

Comparison of Energy Consumption between a Standard Air Conditioner and an Inverter-type Air Conditioner Operating in an Office Building

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Abstracts

Demand for air conditioners (ACs) has exponentially increased worldwide over the last few years. Countries with booming economies report high growth of sales of room air conditioners. Sri Lanka is not an exception. With the increased gross domestic product (GDP) and warming climates, demand for room air conditioners is expected to further increase. Meeting the increased demand for electricity will be a challenge. Increased use of energy efficient air conditioners has positive impacts on the national grid, especially during periods of high demand. In a regular AC, the compressor runs at a fixed speed and is either ON or OFF. In an inverter AC, the compressor is always on, but power drawn depends on the demand for cooling. The speed of the compressor is adjusted appropriately.

In this study, the energy consumption of a regular and an inverter AC of the same capacity was evaluated in a typical office room, under similar operating conditions. Energy consumption was measured for six consecutive weeks and compared. Results show that the daily average energy consumption (for an 8-hour operating period) was 13.5 kWh for the standard AC and 8.7 kWh for the inverter type AC. Therefore, it is concluded that inverter technology can save about 35% of electricity consumed over a standard air conditioner. With the expected growth of air conditioner use and ambient temperature rise, inverter technology can significantly contribute to reduce the peak demand and energy use.

Keywords: air conditioner, inverter AC, energy efficiency

Introduction

Research work described in this paper was intended to compare the energy consumption of a standard (non-inverter) air conditioner with an inverter-type air

conditioner of the same capacity, operated in similar environmental conditions in a normal office room during working hours. With the results, authors investigate the potential energy savings by deploying an increasing share of inverter ACs and the influence it can have on the national grid in terms of peak demand and energy savings, and reduction of GHG emissions from electricity generation.

Worldwide Growth in Sales of Room Air Conditioners

Energy consumption in air conditioners is rapidly increasing around the world. The demand for air conditioners have exponentially increased worldwide over the last few years. Since almost 90% of the homes in high income countries have already installed air conditioners, the recent and future growth is mainly driven by middle income countries. [1, 2]. According to a study conducted by the Japan Refrigeration and Air Conditioning Industry Association [3], the overall world AC sales in 2015 was estimated to reach 92.46 million units. The association divides AC sales into six main geographic areas. They are Japan, China, rest of Asia, Europe, North America, and other countries. Amongst them, the largest market is China, where sales reached 32.33 million units. The second largest market was Asia, excluding Japan and China, and the demand was 15.15 million units. The demand for AC units in North America reached 14.35 million units in 2015.

The largest share of AC sales is in room air conditioners. In 2015, world demand for room air conditioners was estimated to be 79.39 million units. Same as for all ACs, the largest market for room air conditioners was China and the demand reached 30.25 million units. The demand for room air conditioners in Asia, excluding Japan and China, was 13.72 million units. According to these studies, it is evident that countries with rapidly growing economies have a

growing demand for ACs. As the economy and population of these countries grow, along with increased access to electricity and warming climates, it is expected that the demand for ACs would increase exponentially, not only for comfort but also as a health necessity [2,4]. According to a report on the global AC demand by Lawrence Berkeley National Laboratory [4], the AC penetration rate in urban areas in China has increased from a few percent to 100 percent in just 15 years. AC sales are increasing in India, Indonesia and Brazil by between 10 and 15 percent per year [4]. India, with over 1.25 billion people, had only a 5 percent penetration of air conditioning in year 2011. Studies have found a clear relationship between household income and AC adoption [4,5]. Sri Lanka is not an exception. Table 1 shows the increasing demand for room ACs in Sri Lanka.

Table 1 - Demand for Room ACs in Sri Lanka [4]

Year	Demand for room ACs (in thousands)
2010	50
2011	62
2012	73
2013	73
2014	74
2015	77

Therefore, it is evident that there is a rapid growth in penetration of ACs, mainly in developing countries, including Sri Lanka. The main challenge would be to meet the increased demand for electricity. If electricity demand is met by fossil fuels, it would generate increased emissions [2,4]. Therefore, it is important to explore new technologies and solutions that would reduce the electricity consumption of an AC. As a solution, AC manufacturers have attempted to make them more energy efficient [4]. Inverter type ACs are one of those newest technologies that manufacturers have introduced to the market more than a decade ago.

