SSURJET

Sir Syed University Research Journal of Engineering & Technology
2022, Vol. 12, No. 2,
https://doi.org/10.33317/ssurj.466

An Investigation to Reduce Electricity Bills using Inverter AC in Pakistan

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Received March 17, 2022; Revised June 09, 2022; Accepted June 22, 2022

Abstract

The cost affiliated with the energy usage of a Conventional Air Conditioner (AC) is pretty high, an average salaried person cannot afford it. A room of dimensions 5.8 x 4.5 x 3.6 m is used for the energy assessment, in which the Inverter/VRF and Conventional air conditioning system are used separately to attain a set temperature of 25 °C for the weather in Hyderabad, Pakistan. Through the simulated results, the month of May has the highest energy use, with 467 kWh for Conventional air conditioning and 310 kWh for Inverter air conditioning. When compared to Conventional AC, Inverter or VRF AC can save up to 50 % on energy. In Pakistan, according to NEPRA pricing, Inverter AC can have a payback time of 5 to 11 months for various brands of ACs, and they can reduce an ordinary consumer's annual electricity cost by up to 48 percent.

Index Terms: *Conventional Air Conditioner, Inverter Air Conditioner, National Electric Power Regulatory Authority, Payback Period, Thermal Comfort.*

I. INTRODUCTION

Energy demand is expanding day to day. Every year, an enormous amount of energy is consumed for meeting the total thermal load of the buildings [1]. In most developed countries, the percentage of energy consumption by the building sector is between 20 and 45 percent [2]. In 2040, global primary energy use will grow fourfold [3]. The energy assets should be handled carefully to connect with increasing demand. Heating, Ventilation, and Air Conditioning i.e., HVAC frameworks play a significant part in energy utilization in buildings. Primary factors for growing energy demand can be because of an increase in population, the urgency for higher comfort levels, and a longer period consumed by people in the buildings [4]. Air conditioning has progressed from a solo facility for a single building too many entities for different accommodations inside the same building [5]. A Variable Refrigerant Flow (VRF) system can serve similar requirements for the installation of many separate units with lesser space, the reason is it comprises of a single condenser and many evaporators.

Variable Refrigerant Flow (VRF) is a refrigerant technology in which the flow rate of a refrigerant is varied with the assistance of the variable speed-driven compressor unit and the electronic expansion valves equipped in every evaporator to meet the cooling/heating loads as sketched in figure I [6]. The condenser component of a multi-split VRF air conditioner comprises of usually two or maybe three compressor units, one of which is a variable speed compressor. The condenser unit is installed with an inverter-driven compressor enabling the frequency variation from 20–30 Hz to 105–120 Hz. By altering the frequency of the inverter, the condenser unit alters its potentiality by changing the flow rate to intersect the desired cooling loads of the spaces. A heat exchanger with an electronic expansion valve is included in the evaporator component. An air temperature-measuring device and a blower are also placed in the evaporator unit to compare the actual and set temperature of the room and to circulate the cold air in the room respectively. Following the temperature gradient, the flow rate of the refrigerant through the evaporator is controlled by adjusting the electronic expansion valve. Each evaporator unit can be operated independently depending on the difference between the predetermined temperature and the current room temperature. As a result, several zones with different fixed temperatures can exist, which we can refer to as personalized comfort control [7]. Author Ahmed along with his associates in the year 2020 experimentally examined the performance of Inverter AC with non-inverter/ Conventional AC. The experiment was performed under the same weather conditions and the same tonnage air conditioners were installed in an office room for 108 days. According to the findings, Inverters can save up to 44 % of energy consumption when compared to non-inverters [8].

