Innovative and Efficient Solutions for You

Inverter Technology

True innovation in climate control

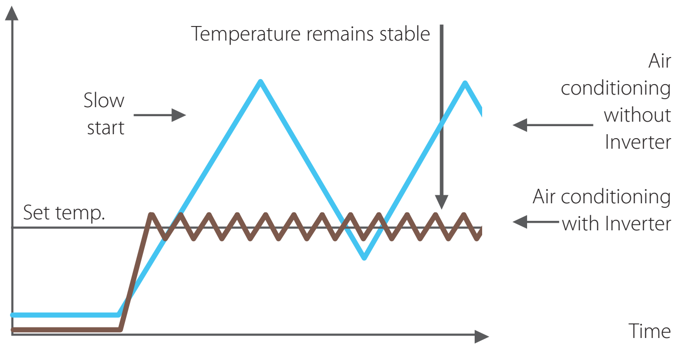
INVERTER

What is Inverter Technology?

Daikin's **inverter technology** is a **true innovation** in the field of climate control. The principle is simple: inverters adjust the power used to suit the actual requirement - no more, no less! This technology provides two clear benefits:

- **Comfort:** The inverter repays its investment many times over by improving comfort. An air conditioning system with **an inverter continuously adjusts its cooling and heating output** to suit the temperature in the room, thus **improving comfort levels.** The inverter reduces system start-up time, so the required room temperature is reached more quickly. As soon as the correct temperature is reached, the inverter ensures that it is constantly maintained.

- **Energy efficient:** Because an inverter **monitors and adjusts** the ambient temperature whenever needed, **energy consumption drops by 30%** compared with a traditional on/off system.



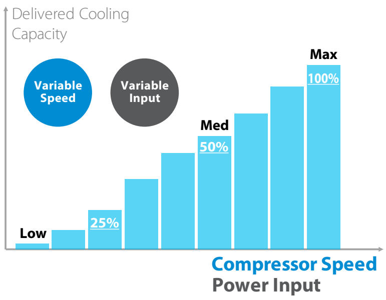
The inverter technology is integrated in the outdoor unit. The inverter technology can be compared to the technology in a car: "The harder you push the accelerator, the faster you go."

An inverter unit will gradually increase its capacity based on the load needed in the room to cool down or heat up the room. The non-inverter can be compared with switching on or off a lamp. Switching on this type of unit will start to run full load.

Two main technologies

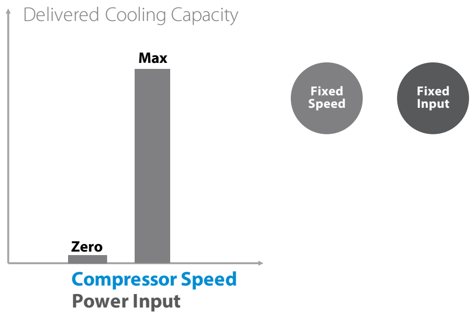
With INVERTER

Uses very smart control that will regulate the compressor speed according to the cooling need (load).



With Non Inverter (On/Off)

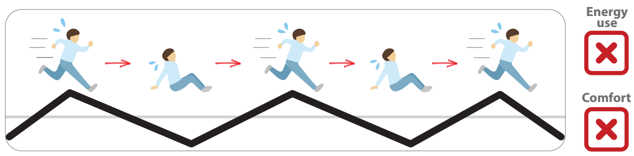
Has NO intelligence: it will try to meet the cooling need by using 2 fixed speeds - Zero or Maximum speed



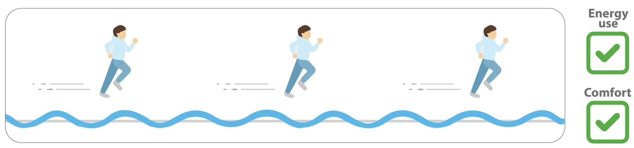
Why do you need INVERTER in Middle East?

The amount of cooling (heating) capacity required depends on the outside temperature and the heat inside the room to be treated. Since the outside temperature varies all year long, but also during the course of the day, the cooling requirements will also vary all year round. Only a smart system – Inverter – can constantly adjust the delivered capacity to meet the specific requirements.