The constant speed AC, the dominant type in the market, is now gradually replaced by the inverter ACs. Sales of inverter driven ACs have reached 100% of the market in

Japan and a significant portion in the EU (50% in 2008) and Australia (55% in 2008). This trend is promising in terms of energy savings and will help reduce future energy consumption and corresponding reduction in GHG emissions [6].

Difference between an Inverter AC and a Regular AC

The cooling load of an AC is a variable and depends on room occupancy (number of persons), desired comfort level of the customer (set temperature), outdoor environmental conditions and many other parameters. In most ACs, the actual cooling load fluctuates. However, in regular ACs, the system is not designed to handle this variable load, but for the expected peak load. In an AC, the compressor is the component which consumes electricity. In non-inverter type ACs, the compressor is either ON or OFF. When it is ON, it works at full capacity and uses the full amount of electricity it is designed to consume. When the set temperature in the AC is reached, the compressor is cut-off and cooling is stopped. When the thermostat senses that the room temperature has increased, the compressor switches ON again, automatically. That means, in normal air conditioners, the compressor is switched ON and OFF intermittently.

The inverter driven AC with varying cooling capacity has been studied during the last two decades and the well-known technique is to control the rotational speed of the compressor based on its cooling load. A three-phase induction machine (IM) is generally used as the compressor motor. In an inverter type AC, the inverter is used to control the speed of the IM by changing the frequency of the power supply to drive the variable refrigerant flow and thereby regulating temperature of the conditioned-space. The variable frequency drive is used to achieve the desired frequency, and the rotational speed will be proportional to the input frequency. This will adjust the flow rate of refrigerant based on the temperature of the room. With this technology, the compressor of the AC is always ON, but varies the power input depending on the temperature of the return air and the level set in the thermostat [1]. Hence, the flow of refrigerant is dependent on the cooling needs of the space.

Several studies have modelled the variable speed compressor to simulate the inverter AC. Shao et al. [7] by their modelling and experimental investigation, found that the refrigerant flow is determined only by the compressor frequency and is independent of the condensation and evaporation temperatures. They also found that the coefficient of performance (COP) of the inverter air conditioner changes slightly with the speed of the compressor, and the optimal frequency which gives the highest COP is usually the basic frequency [7].

Advantages and Disadvantages of Inverter ACs

Split-type variable speed (inverter-type) ACs were the best available technology in Europe by 2012 [8]. Variable speed or the inverter ACs are more effective when they are run at part load, than the regular constant speed ACs serving a cooling load below its rated capacity. In other words, the efficiency advantage is highest when they run at part load conditions [6,8].

- Inverter-type ACs can keep the temperature more stable, increasing thermal comfort.
- They can initially cool a warm room faster to a convenient temperature.
- They are more energy efficient.

The main disadvantage of an inverter AC is its high initial cost compared with a regular AC.

- Electronic components and control circuitry are more complicated compared with the non-inverter type which makes the AC more expensive.
- There is a controversial statement regarding the effect of inverter AC on the power quality of low voltage distribution networks.

Mirchevski et al. [9] found that inverter ACs form a considerable share of nonlinear load in the residential sector and a source of harmonics on the electricity grid. In contrast, Moller et al. [10] conclude completely opposite results, where the inverter fed AC units utilizing three-phase motors provide the most suitable solution to power quality issues compared with

high penetration of non-inverter ACs. Therefore, a comprehensive study on the power quality issue of a large penetration of inverter ACs in the national grid is required.

Materials and Study Methodology

Two AC units, an inverter and a non-inverter, were tested under similar operating conditions. Both were rated single-phase 240V, 50Hz. Each unit was mounted on the same wall of an office room and the temperature control settings of the units were set to 26°C, so that it creates the normal operating load in an office building.

Methodology

The energy consumption of the two AC units was evaluated by using a Circutor™ power analyser. The ACs were operated on alternate days; standard, non-inverter AC on one day, and the inverter AC on the following day. Energy consumption was measured in one-minute intervals over 6 consecutive weeks, so that the effect of fluctuation of ambient temperature may be assumed to be cancelled out. Temperature and relative humidity were logged in one-minute intervals using data loggers.

