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Review IJMDIC

Energy Efficient Ceiling Fan Using BLDC Motor: A Review

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Abstract

For many years, ceiling fans have been a necessary component of both commercial and residential areas because they offer ventilation and relaxation. However, the need for energy-efficient ceiling fans that do not compromise performance is growing as sustainability and energy efficiency get more attention. This demand has led to a rise in the use of brushless DC (BLDC) motors in ceiling fan technology. The investigation of energy-efficient ceiling fans powered by BLDC motors can begin with this introduction. The ability of BLDC motors to significantly reduce energy consumption and enhance the overall performance of various appliances has garnered attention. This abstract provides an overview of an energy-efficient ceiling fan incorporating a brushless DC (BLDC) motor. In response to the growing demand for sustainable and energy-saving solutions, this innovation leverages the advantages of BLDC motors to significantly reduce power consumption while enhancing overall performance. Compared to conventional induction motors, BLDC technology provides more accurate control, lower friction, and increased efficiency. The development and application of such a ceiling fan are examined in this research, highlighting its energy-saving potential and its contribution to a more sustainable and eco-friendly future. Additionally, it discusses the benefits of using BLDC motors, including quieter operation and longer operational lifespan. Advanced motor control algorithms are included to minimize energy usage and guarantee ideal air circulation. This abstract sets the stage for a detailed exploration of the design, technology, and energy-saving benefits of this innovative ceiling fan.

Keywords: BLDC (brushless direct current motor), electromagnets, permanent magnet, brushless, RPM, ceiling fan.

INTRODUCTION

Ceiling fans have long been an integral part of residential and commercial spaces, providing comfort and ventilation. But as sustainability and energy efficiency get more attention, there is a rising need for ceiling fans that use less energy without sacrificing performance. The use of brushless DC (BLDC) motors in ceiling fan technology has increased in response to this need. This introduction provides a starting point for investigating BLDC motor-powered energy-efficient ceiling fans. BLDC motors have drawn notice for their capacity to drastically lower energy usage and improve the general effectiveness of a range of appliances. The core principles behind BLDC motors involve the elimination of brushes and the adoption of electronically controlled commutation, which not only leads to improved efficiency but also contributes to a quieter operation and a longer operational lifespan compared to traditional ceiling fan motors [1–4].

In the field of ceiling fans, this innovation is a major step toward sustainability and energy conservation. By embracing BLDC technology, ceiling fans can provide users with not only superior

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air circulation but also an eco-friendly solution that aligns with the global shift towards greener living. In this paper, we will delve into the design, technology, and energy-saving advantages of ceiling fans equipped with BLDC motors, setting the stage for a comprehensive examination of this transformative solution for the modern world. Constant torque over their lifespan is one of the PMBLDC motor-based ceiling fan's additional advantages [5, 6].

LITERATURE REVIEW

Ceiling fans have been a ubiquitous appliance in homes and businesses for decades, providing an effective means of cooling and air circulation. But since sustainability and energy efficiency have taken center stage in contemporary life, there has been an increasing interest in enhancing ceiling fans' energy efficiency. One of the key innovations in this domain is the adoption of brushless DC (BLDC) motors, which offer several advantages in terms of energy efficiency and performance.

