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METHODS OF IMPROVING ENERGY EFFICIENCY FOR DOMESTIC AIR CONDITIONING SYSTEMS

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ABSTRACT
In India, Minimum Energy Performance Standard (MPES) is based on Energy Efficiency Ratio (EER) governed by Bureau of Energy Efficiency. The standard EER is calculated at 35°C ambient temperature; moreover, it does not consider varying weather conditions prevailing over a season. Seasonal Energy Efficiency Ratio (SEER) gives a better representation of AC efficiency because it considers seasonal temperature variations also. A comparative analysis is performed for inverter AC vs. conventional AC using standard tests data from the manufacturers to compare EER and SEER values at different ambient temperatures. The effect of temperature differential on AC performance is also studied. The test result indicates SEER values to be more consistent. The important inferences concluded from test results are explained in the last section that will help in saving on running cost.

KEYWORDS: Energy Efficiency Ratio, EER, Seasonal Energy Efficiency Ratio, SEER, Inverter AC, Bureau of Energy Efficiency

I. INTRODUCTION
India's energy demand is increasing in the residential and commercial sector which is expected to grow by two times in next two decades to sustain economic growth. Presently residential sector accounts for 22%, of the electricity consumption in India [1]. Many policies have been drafted to check and minimise energy usage in commercial areas, but no significant efforts have been made in this area. The split and window air conditioners are the highest energy consuming gadgets in an Indian home. In a technical report published in 2014 on energy projections of India [2] indicates that the residential sector accounts for 21% of total electricity consumption. The demand for domestic air conditioners is growing rapidly in India due to reducing prices, easy financing options and increased purchasing power of the consumers. The growth of domestic air conditioners from 2004 to 2015 is shown in figure 1. It is, therefore, necessary to run these machines at highest possible efficiencies to save energy and cut running cost, but unfortunately, consumers have little knowledge about the judicious use of energy while operating on such high energy consuming equipment. By using standard operating procedures, energy savings can be achieved.

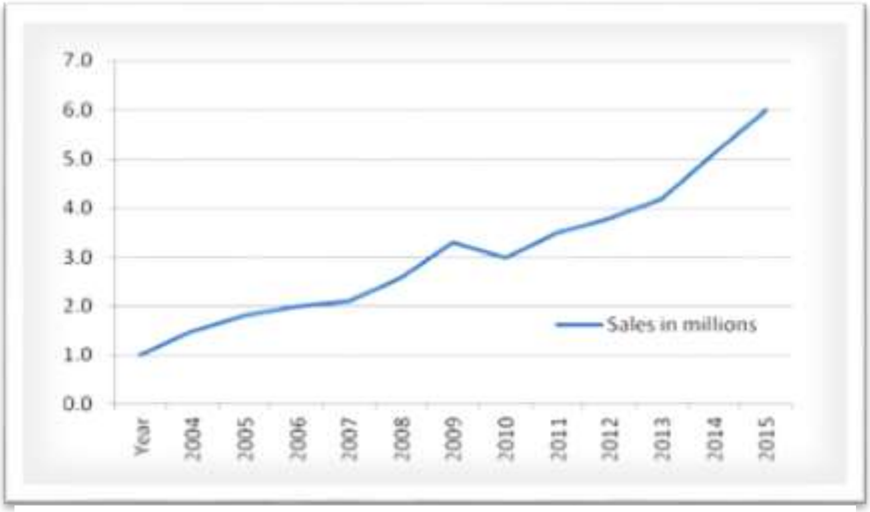

Figure 1 **Growth of domestic Air-conditioners in India**

II. THEORETICAL BACKGROUND

Subheading

There was no benchmarking of an air conditioner in India till 2012. The manufacturers were least bothered about the energy efficiency and running cost. Their exclusive focus was to reduce the cost of the unit. Therefore, little R&D activity was done and no significant innovation in this field has been reported till 2012. The Bureau of energy efficiency (BEE) has initiated standards and labelling program for electrical appliances in 2006, room AC came into its preview in the year 2012, making it mandatory to earn at least 1-star label under MPES before it could be launched in Indian market [3].

Table 1 Mandate EER values for 2017, BEE

EER values (w/w)		
Star rating	**Max**	**Min**
1 star	2.7	2.89
2 star	2.9	3.09
3 star	3.1	3.29
4 star	3.3	3.49
5 star	3.5	