Khatri and Joshi in the year 2017 analyzed the potential of a VRF AC in comparison with a Conventional AC using field performance testing. These two types of air conditioners were installed in two indistinguishable rooms, with 14.5 m^2 floor zone each. Readings and observations were considered from Jan to May, the air conditioners were in operating mode from 10:00 to 18:00. The auxiliary heating stack provided by the electric heaters was 2000 W and 4000 W, respectively, to vary the interior cooling load. Winter and summer observations were taken at 23 °C and 25 °C set points respectively, results were drawn in form of the tabular and graphical representations. The outcomes were examined, and it was discovered that the VRF innovation is energy saving in the part-load context only; i.e. 39 percent savings were noticed, when the outdoor dry bulb temperature is approximately equal to the evaporator set point temperature [9]. In the past author, Yurtseven, and fellow researchers (2014) examined the performance of Conventional AC and Inverter AC in two indistinguishable rooms for energy consumption. Both rooms were identical in terms of geometry and occupancy. The Inverter AC can save energy between 11 and 38 percent, which is considerably huge [10]. Elzanati and Ameen in the year 2013 analyzed the two systems namely solar AC and Inverter AC in the grid station of Bahrain to choose the most economical technology. They concluded that the use of a variable speed AC system could be considered an energy-saving technology [11]. Saidur and associates (2012) inquired about the consequences of using (Variable Speed Drives) VSDs. They found that it is promising in terms of profit and energy consumption in compressors, pumps, and many other related different apparatuses. Moreover, they also stated that the usage of variable speed drives in HVAC systems provides remarkable opportunities to minimize energy consumption [12]. In a present environment for the cooling season, Aynur and companions (2009) reconstructed the association of Variable Air Volume (VAV) and Variable Refrigerant Flow (VRF) cooling schemes; it directed that the VRF air conditioner delivered 27.1 to 57.9 percent savings as compared to the VAV air conditioner [13]. In 2008 Ohyama and Kondo wrote a research paper, in this paper, they reviewed that VRF technology can minimize energy utilization to less than half as compared to the air conditioners driven by a uniform speed compressor [14].

