

E=Ke*ωm
Where Ke is the back emf constant.

The mathematical model of BLDC motor can be represented in matrix form with the following considerations:
La=Lb=Lc=L, since stator self -inductances are independent of rotor positions.
Mab=Mac=Mba=Mbc=Mca=Mcb=M.
Ra=Rb=Rc=R, since for a balanced system all the phase resistances are equal.

Thus the matrix becomes

$$\begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix}\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}=\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}-\begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}-\begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix}$$

The electromechanical torque is expressed as:

$$Tem = J\frac{dWm}{dt}+\text{Bwm}+\text{TL}$$

Where J is the moment of inertia is the frictional coefficient and wm is the angular velocity of the motor and TL is the load torque.

Tem=mw 1(Eaia+Ebib+Ecic).
The trapezoidal back emf waveforms are modelled as a function of rotor position as

$$\begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix}=K_e W_m\begin{bmatrix} f_a(\theta) \\ f_b(\theta) \\ f_c(\theta) \end{bmatrix}$$

where fa(θ),fb(θ),fc(θ) are functions of rotor position.

$$f_a(\theta)=\begin{cases}(6/\pi)\theta & (0\angle\theta\le\pi/6)\\ 1 & (\pi/6\angle\theta\le5\pi/6)\\ -(6/\pi)\theta+6 & (5\pi/6\angle\theta\le7\pi/6)\\ -1 & (7\pi/6\angle\theta\le11\pi/6)\\ (6/\pi)\theta+12 & (11\pi/6\angle\theta\le2\pi)\end{cases}$$

fb(θ) and fc(θ) are 120 degree and 240 degree phase shifted with respect to fa(θ).

CONSTRUCTIONAL DETAILS



Fig 4: BLDC motor

BLDC motors come in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motors are the most popular and widely used.

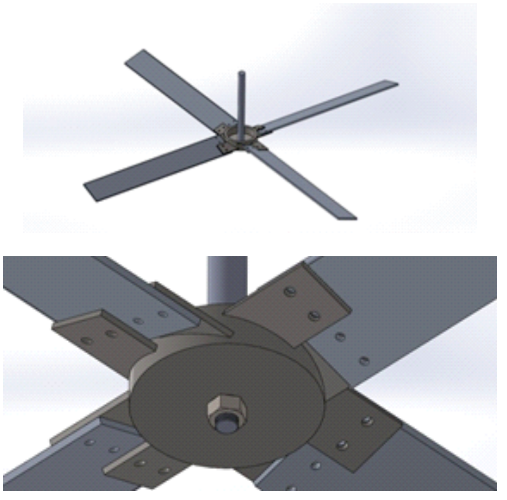


Fig 5: Fan model

The fan has a diameter of 2.18m. The weight of the blade is about 27 kg. Here we use a BLDC motor which weighs about 10kg. This is solar powered fan which can use solar energy for their running. The solar energy obtained is firstly boosted upto 48V using a boost converter. In this there is no stages of coversion occurs which demands no loss of power through conversion, which makes it much more efficient.

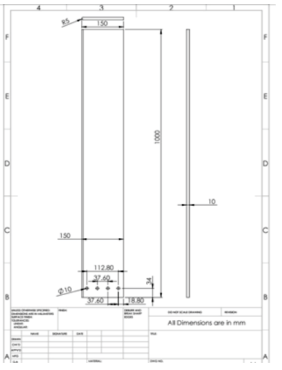


Fig 6: Fan blade schematic view

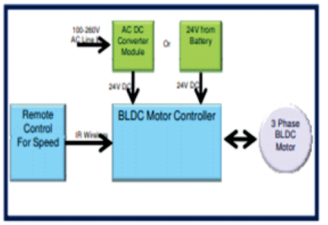


Fig 7: BLDC motor controller

CONCLUSION

BLDC motor based ceiling fan solution will provide an insight into the present status as well as into various challenges faced in deriving the solution along with some of the basic fundamentals of the DC, BLDC and AC motors in general. Energy efficient fan is such a measure which has greater role in reducing the power consumption and hence we have a BLDC fan. It is highly compatible, highly efficient, less noisy, reliable, longer life-time and have a linear torque – speed characteristics fundamentals of the DC, BLDC and AC motors in general. This project provides an overview of the various building blocks of the solution and identifies the right technology-approach to be adopted for energy utilization. The project provides an overview of HVLS fans and discuss the environmental benefits of air movement, thermal comfort, supplementing traditional HVAC systems with HVLS fans, innovation in fan technology, and the standards that govern fan performance.

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