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Realization for low cost and energy efficient ceiling fans in the developing countries

Tauseef Tauqeer[a,b,*], Muhammad Afnan Ansari[a,b], Ammar Hasan[b]

[a] Information Technology University (ITU), Lahore, Pakistan
[b] National University of Sciences and Technology (NUST), Islamabad, Pakistan

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ABSTRACT

This article focuses on power consumption mitigation of ceiling fan through induction motor design optimization. Efficiency of the fan is vastly dependent on the motor design i.e. the materials and techniques used to build the motor. The fan industry in developing countries like Pakistan are using inefficient design techniques in addition to the low grade materials to manufacture the motors. Consequently, none of the locally available fans of Pakistan market are able to meet international standards. High electricity cost, increased power consumption and the incapability to meet international standards are the prime motivations to improve the existing design practices in the fan industry of Pakistan. Detailed analysis and experiments are performed with nine ceiling fans manufactured and tested at a fan industry located in Gujrat, Pakistan. Design optimization predicted 35% improvement in the energy profile, which is latter verified by the experimentation. Seven out of the nine Designed Ceiling Fans (DCF_s) met the characterization of Pakistan Standard 1 (PS1) and six met the Bureau of Energy Efficiency (BEE) star ratings specifications. A comprehensive comparison is carried out between commercially available ceiling fans (CCF_s) and DCF_s with respect to energy consumption, standards, annual customer saving, impact on national grid and performance. In addition, a fan characterization platform is developed for better quality control and logging of the electrical parameters during fan manufacturing. In order to achieve static balancing, an automatic blade sorter is designed to bundle the blades with same weight before shipment.

1. Introduction

The demand of energy is rapidly growing at the rate of 1.7% worldwide every year [1]. Developing countries like Pakistan, are splurging considerable amount of foreign exchange on the import of non-renewable energy sources i.e. petroleum, natural gas, kerosene oil, coal etc. It is reckoned that non-renewable energy sources deplete almost 60% of Pakistan's foreign exchange [2]. Climate region of Pakistan is comprised of four sub-tropical areas i.e. Highland, plateau, low lands and coastal areas. Besides sub-tropical continental highland region, other three regions are exceptionally hot in summer season [3]. The maximum temperature regime map of Pakistan is shown in the Fig. 1. Dwellers of these regions bank on ceiling fans and Air Conditioning Systems (ACS) to achieve thermal comfort. It is surmised that there is a comprehensive increase in the energy consumption during summer season. Statistics show that, there has been 25% increase in the Demand of Energy (DoE) since last four years. In year 2025, DoE may reach up to 85% if indispensable actions are not taken to preserve energy and fossil fuels [4,5]. The ceiling fan has very little capital expenditure and operational expenditure as compared to ACS [6] and thus are being preferred in these three sub-tropical regions. Due to frequent power cuts in developing countries, solar cells with uninterruptable power supplies is an attractive solution. While using renewable resources, highly efficient devices are required at load side because of limited battery capacity.

Random samples of forty nine (56 in.) ceiling fans were drawn from the local market and characterized for performance analysis. The main parameters scrutinized while testing performance profile of ceiling fans were speed of fan blades in revolution per minute, power consumed in watts and air delivery in $m^3\ min^{-1}$. The measured energy consumption per hour has upper bound of 149.4 W and lower bound of 62.7 W. The maximum Service Value (SV) recorded was $3.50\ m^3\ min^{-1}\ W^{-1}$, whereas the minimum SV was $1.34\ m^3\ min^{-1}\ W^{-1}$. The SV of ceiling fan is defined as the average air delivery ($m^3\ min^{-1}$) per electric power consumption (W). The average SV of these samples turned out to be $2.33\ m^3\ min^{-1}\ W^{-1}$. The results were compared with PS1 [7] and BEE Star Ratings, which are stated in the Tables 1 and 2, respectively.

BEE criteria is employed in India and has ratings on different

* Corresponding author at: Information Technology University (ITU), Lahore, Pakistan.
E-mail address: tauseeftauqeer@gmail.com (T. Tauqeer).