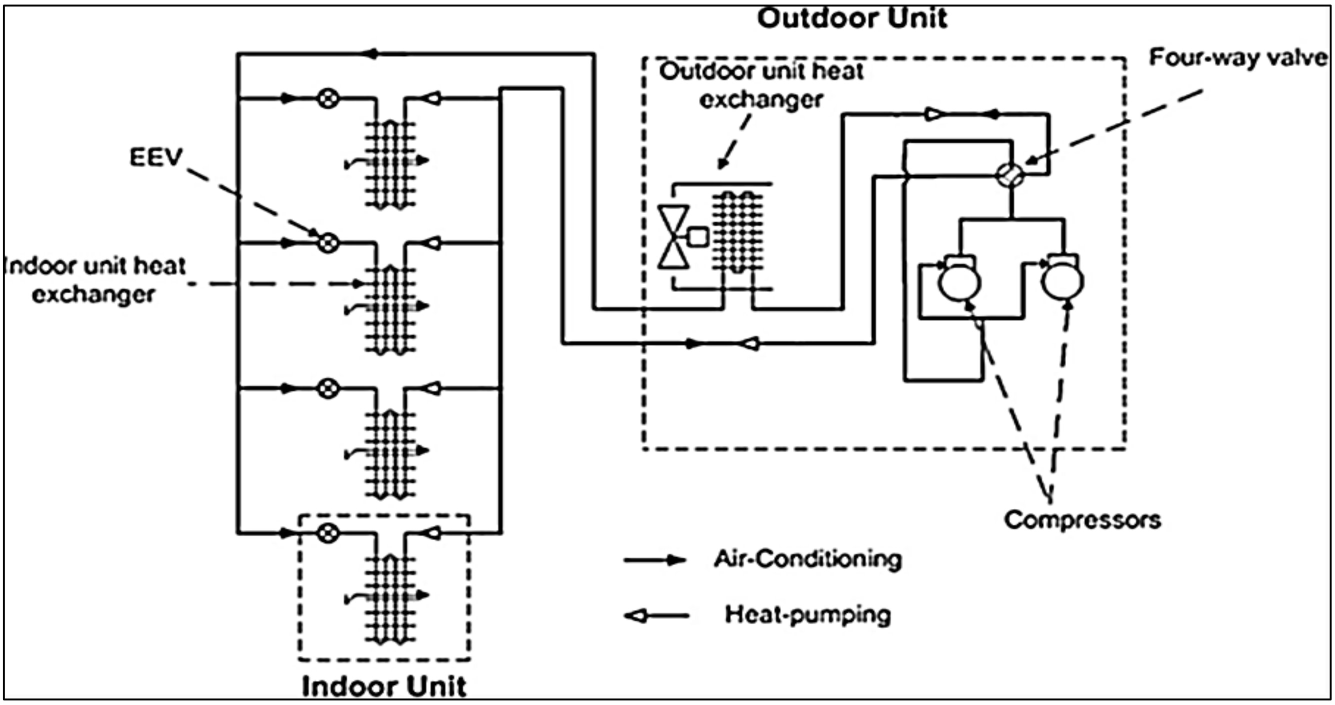

Figure I: A Multi-Split Inverter System with Four Indoor Units

II. METHODOLOGY

A. Description of Building Model

In the ‘EnergyPlus’, building energy simulation package, a room measuring 5.8 m × 4.5 m with a height of 3.6 m is utilized to simulate energy consumption.

Location, area, volume, orientation, time zone, doors, windows, material, and internal gains are all included in the building description in table I.

Table I: Information about the Structure/Building

Locality	Hyderabad, Pakistan
Latitude	25.3 Degree
Longitude	68.4 Degree
Altitude [m]	41 m
Time Zone	GMT +5 Hours
Apartment Type	Single-Flooring, Single-Zone, Medium Workplace Activity
Positioning	Sun Visible from All Sides
Windows and Area	02, Area: 4 m^2
Doors and Area	01, Area: 2.9 m^2
Ground to Roof Elevation	3.6 m
Flooring Area	26.1 m^2
Wall	4 inch Double Brick Plastered with Cement
Window	Aluminium Glass, Thickness: 5mm
Door	Solid Wood, Thickness: 20 mm
Roof	Cement for Reinforced Concrete
Zone Occupants	02
Lighting Load [Watt]	278
Equipment Load [Watt]	199

B. Energy Consumption

In two geometrically and thermally symmetrical rooms, Conventional AC and an Inverter AC are used individually to attain the fixed temperature of 25 °C in Hyderabad, Pakistan. In the 'EnergyPlus' building energy simulation package, air conditioning systems of both types are simulated in a specified room to calculate the energy utilization over a 12-month period with 446 running hours per month. By using the EnergyPlus IDF Editor, the source code scheme for calculating the energy usage of Conventional AC and VRF AC is selected from HVAC models. The 'EP-Launch' is used to open the file after the program is finished. The algorithm can be simulated for your specified period by selecting a suitable weather file. R-410a and R-22 are the refrigerants used in the Conventional AC and Inverter AC respectively. A graphical sequence of energy consumption computation is shown in figure II and figure III respectively.