The MPES corresponds to 1-star in the Indian market for AC manufacturers. A stiff competition started off among various manufacturers to earn highest star rating. Obviously, the cost of room AC also shot off momentarily due to aggressive R&D activates of the manufacturers resulting in high product cost. This trend helps in generating a market of more energy efficient AC units in India. The minimum energy performance standard value for the year 2017-18 is given in table-1. Energy savings up to 45% has been reported in industrial chillers and refrigeration units through variable speed compressor drive along with many additional advantages like reduced start-up current and torque, fewer ON/OFF cycles and minimum system failures, Shimma [4] investigated the applications of inverter based air-conditioning system to evaluate energy saving aspects. Another study reported 49% higher EER using twin speed compressor during a comparative study of the part-load efficiency of a compressor [5] [6]. Similarly, Cohens examined the effect of variable-capacity compressors in domestic and smaller industrial air-conditioning systems and suggested many necessary modifications required to attain higher efficiencies [7]. One of the research based on SEER performance analysed the effect of ON/ OFF cyclic loading over a range of ambient temperatures, reported a significant scope of energy savings through capacity modulation [8]. The study done by Lida has shown the improved values of EER and SEER up to 26% using an inverter driven compressor driven by 4 HP rotary compressors at 25Hz and 75 Hz [9]. Wong [10] studied volumetric and isentropic efficiencies and confirmed higher values of COP with reducing compressor speeds. Lloyd [11] investigated the effect of various waveforms on the efficiency of motor and

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compressor load and observed that sinusoidal waveforms had shown highest efficiency. Itami [12] conducted a study on similar grounds to evaluate the performance factor for frequency controlled rotary compressors and highlighted some useable parameters for attaining higher EER values [13]. ASHRAE invested much money in investigating the effect on the efficiency of chillers based on variable speed centrifugal compressors under Project RP-409 [14].

III. RESEARCH DATA

The energy efficiency ratio does not consider performance shift due to changing weather and load conditions. As per definition, EER is a ratio of output cooling in BTU per hour to total electrical input at full load conditions [15]. The values of EER are taken from BEE report [3] on room AC from various manufacturers, measured at different ambient conditions. These values are then converted into SEER values as per following formulae:

$$SEER = \frac{1.12 - \sqrt{1.2544 - 0.08 \times EER}}{0.04}$$

This shortcoming is fulfilled by SEER which gives a better representation of energy efficiency of AC units for benchmarking of air conditioner across many countries. This analysis is done to compare the performance of one tonne conventional AC with variable speed Inverter AC. The values of current, power, EER and SEER have been collected for different ambient temperatures corresponding to set-temperature of 22 °C as shown in Table-2. The second case analysis is done to know the effect of temperature differential on power consumption, EER, and SEER as shown in Table-3.

Table 1 **Current vs. EER and SEER values for non-Inverter AC**

Ambient Temp	Set temp	Current drawn	Watts	EER	Theoretical SEER
29	22	9.91	2180	5.5	5.4
31	22	11.48	2526	4.8	4.6
35	22	12.39	2726	4.4	4.3
39	22	15.86	3489	3.4	3.3
43	22	16.83	3703	3.2	3.1

Actual SEER value = 4.10

Table 2 **Current vs. EER and SEER values for Inverter AC**

Ambient Temp	Set Temp.	Current drawn	Watts	EER	Theoretical SEER
29	22	7.89	1736	6.9	7.1
31	22	8.43	1855	6.5	6.5
35	22	10.13	2229	5.4	5.3
39	22	11.43	2515	4.8	4.6
43		12.35	2717	4.4	4.3

Actual SEER value = 5.42

IV. RESULTS AND DISCUSSION

Table-2 clearly indicates that value of current increases with the increase in ambient temperature. At 29°C, the amount of current is 9.91 ampere with corresponding EER value of 5.5. The current value shoots up to 16.83 amperes at 43 °C ambient temp with EER value of 3.2, indicating that high current drawn by the compressor at higher ambient temperature. In the case of inverter AC, the values of current are relatively on the lower side as shown in table-4. The respective values of current at temperature 29 °C and 43 °C are 7.89 and 12.35 amperes.

Table 3 **Temperature differential vs. EER and SEER**

Temp difference	Current drawn	Watts	EER	SEER
8	7.78	1712	7.0	7.2
9	8.01	1762	6.8	6.9
11	8.89	1956	6.1	6.2
13	9.87	2171	5.5	5.5
15	11.11	2444	4.9	4.8

Actual SEER value = 5.97

The comparative results of an inverter and non-inverter AC for Current, Power, and EER is shown in table-2 and table-3. The graphical representation of these results is shown in figure-1.