With Non Inverter Start and Stop operation



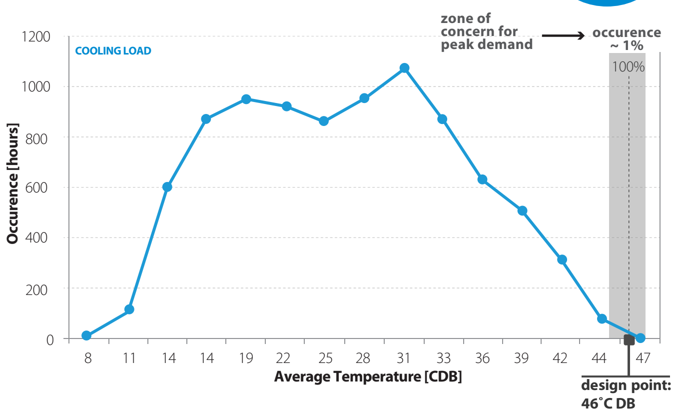
With INVERTER Smartly controlled speed operation



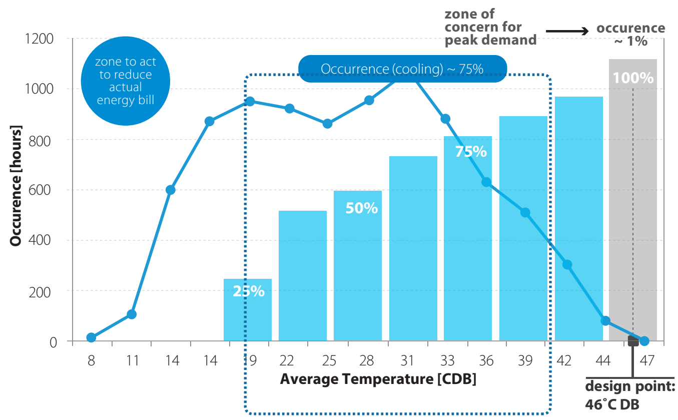
How does inverter help in electricity savings?

Why is the design efficient only for summer?

Very hot climate... but not all the year long!



Target Area



Source: Dubai Airport Weather Data

Temperature distribution vs AC load

Figure 1 shows temperature distribution of typical Middle East condition where design is done at 46 degrees summer conditions. However, occurance of 46 degrees and above is less than 3%. So how about optimizing your AC unit for the rest of the 97% where we operate the most?

Part-load Zone (Target Area)

Figure 2 shows that as the temperature goes down from design temperature of 46 degrees Celsius, the cooling load also decreases with temperature. Inverter technology reacts quickly to this change and reduces speed of compressor to save on energy. Yearly bill with Inverter is lessened by 50%.

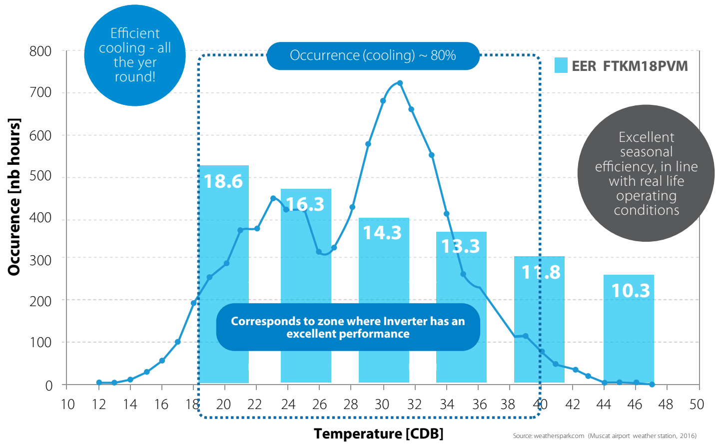
Conclusion: Inverter technology optimizing full year efficiency pays off faster!