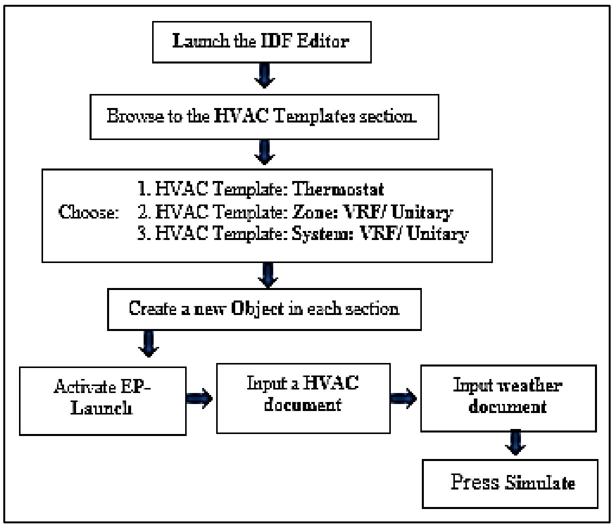

Figure II: Energy Consumption as a Flowchart

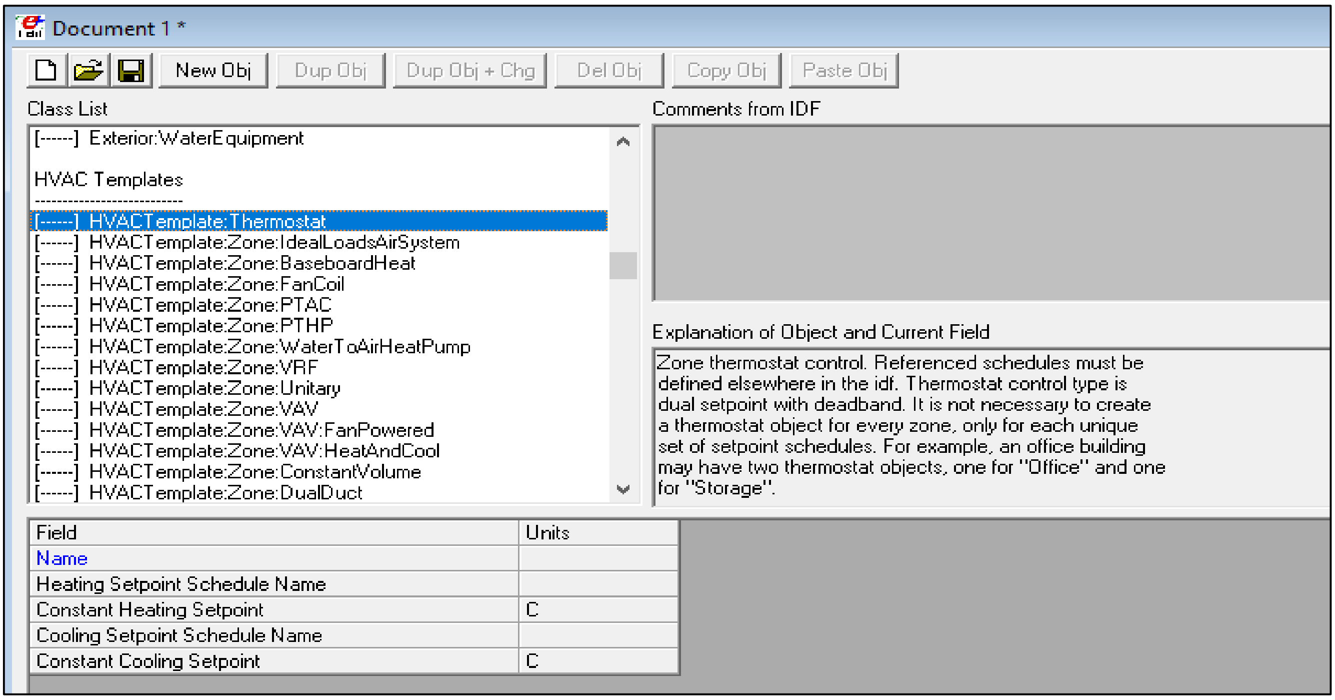

Figure III: Computation of Energy Consumption

C. Economic Analysis

Based on parameters such as the payback period, an Inverter AC is assessed to determine energy savings and fiscal entitlements. The energy savings from the Inverter AC are considered for a period of 12 months and the payback is calculated using eq. (1).

$$\text{PBP} = \frac{Investment\ Cost\ (a)}{Annual\ Savings\ (b)} \tag{1}$$

III. RESULTS AND DISCUSSIONS

A. Temperature Profile

In EnergyPlus, a building energy modeling software, the temperature at peak hot hours is determined over the course of a year. As indicated in figure IV, the highest temperature is 48.5 °C, and the lowest temperature of 28 °C in the month of May.