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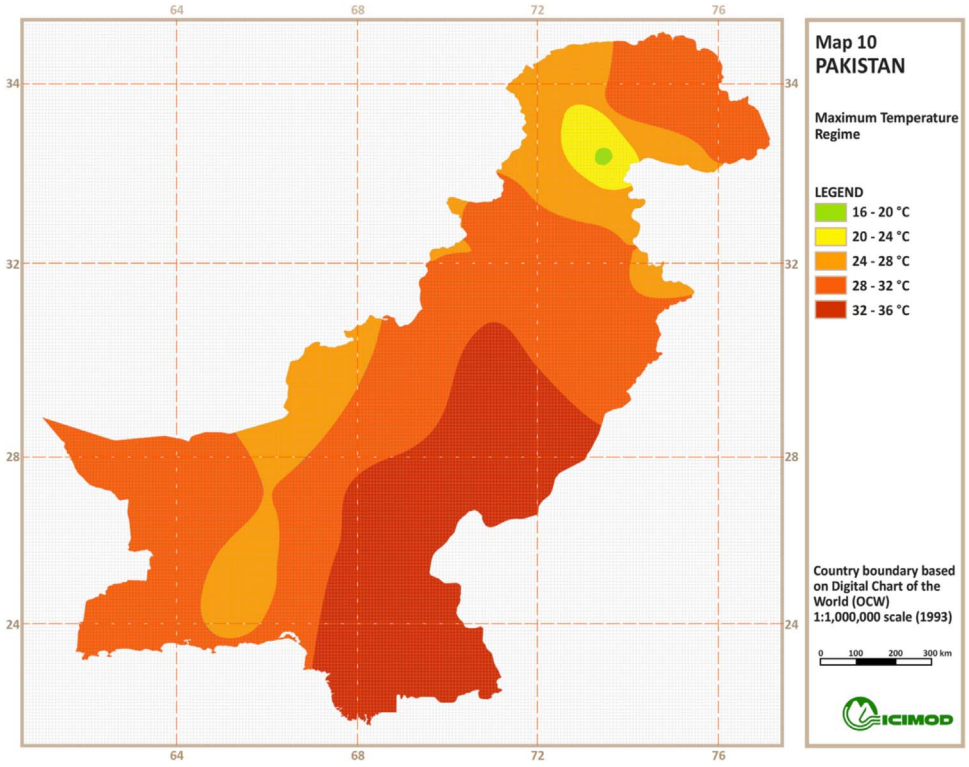

Fig. 1. Map showing maximum temperature regime of Pakistan [3].

Table 1
Ceiling fan performance parameters regularized by PS1 [7].

Parameters	Value	Tolerance
Rated input Power	80 W or lower	10%
Rated air delivery	250 m^3 min^{-1} or higher	−10%
Minimum Service Value (SV)	3.12 m^3 $min^{-1}W^{-1}$ or higher	N/A
Maximum speed with load	330 rpm	N/A

Table 2
BEE Star ratings [8].

Star ratings	Service value m^3 min^{-1} W^{-1}
Star 1	≥3.2 to < 3.4
Star 2	≥3.4 to < 3.6
Star 3	≥3.6 to < 3.8
Star 4	≥3.8 to < 4.0
Star 5	≥4.0

brands of ceiling fans for both energy consumption and service value [8]. Pakistan also possesses same climate regions as India. The standards and labeling programs classify fans by fan size or sweep [9] and blade count. Comparison with BEE Star rating uncovered that none of tested samples satisfy the star rating 3 or higher. Two out of forty nine samples could only satisfy star rating of 2 whereas two samples satisfied star rating of 1. Ceiling fan with an average power rating of 80 W having air delivery of 250 m^3 min^{-1} results in service value of 3.12 m^3 min^{-1} W^{-1}. A fan with such features, will fulfill PS1 but does not satisfy even the lowest BEE star rating. If every manufacturer in Pakistan starts manufacturing PS1 quality ceiling fan, 1000 GW h of energy can be annually saved which is 3.5% of the entire energy consumption of Pakistan's domestic sector [10]. This article proposes several recommendations for motor design to improve the efficiency of ceiling fan with high performance operation.

2. Existing technology review

The equivalent circuit diagram and construction of a permanent

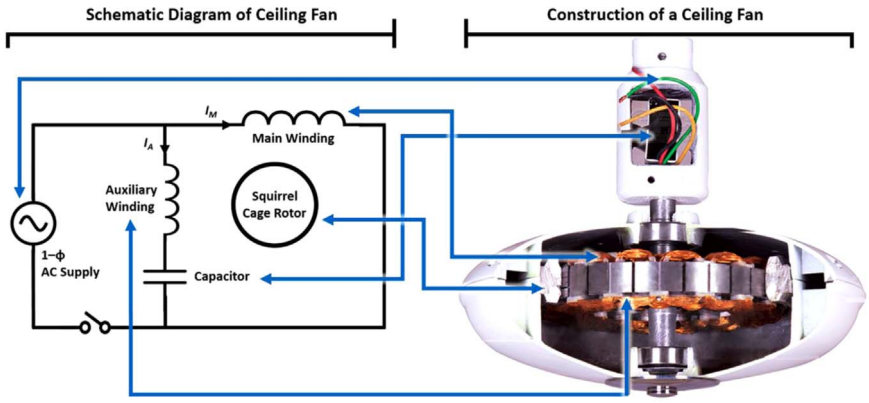

Fig. 2. The equivalent circuit diagram and the construction of single phase-squirrel cage induction motor based ceiling fan [11].