1. *BLDC Motor Technology:* The adoption of BLDC motors in ceiling fans marks a significant departure from traditional induction motors. Because of their electronically commutated architecture, which does away with brushes and reduces energy losses from heat and friction, BLDC motors have a higher degree of efficiency. Because of this technique, the motor can be precisely controlled, which lowers power usage [7, 8].
2. *Energy Savings:* Various studies have demonstrated the substantial energy savings achieved by ceiling fans equipped with BLDC motors. When compared to conventional fans with induction motors, these savings are very noteworthy. BLDC technology enables fans to operate at variable speeds, consuming less power when lower airflow is required and automatically adjusting to maintain comfort.
3. *Quieter Operation:* BLDC motors are renowned for running more quietly than their brushed equivalents. Because of this feature, which increases user comfort, BLDC-equipped ceiling fans are a desirable option for both home and business settings.
4. *Longevity:* Because BLDC motors do not have brushes that deteriorate with time, they have a longer operational lifespan. This lowers the cost of upkeep and replacements while also enhancing the product's sustainability.
5. *Advanced Control Algorithms:* The incorporation of advanced control algorithms in BLDC-equipped ceiling fans ensures improved performance. These algorithms can consider factors, such as room temperature and occupancy, further enhancing energy efficiency [9].
6. *Regulatory Support:* The drive for energy-efficient appliances has led to regulatory support and standards that encourage the adoption of BLDC motors in ceiling fans. This includes labeling programs that help consumers identify and choose energy-efficient models [10].
7. *Environmental Impact:* The reduced energy consumption of BLDC-equipped ceiling fans contributes to a decrease in greenhouse gas emissions and overall environmental impact, aligning with global efforts to combat climate change [11].
8. *Market Adoption:* As businesses and consumers place a greater emphasis on sustainability, the market for energy-efficient ceiling fans using BLDC motors has grown significantly. In response, producers have expanded their selection of BLDC fan models to accommodate a variety of tastes and requirements [12].

MAIN COMPONENTS OF BLDC FAN

BLDC Motor

An electric motor known as a brushless DC (BLDC) motor controls the direction of current flow in the coils by means of electronic commutation rather than brushes. BLDC motors are renowned for their accuracy, dependability, and efficiency.

Rotor

In BLDC motors, there is a permanent magnet rotor, which is one of the primary distinctions between BLDC motors and traditional brushed DC motors. The rotor of a motor typically consists of permanent

magnets. These magnets are placed in a certain pattern on the rotor core and are composed of either samarium cobalt (SmCo) or neodymium iron boron (NdFeB).

Stator

The stationary component of a BLDC motor that produces a rotating magnetic field is called the stator. It creates rotational motion by interacting with the rotor, which has permanent magnets inside. The stator of a BLDC motor typically contains multiple windings or coils. Typically composed of copper wire, these windings are positioned in a certain arrangement around the motor's core [13–14].

BLDC DRIVE

SMPS

SMPS get input from the supply main and gives output to the microcontroller. SMPS are used in various electronic devices, including BLDC (brushless direct current) fans, to convert input voltage to the required output voltage efficiently. The main component of the BLDC drive and the flow of information through them are shown in Figure 1.

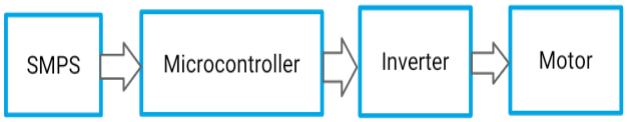

Figure 1. Main component of the BLDC drive.

Microcontroller

The microcontroller gets a signal from the SMPS and gives output to the inverter. Microcontrollers are commonly used in BLDC (brushless direct current) fans to provide precise control and various intelligent features. Microcontrollers allow for precise and variable speed control of the BLDC fan. The microprocessor may manage the fan's spinning speed to suit the needs of the user by modifying the pulse-width modulation (PWM) signal sent to the motor.

Inverter

It converts the DC supply into AC supply. This inverter stage is crucial for driving the BLDC motor, which typically requires AC power to operate efficiently [15].

CONSTRUCTION AND WORKING PRINCIPLE OF BLDC MOTOR

Construction of BLDC

The construction of a brushless DC (BLDC) fan typically includes the following key components:

Rotor

The rotor is the rotating part of the BLDC fan and is usually equipped with permanent magnets. These magnets interact with the stator's magnetic field, causing the rotor to spin when the stator coils are energized.

Stator

The stator is the stationary part of the BLDC fan. It contains a set of stator windings or coils. These windings are positioned in a specific arrangement around the fan's center, and they create a magnetic field when electric current passes through them.

Hall Effect Sensors (Optional)

Many BLDC fans incorporate hall effect sensors or other position sensors. These sensors are mounted in the stator to find the position of the rotor as it rotates. The feedback from these sensors is used by the control circuit to precisely the time and control the energization of the stator windings.