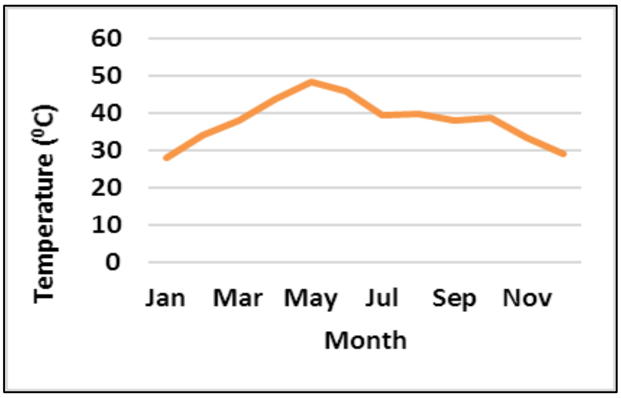

Figure IV: The Average Temperature at Peak Hot Hour over the Course of a Year

Figure IV shows that the temperature is highest at 14:00 in the month of May. Figure V depicts the temperature pattern at 14:00 for the entire month of May. With a temperature of 48.5 °C on May 19, it is the hottest day of the year.

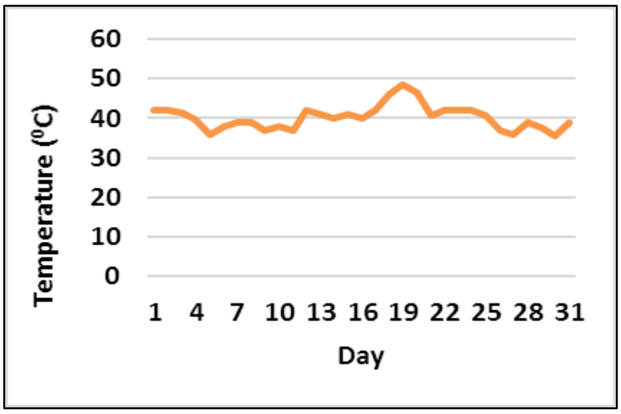

Figure V: The Temperature at its Hottest Point Throughout the Month of May

Figure VI depicts the temperature distribution for May 19. It reveals that the peak hot temperature is 48.5 °C at 14:00 and the highest cold temperature is 28 °C at 5:00.

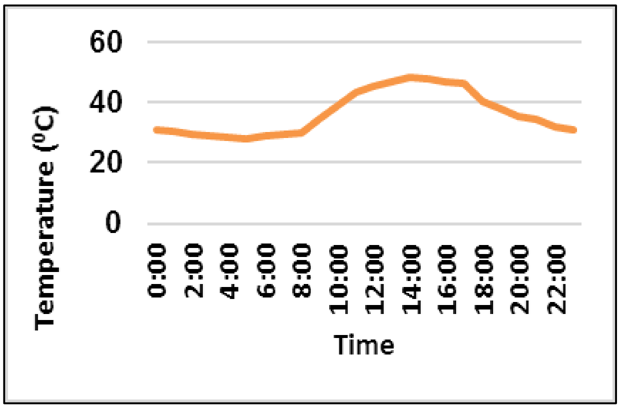

Figure VI: The Temperature Profile for May 19

B. Energy Consumption

Hourly, daily, and monthly energy usage of Conventional AC and Inverter AC is calculated for the predetermined temperature of 25 °C:

1) Hourly Energy Consumption:

On 19th May, at a predetermined temperature, Figure VII illustrates the hourly energy usage of the air conditioner of both types.

