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Energy Conservation through BLDC Motor Ceiling Fan in Saranathan College of Engineering: Case Study and Recommendations

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ABSTRACT

Ceiling fans constitute a significant portion of home power consumption, especially in warm-climate developing nations. This research explores a range of solutions to enhance the efficiency of ceiling fans and assesses the global potential for power savings and greenhouse gas (GHG) emission reductions. Leveraging commercially available technologies, it is feasible to achieve a remarkable 60% increase in ceiling fan efficiency. By implementing these efficiency upgrades in all ceiling fans sold by 2025, an impressive 80 TWh/year of electricity could be conserved, leading to the avoidance of 30 million metric tonnes of Carbon Di-oxide emissions worldwide. Additionally, this study investigates the effectiveness of policies and programs such as energy efficiency standards, consumer labelling, and financial incentives in expediting the adoption of energy-efficient ceiling fans. Furthermore, we delve into the advantages of integrating Brushless DC Motors (BLDC) in ceiling fans, where the linear relationships between current-to-torque and voltage-to-rpm offer enhanced energy conservation prospects.

Keywords— BLDC Fan, Energy Saving, Ceiling fan, Energy conservation, Energy audit.

1. Introduction

India has been recording a phenomenal GDP growth of more than 8% per annum, leading to a tremendous increase in energy demand. However, the ways to generate energy in India are limited due to various factors such as environmental concerns and the availability of raw materials like fossil fuels. This situaton makes energy conservation the best option to curtail energy needs as much as possible. To understand the energy consumption in various segments, we can refer to the graph and table provided. The data shows that the residential sector offers the greatest potential for conservation. In contrast, other sectors are heavily commercialized, and there may not be enough incentives to propose and sustain significant energy conservation through alternate energy-efficient appliances. This paper's specific focus is on the residential sector, with particular attention to ceiling fans, which sell more than 30 million units annually and have an installed base of over 250 million units in India. Ceiling fans contribute significantly to residential electricity consumption, particularly in warm climates and developing countries like India. For instance, in 2000, ceiling fans alone accounted for approximately 6% of residential energy use in India, and this figure is expected to increase to 9% by 2020. The energy output of these ceiling fans is influenced by factors such as blade size and RPM, remaining consistent across other variables. Implementing the

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proposed conservation idea could lead to energy savings equivalent to the output of 15 mid-sized power plants.

Fig.1.Control board of BLDC

2. BLDC for Celling –Why?

Today, typical ceiling fans are based on AC motors, which are known for being power-hungry. These AC motor-based fans usually have RPM control through capacitor or resistor-based regulators, but this method is not very efficient and leads to some loss in the regulator itself. Additionally, fluctuating mains voltage makes it challenging to maintain a constant RPM based on the AC mains supply. Furthermore, the existing AC motor solution results in power factor (PF) degradation and introduces ill effects like harmonics injection to the AC mains [1]. The total amount of airflow or displacement provided by the fan is determined by the blade size and RPM, which remains constant regardless of other factors. To address these issues, the proposed solution is to replace traditional AC motors with BLDC (Brushless DC) motor-based ceiling fans. BLDC motor-based fans offer much better efficiency and excellent constant RPM control, as they operate on fixed DC voltage [2]. The proposed BLDC motor, along with the control electronics, operates on 24V DC through an SMPS with an input AC voltage range of 90V to 270V. A comparison between BLDC and conventional ceiling fans is shown below (considering a 42” ceiling fan). BLDC Vs Conventional fan Power Consumption: The BLDC motor consumes less than half the power at full speed and about 20% of the power at low speed compared to the conventional motor- The Power Supply (PS) used operates at 85% efficiency, and the electronics consume less than 0.5W [3] . The power curves for the BLDC ceiling fan consider the total power consumed from the wall socket. By switching to these most energy-efficient fans fitted with BLDC motors, consumers can enjoy various benefits, including energy savings, reduced electricity bills, noiseless operation, and the convenience of a remote control to operate the fan. It's time to say goodbye to outdated induction motors and embrace these path-breaking fans for a more sustainable and efficient cooling experience [4}.