Inverter Efficiency

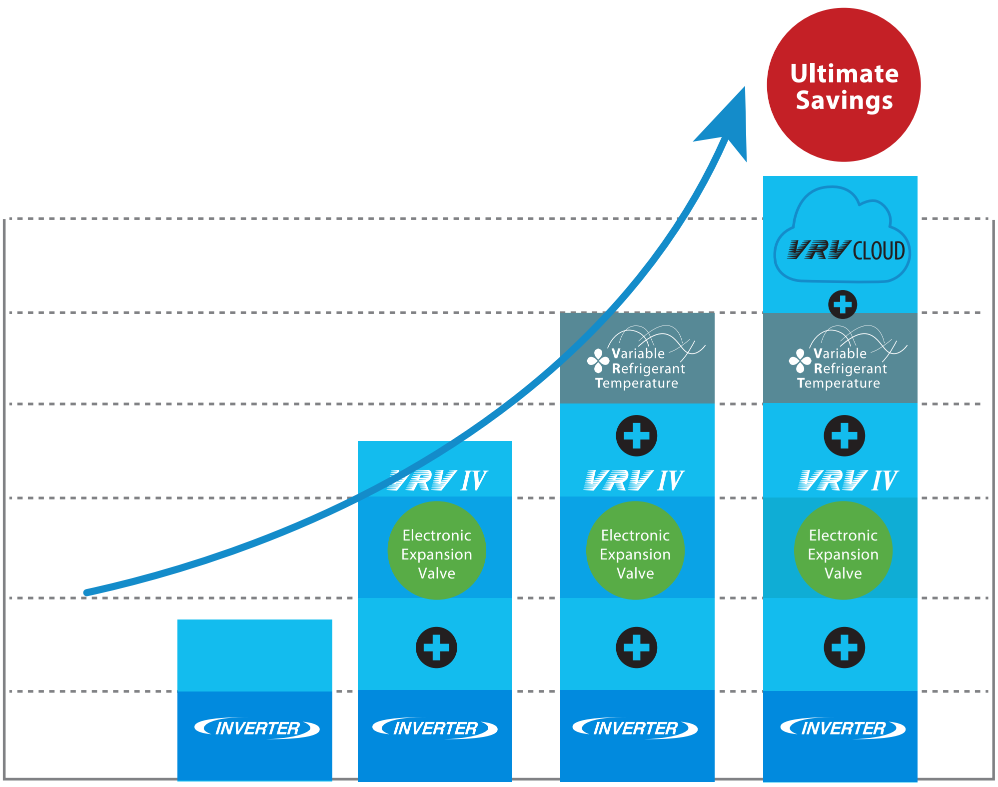
Raise the bar of efficiency - through technology

Advantages of Inverter technology

- Comfort temperature is reached faster
- Start-up time is reduced by 1/3
- Saves a lot of energy and money: up to 30% to 50% less power consumption (compared to normal on/off units)
- No voltage peaks by avoiding cycling of the compressor
- No temperature fluctuations



The smarter the technology, the lesser the energy used



What is Inverter Technology?

The inverter is an electronic power component that continuously varies the electricity supply frequency of an electric motor.

Any inverter is composed of 3 sections:

a) RECTIFIER transforms the alternating current (AC) into a direct current (DC)

b) DC BUS acts as a temperory energy reservior

c) INVERTER generates a 'new' alternating current (AC) of suitable frequency to meet the power demands of an appliance.

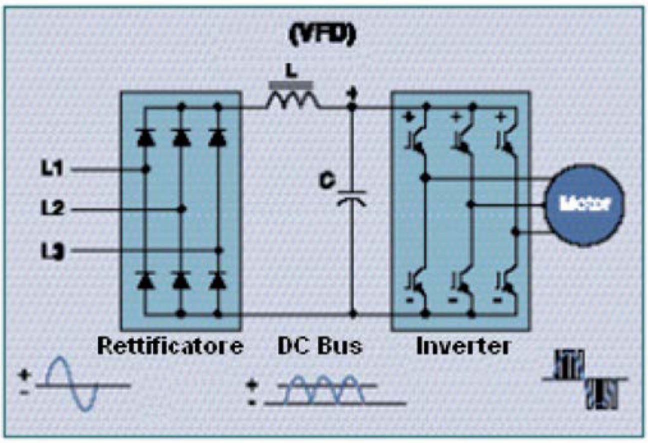


Figure 1: Diagram of a "6 -pulse" inverter type

The continual variation of frequency in turn continuously varies the rotation speed of a motor, according to the equation below (valid for markets with a standard frequency of 50Hz):

EQUATION 1

$$RPM = \frac{Hz \text{ x } 120}{n° \text{ poles of the motor}} = \frac{50 \text{ x } 120}{n° \text{ poles of the motor}}$$

Equation (1) shows that the rotation speed of a motor depends on the frequency of the current (Hz) supplied and its number of poles.