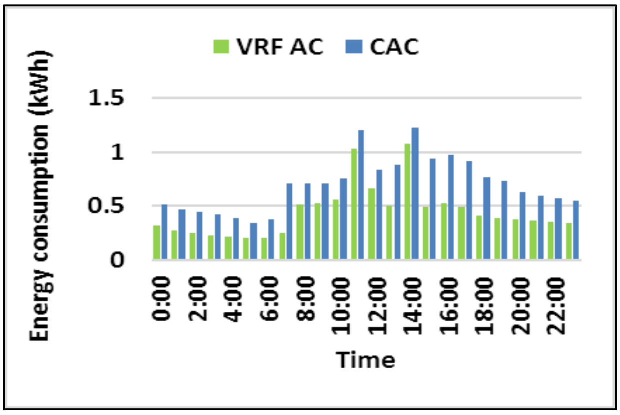

Figure VII: The Inverter AC and Conventional AC Hourly Energy Consumption for May 19

Conventional AC total energy use on May 19 was 16.64 kWh, with 1.23 kWh consumed during peak hot hour at 14:00 and 0.342 kWh consumed during peak cold hour at 5:00. The overall energy usage for Inverter AC on May 19 was 10.54 kWh, with peak hot hour energy consumption of 1.075 kWh at 17:00 and peak cold hour energy consumption of 0.205 kWh at 5:00. When making a comparison between Inverter AC with Conventional AC, it is deduced that Conventional AC operates at a fixed speed regardless of load, whereas Inverter AC operates at a flexible speed with regard to load, therefore it consumes less kWh of energy at night due to the lower temperature.

2) Daily Energy Consumption:

It has previously been calculated from figure VII that the energy usage is at its highest at 14:00. So, for the entire month of May, the energy usage is evaluated for one hour at 14:00.

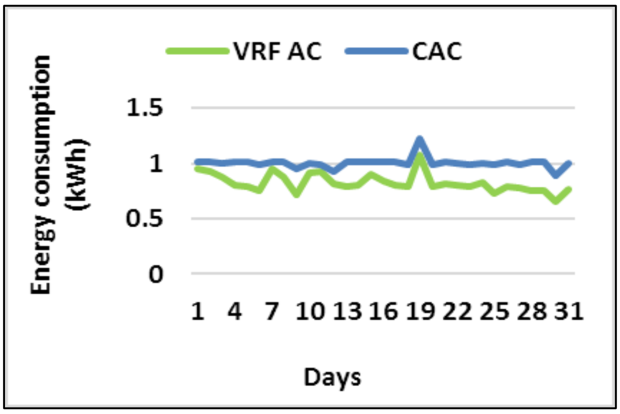

Figure VIII: During the Month of May, Daily Energy Usage by Inverter AC and Conventional AC

Figure VIII shows the energy consumption of both types of air conditioners in May at 14:00 at a predetermined temperature of 25 °C. The overall energy usage for Conventional AC in May was 31.1 kWh, with the highest energy usage of 1.22 kWh on May 19 and the lowest energy usage of 0.892 kWh on May 30. The overall energy usage for Inverter AC in May is 25.6 kWh, with the maximum energy usage of 1.09 kWh on May 19 and the minimum energy usage of 0.67 kWh on May 30.

3) Monthly Energy Consumption:

The energy usage is evaluated for the entire year, from January to December as depicted in figure IX.

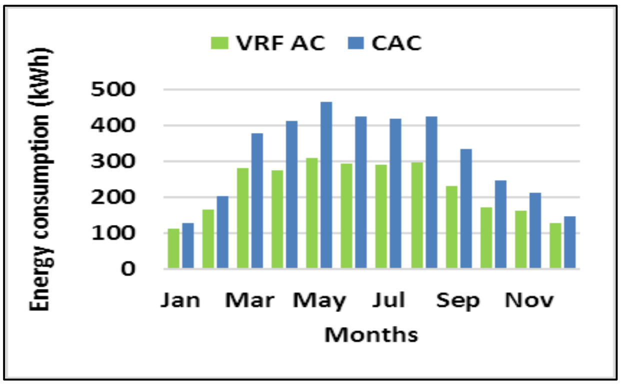

Figure IX: Inverter AC and Conventional AC Monthly Energy Consumption from January to December

May has the highest energy usage of 467 kWh for Conventional AC and 310 kWh for Inverter AC. December has the lowest energy usage of 147 kWh for Conventional AC and 128.2 kWh for Inverter AC.