3. BLDC Fan replacement in SARA:

Now let us mathematically calculate how much electricity would be consumed, how much money would be saved using BLDC technology and how long it would take to recover the price of a BLDC When considering the energy-saving benefits over time, a typical induction-based fan consumes around 75 watts, whereas a BLDC fan only consumes about 30 watts. Unlike lights that are usually used only during nights, fans are appliances that run most of the time, especially in areas with high ambient temperatures and little airflow of cool air. Assuming they run regularly for 15 hours a day, 365 days a year, we can calculate the energy savings as shown in the table below. By using a BLDC motor, the annual energy consumption can be significantly reduced, leading to substantial energy savings. The BLDC motor consists of an external armature known as the stator and an internal armature (permanent magnet) referred to as the rotor, making it similar to an AC motor (Permanent magnet type) . The main difference lies in the controller implementation and the way the AC

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(switched DC) is fed into them. The AC supplied to the BLDC motor is not a pure sinusoidal AC but rather a controlled pulse-width modulated waveform through an electronic controller [5] . By making the switch to BLDC fans, consumers can enjoy not only energy savings but also a more efficient and environmentally friendly cooling solution due to the reduced power consumption and improved motor technology.

SARA ONLY		
Exisiting no of ceiling fan	700	nos
working days considered	200	days
Working hours	8	hrs
Power consumed by ceiling fan	70	w
Power consumed by BLDC fan	35	w
Energy consumed by ceiling fan	78400	kWh
Energy consumed by BLDC fan	39200	kWh
Energy saving per due to BLDC	39200	kWh
EB unit charges including 5% tax	6.67	per unit
Total energy consumed by ceiling fans	522928	Rs.
Total energy charges saved through BLDC fans	261464	Rs.
cost of 1 nos of BLDC fan	3500	Rs.
Capital cost of BLDC fans	2450000	Rs.
payback period for the BLDC retrofit	9.3703148	years
Old ceiling fans (Resale value)	300	per fan
old ceiling fans resale gain	210000	Rs.
payback period (considering Resale of old fans)	8.567145	years

Table 1. Energy conservation calculation for College campus

BOYS HOSTEL		
Exisiting no of ceiling fan	141	nos
working days considered	200	days
Working hours	15	hrs
Power consumed by ceiling fan	70	w
Power consumed by BLDC fan	35	w
Energy consumed by ceiling fan	29610	kWh
Energy consumed by BLDC fan	14805	kWh
Energy saving per due to BLDC	14805	kWh
EB unit charges including 5% tax	6.67	per unit
Total energy consumed by ceiling fans	197498.7	Rs.
Total energy charges saved through BLDC fans	98749.35	Rs.
cost of 1 nos of BLDC fan	3500	Rs.
Capital cost of BLDC fans	493500	Rs.
payback period for the BLDC retrofit	4.99750125	years
Old ceiling fans (Resale value)	300	per fan
old ceiling fans resale gain	42300	Rs.
payback period (considering Resale of old fans)	4.569144	years

Table 1. Energy conservation calculation for Hostel campus

With BLDC fans you can save approximately 1500 rupees per year. BLDC fans start with the pricing of around Rs.3, 000 while ordinary fans cost roughly around Rs.1, 500/-. So, in short, if you run your fans for more than 15 hours daily and per unit electricity cost exceeds Rs. 6/-, you can expect to recover the complete cost of the fan in less than 2 years in the form of energy savings which BLDC fans give.

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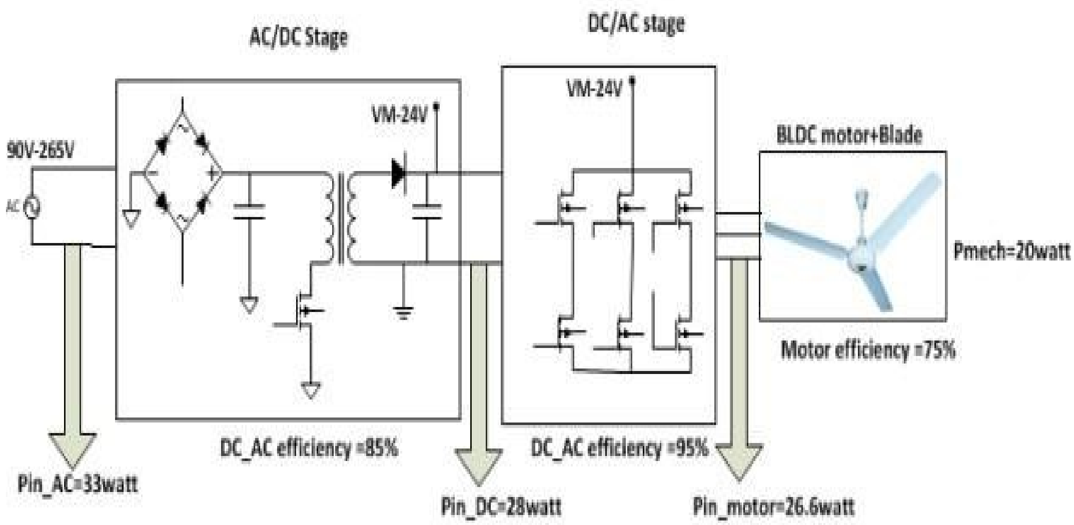