Name Plate Data of the Two Air Conditioners Tested.

Name plate of non-Inverter Air Conditioner

Make	: Frostaire
Model	: TFI-18CR/ TFO-18CR
Capacity	: 18,000BTU/hr
Rated Current	: 9.1A Maximum : 11.8A
Rated Power	: 2000W Voltage : 220-240V
Refrigerant	: R22 / 1.06kg

Name plate of Inverter Air Conditioner

Make	: Hisense
Model	: AS-18TR45FATG1
Capacity	: 18,000BTU/hr
Cooling Power	: 1600kW Voltage: 220-240V
Cooling Current	: 7.2A
Refrigerant	: R410A / 0.32kg

Results

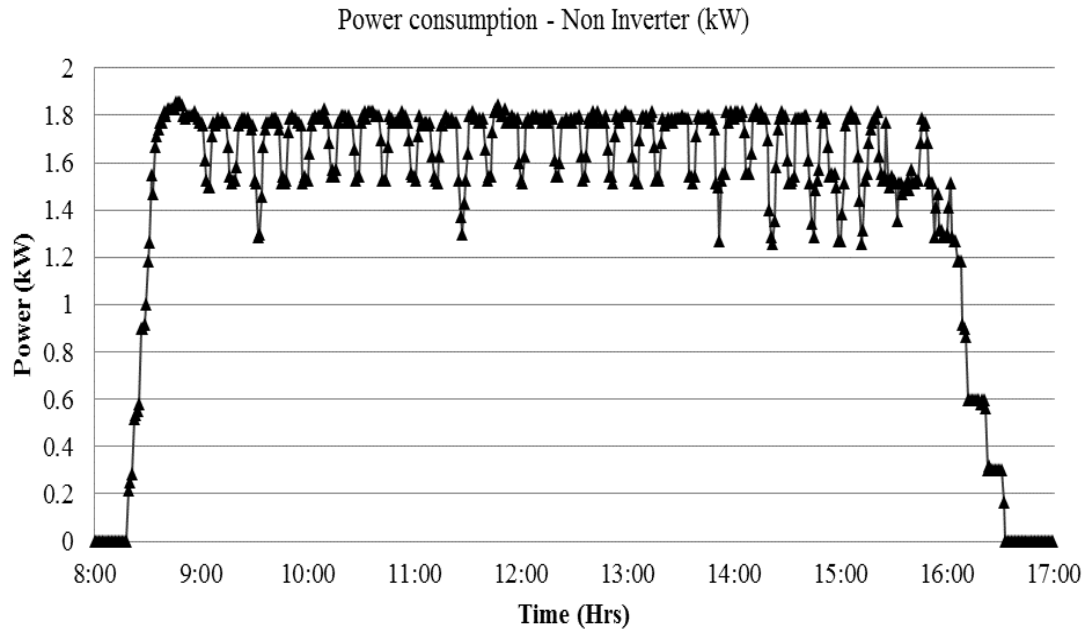
Figure 1 and Figure 2 show the variation of power drawn by the standard and inverter type ACs, respectively, operating at similar

temperature settings during normal office hours 08:00 to 17:00, under similar (assumed) outdoor conditions.

Figure 3 shows the daily energy used in each AC. Since the measurement was done

over 6 weeks, fluctuations of outdoor conditions are expected to be cancelled out or similar for both ACs.