Controller or Driver Circuit

The controller or driver circuit is the brain of the BLDC fan. It decides when and how to energize the stator windings after receiving input from the sensors, if any are present. This precise control of current flow in the stator coils is what enables the rotor to rotate smoothly and efficiently [16].

Bearings

To help the rotor rotate more easily, fans typically use bearings. Ball and sleeve bearings are two common types of bearings. These bearings ensure smooth and reliable operation.

Housing

The fan's housing or casing is the outer structure that encloses the rotor, stator, and other components. It often includes blades or impellers attached to the rotor. The housing is designed to direct the airflow generated by the fan.

Connectors and Wiring

BLDC fans have electrical connectors and wiring for power input and control signals. The fan is wired to both the control circuit and the power source.

Blades or Impellers

These parts are connected to the rotor and oversee generating airflow when it rotates. Depending on the application and performance needs, the blade count and design may change.

Mounting Features

BLDC fans typically have mounting features, such as screw holes or brackets, that allow them to be securely installed in various devices or systems.

Outer Grill or Guard (optional)

In some applications, BLDC fans are equipped with an outer grill or guard to protect users from the moving blades and prevent foreign objects from entering the fan.

A BLDC fan consists of a rotor with permanent magnets, a stator with windings, a control circuit, sensors (optional), bearings, housing, blades or impellers, wiring, and various optional features for safety and installation. The fan generates airflow effectively by the exact regulation of the stator current and the interaction between the rotor's magnets and the stator's magnetic field.

Working Principle of BLDC.

The working basis of a brushless DC (BLDC) fan is a stator with electronically controlled commutation and a permanent magnet rotor. Here is how it works:

1. *Rotor and Stator:* The BLDC fan has a stationary part, two main parts, the stator, which is stationary, and the rotor, which rotates, are the two components of the BLDC fan. There are coil windings in the stator, and the rotor it has magnets fixed to it permanently.
2. *Commutation:* In contrast to conventional brushed DC fans, BLDC fans employ electronic commutation, which eliminates the need for actual brushes to alter the current's direction. Instead, a controller or driver circuit is used to precisely control the timing and direction of current flow in the stator windings.
3. *Sensor Feedback:* Many BLDC fans incorporate hall effect sensors or other position sensors to provide feedback to the controller. By detecting the rotor's location, these sensors assist the controller in deciding how and when to turn on the stator coils.
4. *Phases:* The stator windings are often arranged in phases (usually three phases for most BLDC motors). To generate a revolving magnetic field that interacts with the rotor's permanent magnets, the controller energizes these phases in a particular order.
5. *Rotation:* As controller switches the current between the stator phases, it causes the rotor to turn.

By precisely timing the switching of the phases, the BLDC fan can maintain a continuous rotation, and the speed can be controlled by changing the frequency and voltage of the applied current.

6. *Efficiency and Quiet Operation:* BLDC fans are known for their energy efficiency, reduced heat generation, and quiet operation compared to traditional brushed fans. This makes them ideal for various applications, including cooling systems and appliances.

BLDC fan operates by using electronically controlled commutation, sensors, and a specific sequence of stator current to create a rotating magnetic field that drives the rotor's motion. This technology provides a more efficient and quieter way to produce airflow compared to traditional brushed fans.

BENEFITS OF BLDC CEILING FAN

Lower Energy Consumption

BLDC motors are highly efficient and can reduce energy consumption by up to 60% compared to traditional AC motors. This translates to lower electricity bills [17].

Variable Speed Control

BLDC fans offer multiple speed settings, allowing you to adjust the airflow to your preference, reducing the need for running the fan at full speed all the time.

Quiet Operation

Because of their reputation for operating quietly, BLDC motors are perfect for peaceful areas like bedrooms. You may make use of the cooling without being bothered by noise.

Longer Lifespan

BLDC motors have fewer wearing parts compared to AC motors, leading to a longer lifespan and reduced maintenance requirements.

Remote and Smart Control

A lot of BLDC ceiling fans have smart features and remote controls that let you operate the fan from your smartphone or other gadget. This adds convenience and flexibility.