C. Energy Savings

The savings by Inverter AC is evaluated by using eq. (2)

$$\text{Energy Savings} = \frac{[Larger\ value\ (a) - Smaller\ value\ (b)]}{Smaller\ value\ (b)} \times 100 \quad (2)$$

$$\text{Energy Savings} = \frac{(a-b)}{b} \times 100 \quad (3)$$

Therefore, in this case, it will be:

$$[Energy\ consumed\ by\ Conventional\ AC\ (a) - Energy\ consumed\ by\ Inverter\ AC\ (b)] / (Energy\ consumed\ by\ Inverter\ AC\ (b)) \times 100 \quad (4)$$

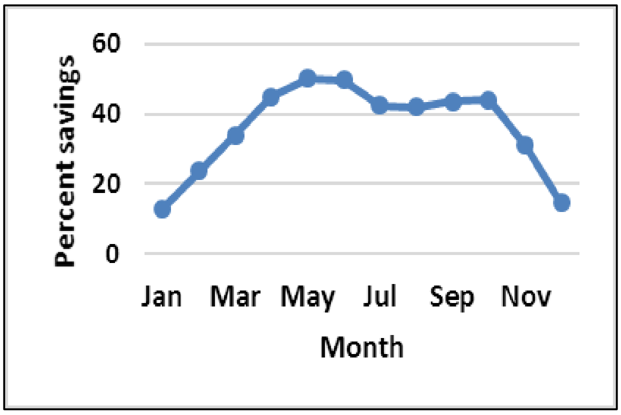

Figure X: Energy Savings by Inverter AC from January to December

Figure X shows the percent savings that have been calculated.

D. Payback Period

In Pakistan, the selling price of an Inverter AC is 44 percent to 53 percent greater than the Conventional AC, as shown in table II [15]. These prices fluctuate from one manufacturer to the next. On average, Conventional AC consumes 404 kWh per month, while Inverter AC consumes 278.5 kWh per month on average. Payback can be calculated using eq. (5)

$$\text{PBP} = \frac{Investment\ cost\ (a)}{Annual\ savings\ (b)} \quad (5)$$

Let 'a' stand for investment cost and 'b' for annual net cash retrieved:

Table II: Conventional AC and Inverter AC Cost

Conventional AC	Price (Rs)	Inverter AC	Price (Rs)
Kenwood Echo Plus KEE-1845S (1 Ton)	83300	Kenwood Echo Plus KEE-1845S) E-Inverter (1 Ton)	120000
Kenwood E-Luxury (KEL-1844S) (1 Ton)	85600	Kenwood e-luxury (KEL- 1844S) E-Inverter (1 Ton)	131000

1) Influence of Electricity Tariff on the Payback Period:

This objective is evaluated using alternative electricity pricing, such as Rs 17 per unit (current cost of electricity as per NEPRA tariff-2022) [16] and Rs 22, Rs 8 for future concerns:

(a) The cost of electricity is Rs 17 as depicted in table III. On average, Conventional AC consumes 404 kWh per month, whereas an Inverter AC consumes 278.5 kWh per month. The annual savings provided by an Inverter AC are Rs 25609.

Table III: Electricity Cost is Assumed to be Rs 17 (i.e., the present case) at Varying Initial Prices

Initial Price Increase (%)	Payback Period (Year)
30	0.38
44	0.58
53	0.67
70	0.92

(b) The cost of electricity is Rs 22 as depicted in table IV. On average, Conventional AC consumes 404 kWh per month, whereas an Inverter AC consumes 278.5 kWh per month. The annual savings provided by an Inverter AC are Rs 33133.