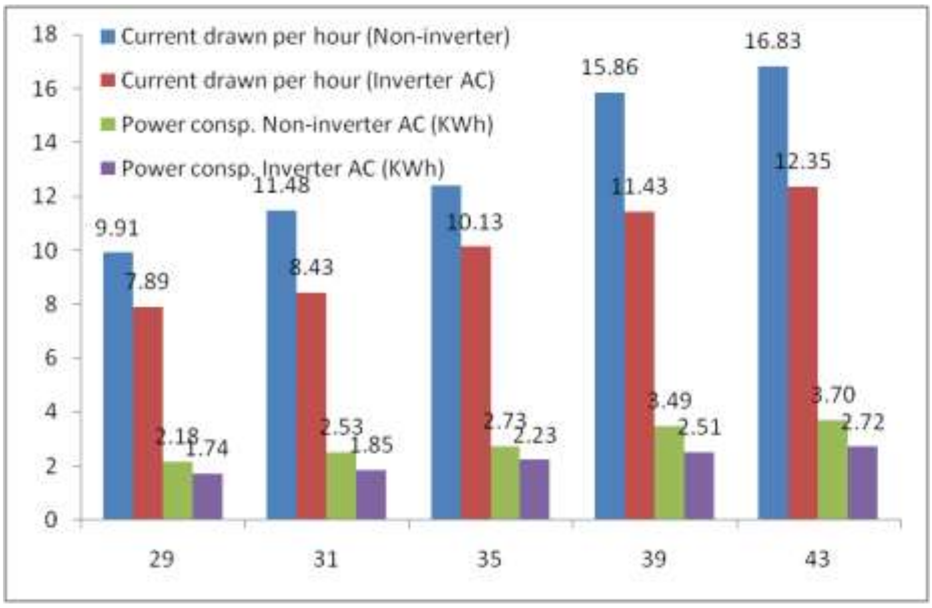

Figure 2 **Comparison of current and power rendered, Inverter vs. Non-Inverter AC**

It can be observed that the value of current is highest 11.11 ampere corresponding to the temperature differential of 15°C; the corresponding value of EER is 4.9. It is clear that AC consumes higher energy as temperature differential across the condenser and cooler increases, but efficiency is reduced proportionately.

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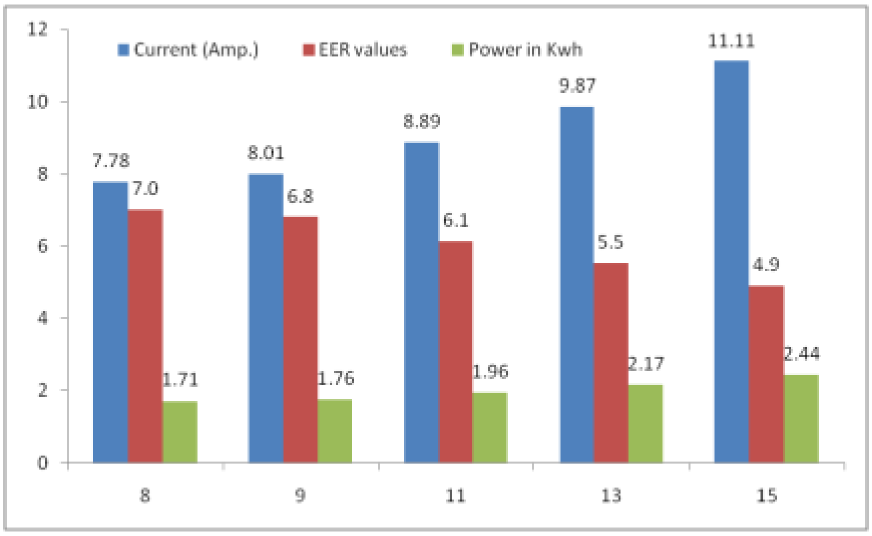

Figure 3 **Effect of temperature differential on Current, EER and Power, Inverter AC**

V. CONCLUSION

Room ACs does consume much energy, but we can minimise it by taking few effective steps. The four critical factors which impact electricity consumption of an air-conditioner are outdoor temperature, set temperature, thermal insulation of the room and condition of air-filters. The AC takes in room's air through front filters fitted behind the grill. The filtered air is cooled by passing it through cooling coil and thrown back into the room by AC-fan behind supply grill. The room temperature keeps lowering with each cycle of operation until the set temperature is attained and thermostat shuts off the compressor. It is observed that people are in the habit of lowering the set temperature as outside temperature increases, which is the worst scenario. A set temperature of 26 °C can be attained much earlier than a set temperature of 18 °C, which makes the compressor run for a longer duration until it shuts off by the thermostat, this results in higher energy consumption with each degree rise in set temperature. As per ACEEE, an increase of each degree in set temperature can save up to 5% of energy consumed. The health of air filters can severely affect the efficiency of an AC. The clogged air filters put a strain on the fan, affects air quality and reduce the heat transfer rate of the cooling coil due to reduced airflow. The poor air flow can also result in ice formation within the unit, severely reducing its cooling efficiency or total failure of the unit in worst cases. Clogged filter can use 15% more energy, according to the Department of Energy. It is recommended to clean air filters at least in two weeks and replace them once in the season. Thermal insulation also plays a significant role in saving energy cost by reducing the load. AC should be installed in a room which is centrally positioned in a house to ensure minimum solar radiation through side walls. Minimise sensible heat losses by shielding air leakages through windows and door. In the end, the condenser unit of an AC should be positioned in a well ventilated and cool area wherever possible. It is better to avoid direct solar radiations falling on condenser through shading either by tree plantations or by some other means.

VI. FUTURE SCOPE

The AC manufacturers pre-set the AC controls for the hottest geological locations, whereas the actual ambient conditions are entirely different over a span of a day and season. For example, the ambient temperature keeps on changing throughout a day from 22°C to 43°C from May to August in North India which demands constant monitoring and adjustments of set temperature for maximum comfort and efficiency. At present AC controller switches are thermostatically operated and temperature controlled, without any closed loop sensor based feedback system. Research can be initiated to develop smart adaptive temperature monitoring system for domestic AC that can regulate the indoor temperature according to outdoor ambient conditions.

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