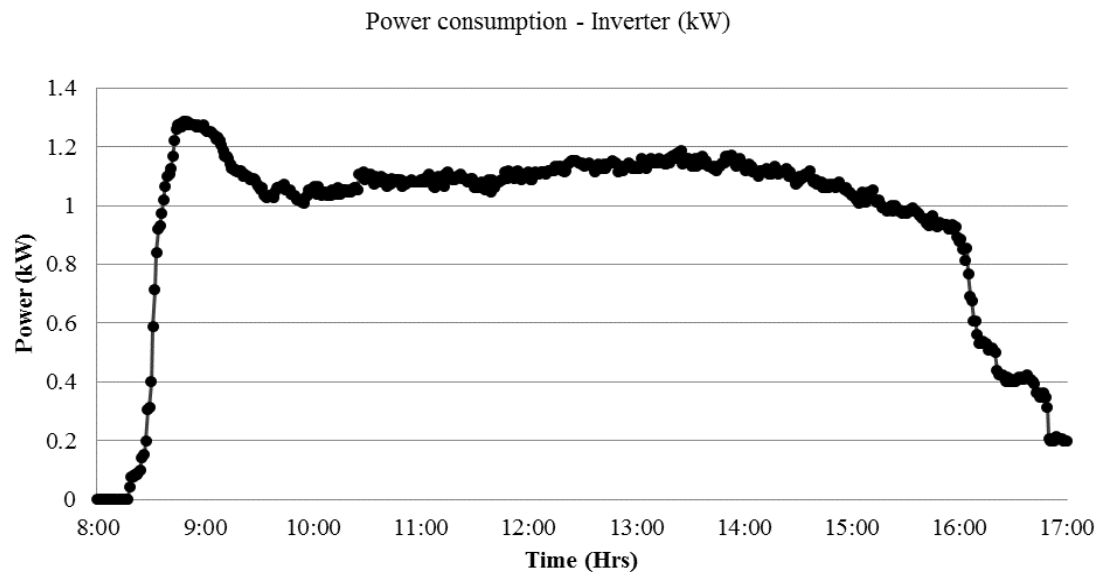
Figure 1 - Power drawn by the Non-Inverter (standard) AC during Office Hours



Since the compressor of non-inverter AC frequently switches ON and OFF, the

current and the power consumption of the AC fluctuate accordingly.

Figure 2 - Power drawn by the Inverter-Type AC during Office Hours



The power consumption pattern of an inverter AC is smoother than a non-

inverter AC because the compressor will not switch between ON and OFF.

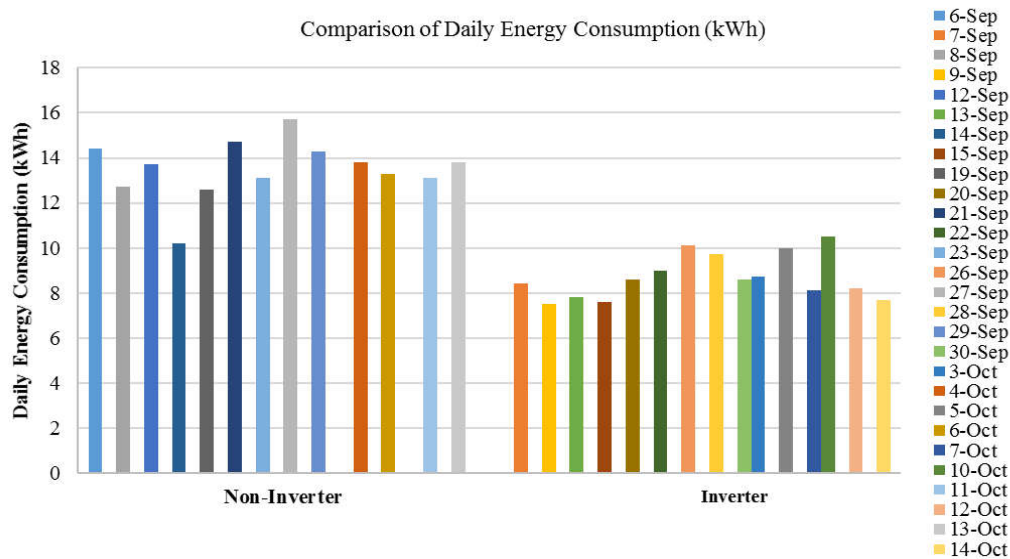
Figure 3 – Energy drawn over 8 hours (08:30 to 16:30) at a Temperature Setting of 26 °C

Figure 3 gives the energy consumption of inverter and non-inverter ACs run in the same space on alternate days for a 6-week period. The daily average energy consumption of the standard AC was 13.5 kWh (for 8-hour operating period) and the

average energy consumption of the inverter type AC was 8.7 kWh for the same period under similar operating. There is a clear reduction of energy consumption in inverter ACs.

Conclusions

It is concluded that inverter technology can save about 35% of energy over a standard AC. With the expected growth of AC use

and ambient temperature rise due to global warming, inverter technology can provide significant savings

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