Table IV: Electricity Cost is Assumed to be Rs 22 (i.e., for future concern) at Varying Initial Prices

Initial Price Increase (%)	Payback Period (Year)
30	0.31
44	0.45
53	0.54
70	0.71

(c) The cost of electricity is Rs 8 as depicted in table V. On average, Conventional AC consumes 404 kWh per month, whereas an Inverter AC consumes 278.5 kWh per month. The annual savings provided by an Inverter AC are Rs 12049.

Table V: Electricity Cost is Assumed to be Rs 8 (i.e., for future concern) at Varying Initial Prices

Initial Price Increase (%)	Payback Period (Year)
30	0.84
44	1.23
53	1.48
70	1.95

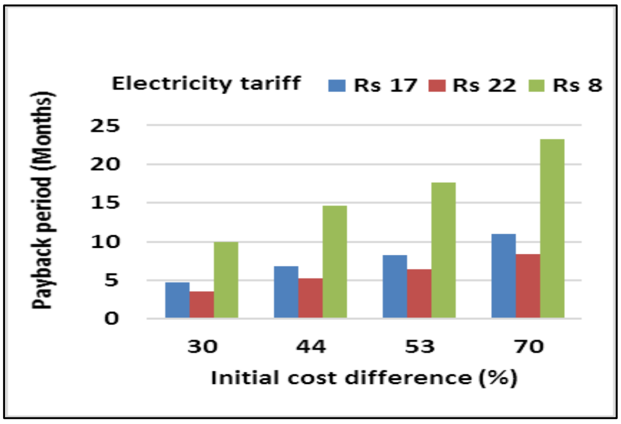

Figure XI: Inverter AC Payback Period Calculated on Initial Price Percentage Difference at Different Electricity Costs

As indicated in figure XI, the Inverter AC will pay for itself in 5 to 11 months with the present cost of electricity (Rs 17), and the remaining values (Rs 22 and 18) are laid down for future consideration.

IV. CONCLUSION

To achieve thermal comfort, heating, ventilation, and air conditioning frameworks such as an air conditioning unit are required. Inverter AC systems can be a good replacement for Conventional AC with minimized energy consumption. A room of 5.8 m × 4.5 m with a height of 3.6 m was selected for the energy calculation, in which the Conventional AC and Inverter AC were operated separately to obtain a predetermined temperature. The simulated model for both types of air conditioners developed in the 'EnergyPlus' is presented in this article. The hottest day is May 19, according to the simulation results, and its hourly energy consumption is computed. The Inverter and Conventional AC have the highest energy consumption at 14:00 and the least at 05:00. The annual energy consumption of a Conventional AC is 2730 kWh, while an Inverter AC consumes 3808 kWh. For both Inverter and Conventional AC, the month of May has the highest energy usage while the month of January has the lowest. The Inverter AC uses 13 to 50 percent less energy than a Conventional AC, according to the comparison of energy context. The savings from an Inverter AC increase as the outdoor temperature rises. The payback period of an Inverter AC in Pakistan, according to NEPRA pricing, is around 5 to 11 months with the present cost of electricity, and it will reduce an ordinary consumer's electrical expenditure by up to 48 percent yearly.

Acknowledgment

The authors would like to thank ISRA University, Hyderabad, Pakistan, for all the support, provided to accomplish this research work.

Authors Contributions

The individual author contributions are mentioned below; Ameen Khan's contribution to this study was the concept, technical implementation, and all correspondence. The methodology to conduct this research work was proposed by Aftab Ahmed Khuhro. Data collection and supervision were performed by Ans Ahmed Memon along with data compilation and validation. Ateeque Ahmed Memon's contribution was project administration, and paper writing.

Conflict of Interest

There is no conflict of interest between all the authors.

Data Availability Statement

The testing data is available in this paper.

Funding

This research received no external funding.

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