Fig.2 Block Diagram of BLDC

Now let us mathematically calculate how much electricity would be consumed, how much money would be saved using BLDC technology and how long it would take to recover the price of a BLDC fan through the energy saving it gives over time [6]. The typical induction-based fan would consume around 75 watts whereas a BLDC fan would consume about 30 watts. Unlike lights which are only used during nights, a fan is an appliance which runs most of the time if the ambient temperature is high with no regular airflow of cool air. So, assuming they run regularly for 15 hours for 365 days calculation would be as shown below in the table.

4. A leap forward:

In Saranathan College of Engineering, there are over 800 conventional fans. Taking a progressive step, the college is planning to convert all these conventional fans to BLDC fans [7]. Historically, ceiling fans have utilized AC induction motors due to their durability, ease of construction, and relatively low manufacturing cost. However, these AC induction fan motors are relatively inefficient, mainly because of the slip associated with single-phase induction motors. In recent decades, there has been a shift towards using Brushless DC (BLDC) motors in appliances, thanks to advancements in electronic commutation technology and the availability of cost-effective and high-performing magnetic materials (Desroches and Garbesi, 2011). Compared to brushed DC motors, BLDC motors offer higher efficiency because they eliminate the friction loss associated with mechanical commutation.

5. Fan blades:

Improving fan blade design has been demonstrated to have a significant impact on fan efficiency. Various approaches have been employed to achieve efficiency improvements. For instance, some methods involve incorporating aerodynamic attachments for conventional blades (Volk 1990), reducing the angle of attack through the use of twisted, tapered (TT) blades (Bird 2004), and implementing TT blades with an air foil (Sonne and Parker 1998). In this paper, we focus on the last option due to the widespread use of this type of blade and the potential for substantial energy savings associated with this design. TT blades with an air foil enhance efficiency by reducing energy losses caused by turbulence and flow separation, as discussed by Parker et al. (1999). Optimal blade design necessitates a balance between multiple objectives, including maximizing airspeed, achieving uniform airspeed along the fan radius, and maximizing airflow coverage. Testing of one patented blade design indicates that the subject invention exhibits an efficacy 86–111% higher than that of a conventional flat blade, highlighting its remarkable potential for energy efficiency improvements (Parker et al. 2000). Moreover, these blades can be utilized to reduce motor size and cost while still outperforming a conventional fan. Certain efficient blade designs

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have also been aesthetically adapted to resemble traditional blades from the bottom side while maintaining aerodynamic efficiency on the top side, resulting in a 10–26% improvement in efficiency when compared to conventional designs (Parker and Hibbs 2010). This design approach meets the market preference of some consumers for energy-efficient fans with a traditional appearance.

Fig.3 Comparison of Fan Blades

Fan efficiency improvement opportunities: empirical evidence from the US market Figure 1 shows ENERGY STAR market data for qualifying fans being sold in the USA and Canada (ENERGY STAR 2012a and 2012b). The information regarding motor and blade type [8] was obtained from product catalogues and ceiling fan manufacturers producing fans with the highest efficacy, including Monte Carlo, Fanimation, Regency, and Emerson. The data in the figures can be compared to the performance of the most efficient fans being introduced in the US and Canadian markets. For example, the Emerson Midway Eco fan is advertised as having a 75% reduction in energy consumption due to the Emerson Eco MotorTM (Emerson 2010). The figure shows that fans with BLDC motors have significantly higher efficacy than what the current ENERGY STAR high-speed standard requires (2 m3 /min/W)[9]. These data indicate that engineering improvements, such as those previously discussed, can serve purposes other than just increasing efficacy. These improvements can also be utilized for reducing motor size or material quality to lower manufacturing costs in the absence of policy interventions aimed at improving efficiency. Summary of efficiency improvement options Table 3 provides fan power consumption estimates resulting from various options discussed earlier. As mentioned before, actual reported efficacy improvements for the best blade designs are much higher than those summarized in Table 3. For this study's purposes, it has been assumed that blade design improvements will result in relatively lower efficacy increases of 10–26% (Sonne and Parker 1998), which implies a power consumption of between 55 and 63 W, translating to an approximate 15% improvement in power consumption from a 70-W baseline. These lower efficacy improvement assumptions for fan blades are justified because (a) blade design involves trade-offs related to aesthetics and customer satisfaction, and (b) many high-efficiency blade designs may not be fully adopted, especially in emerging economies with price-sensitive consumers[10]. However, despite the significant potential for energy savings, financial incentive programs aimed at promoting the adoption of highly efficient fans are not yet widespread. In conclusion, improving fan efficiency through various engineering improvements, including BLDC motors and advanced blade designs, offers promising energy-saving opportunities. Policies and financial incentive programs could play a crucial role in accelerating the adoption of highly efficient fans, leading to substantial energy conservation and reduced greenhouse gas emissions.