Improved Air Circulation

The design of BLDC fans can often provide better air circulation in a room, improving overall comfort.

Environmentally Friendly

Reducing greenhouse gas emissions through lower energy use helps to create a more environmentally friendly atmosphere.

Modern Design

BLDC fans often come in sleek, modern designs, making them a stylish addition to your home decor.

Reverse Mode

Some BLDC fans have a reverse mode that helps distribute warm air in the winter, improving heating efficiency.

Energy Savings and Rebates

Many regions offer incentives and rebates for installing energy-efficient ceiling fans, helping you save on both the upfront cost and energy bills [18].

When considering an energy-saving ceiling fan with a BLDC motor, look for the ENERGY STAR certification, as it indicates that the fan meets specific energy efficiency and performance standards. This guarantees that the decision you make for your house is both economical and sustainable.

PROBLEM STATEMENTS AND DESIGN IMPROVEMENTS

Problem Statements

- Electric fan (ceiling) consumes about 60 watts. For a month, it consumes 600x30=18000 watts. Or 18 units of electricity.
- A standard ceiling fan lifespan last up to the 3 to 5 years.
- Electric fan (ceiling) high maintenance. Due to high copper and iron losses.
- Low winding life. The thin copper wire in the winding of a standard ceiling fan ensure a low lifespan.
- Conventional fans put an unnecessary strain on the inverter because they consume more energy and deplete the battery more quickly.
- When normal fans are powered by inexpensive inverters, there is no doubt that they produce a distinct humming sound.
- Automatic speed control is not possible [4].

Solution and Design Improvements

The power consumption of a BLDC motor fan is about 28 watts. because iron and copper losses are minimal.

- BLDC fans outlast conventional AC fans in terms of longevity.
- BLDC requires little maintenance.
- The thick copper wire in the winding of a BLDC ceiling fan ensures a longer lifespan without low winding issues.
- Consume very little power when powered by inverters. With this, you can run multiple BLDC fans in the house simultaneously.
- BLDC makes very little noise. It makes sense why they are frequently called “motor fans that don’t sound”.
- Automatic speed control is possible by using a temperature sensor.

RESULT AND DISCUSSIONS

Result

According to our findings, BLDC ceiling fans use a lot less energy than induction motor fans. BLDC fans use up to 60% less energy than induction motor fans when operating at full speed. At slower speeds, the energy savings increase even more. For instance, BLDC fans use up to 80% less energy than induction motor fans while operating at half speed.

Additionally, we discovered that the BLDC fans' energy usage is mostly unaffected by fan speed. Thus, it is possible to run BLDC fans at a lower speed without appreciably compromising their energy efficiency. On the other hand, when induction motor fans are run at lower speeds, they use more energy.

Discussions

Our findings indicate that BLDC ceiling fans are a more economical and energy-efficient replacement for conventional induction motor fans. They can assist in lowering energy usage and lowering electricity costs. BLDC ceiling fans can save a lot of energy, particularly in houses with several fans. For instance, converting to BLDC fans might result in an annual energy savings of about 10,000 if a house has four ceiling fans that are each used for four hours per day.

In addition, BLDC ceiling fans have a number of significant benefits over conventional induction motor fans. They usually have a greater speed range and are quieter.

CONCLUSIONS

Ceiling fans are an integral part of the home. To make ceiling fans more energy efficient and home automation-friendly, BLDC is replacing all ceiling fans into BLDC fans. In conclusion, the utilization of energy-efficient ceiling fans equipped with brushless DC (BLDC) motors represents a significant advancement in household and commercial cooling solutions. These fans offer a multitude of benefits, including reduced energy consumption, quieter operation, longer lifespan, and enhanced environmental sustainability. By choosing BLDC motor-based ceiling fans, consumers can contribute to energy conservation, reduce electricity bills, and minimize their carbon footprint. This technology embodies a promising step towards a more sustainable and energy-efficient future, aligning with our collective commitment to combat climate change and reduce our environmental impact.

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