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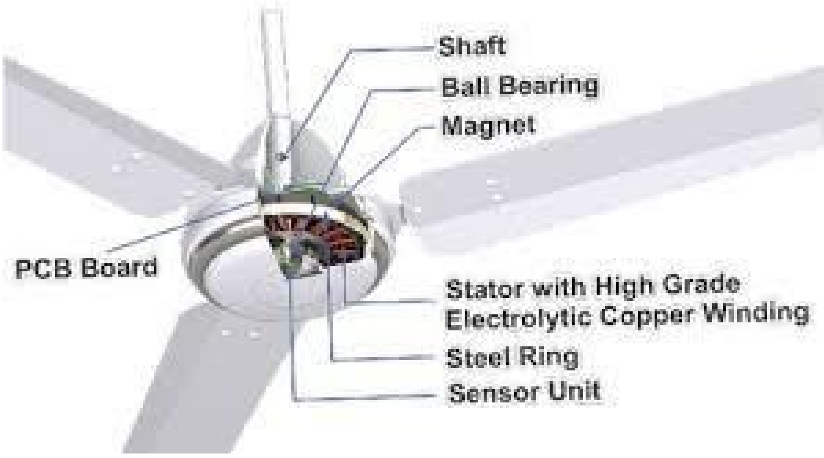

Fig.4 Components of BLDC Fan

In general BLDC fan consumes only 28 to 35 watts, runs three times longer on inverter batteries, and operates noiselessly. The fan incorporates intelligent electronics and a smart remote control. Its design ensures no heating, leading to a longer motor life. Moreover, it maintains a consistent output even with fluctuating input voltage. Additionally, the BLDC motor operates at almost unity power factor, which is advantageous for commercial or industrial connections, especially when charged based on Maximum Demand (MD). Furthermore, the fan can be easily connected to solar power or battery power sources, making it an environmentally friendly and energy-efficient option.

6. Energy Consumption

Now let us mathematically calculate how much electricity would be consumed, how much money would be saved using BLDC technology, and how long it would take to recover the price of a BLDC fan through the energy savings it provides over time [11]. A typical induction-based fan would consume around 75 watts, whereas a BLDC fan would consume about 30 watts. Unlike lights, which are only used during nights, a fan is an appliance that runs most of the time, especially in areas with high ambient temperatures and limited airflow of cool air

7. Conclusions

This paper concludes that an analysis of the potential to reduce global energy consumption and greenhouse gas (GHG) emissions through improvements in ceiling fan components. Cost-effective options, such as improved blade design, AC induction motor materials, and increased utilization of BLDC motors, are identified to enhance the efficiency of ceiling fans. Implementing these technologies could lead to ceiling fan power consumption savings of over 50%. Among various policies used to promote the adoption of efficient products, standards and labelling programs are the most commonly employed to accelerate the market penetration of efficient fans. Efficacy levels are tested under different conditions, including airflow requirements and speeds in various countries, which necessitates careful comparison considering these variations. Nevertheless, the efficacy improvements discussed in this paper are applicable across commonly encountered airflows, offering significant energy savings of a similar magnitude regardless of airflow or test procedure alignment.

However, the highest efficacy levels required by standards and labelling programs in several countries are still significantly lower than what can be achieved by adopting the cost-effective efficiency improvement options mentioned here. Thus, there is a need to revise current efficacy label levels to encourage greater adoption of efficient ceiling fans in the market. Despite the presence of standards and labelling programs, the low penetration level of efficient ceiling fans in both India and the USA suggests the existence of barriers that go beyond information, such as first cost. These barriers, particularly in emerging economies with price-sensitive consumers, may not be fully addressed within a standards and labelling framework. However, financial incentive programs that remove the first-cost barrier and promote the adoption of highly efficient fans are not common. An example under development is the SEEP (Superefficient Equipment Program) in India, where financial incentives will be provided to fan manufacturers to produce and sell highly efficient fans that consume less than half the energy of typical fans sold in the Indian market (Singh et al., 2010). Even if the entire incremental cost of highly efficient fans is covered by financial incentives, the cost of the conserved electricity for efficiency improvements exceeding 50% is estimated to be just 0.7 units.

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