For example:
A motor supplied by an alternating electrical current (AC) at 50Hz and with two poles has a rotation speed (unloaded) of 3,000 rpm A motor with six poles (three pairs of poles) turns (unloaded) at 1,000 rpm.

Continuous modulation of three motor speed fine-tune the power supplied by an electrical component and adjusts the power to meet an appliance's requirement at any moment.

Components of Inverter

According to the laws of similarity applied to rotating operating machines, the power is proportional to the cube of its number of revolutions, as indicated in equation (2): Modulating the power to meet the demands of an appliance optimises energy efficiency, delivering significant energy savings, thus reducing management costs and minimising the impact on the environment.

EQUATION 2

$$Power \propto RPM^3$$

The RECTIFIER is made of components that transforms the current from 'alternating' to 'direct' and can be of different technologies passive or active.

- Passive rectifiers are diodes
- Active rectifiers are silicon controlled

Rectifiers (SCR) or transistors such as Insulated Gate Bipolar Transistors (IGBT), allow the passage of current only if there is a control signal through an activation gate.

In view of the 'alternating' nature of the voltage supplied, at least two rectifiers are necessary for every supply phase: one allows the passage of currents when the supply voltage is positive; the other "opens" when the voltage is negative.

Therefore, in the case of 3-phase supply (L1,L2,L3 in a 50Hz network, 3Ph, 400V), the rectifier is composed of at least six rectifier elements, creating what is known as a "6-pulse inverter".

However, some inverters are fitted with a multitude of rectifiers, even as many as four, six or eight for every phase. These are known as '12 impulse' (4x3 phases) devices, '18 impulse' (6x3 phases) devices or '24 impulse' (8x3 phases) devices.

Providing more rectifiers per phase reduces the harmonic disturbances within a network, compared with those normally induced by an inverter component. If the Rectifier is fitted with active components, such as IGBT transistors, then the inverter device is known as an Active Front End Inverter (AFE-inverter). These devices meet the most stringent laws and standards regarding the maximum levels of harmonic disturbances that can be induced in a network by the VFD component.

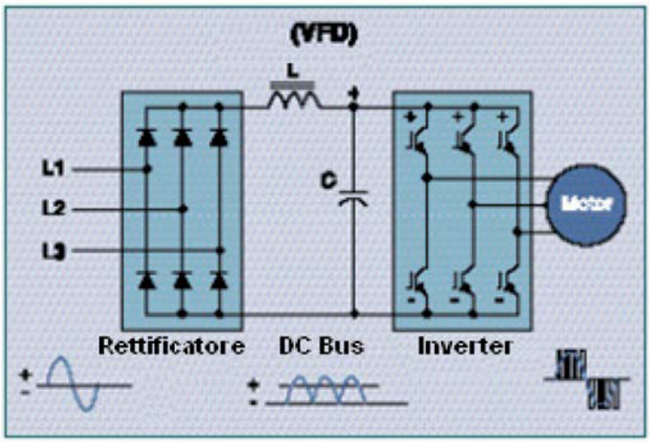


Figure 1: Diagram of a "6 -pulse" inverter type

Main benefits of Inverter

All these components increase the quality, reliability and energy efficiency of the appliance but, depending on the particular appliance, some benefits may be more important than others.

A starter with an inverter has four main benefits:

1) Mechanical Benefits
2) Electrical Benefits
3) Energy Efficiency
4) End User Benefits

1. Mechanical Benefits

A mechanical component is subjected to maximum stress in the 'starting' and stopping' phases, especially in non-ideal conditions requiring lubrication of the moving components.

In such scenarios, repeated and frequent starting/stopping cycles of an electric motor - and specifically of a compressor - increases wear and can affect reliability over time (Figure 2). Mechanical wear in these phases of transition is in direct proportion to the acceleration of the moving parts.

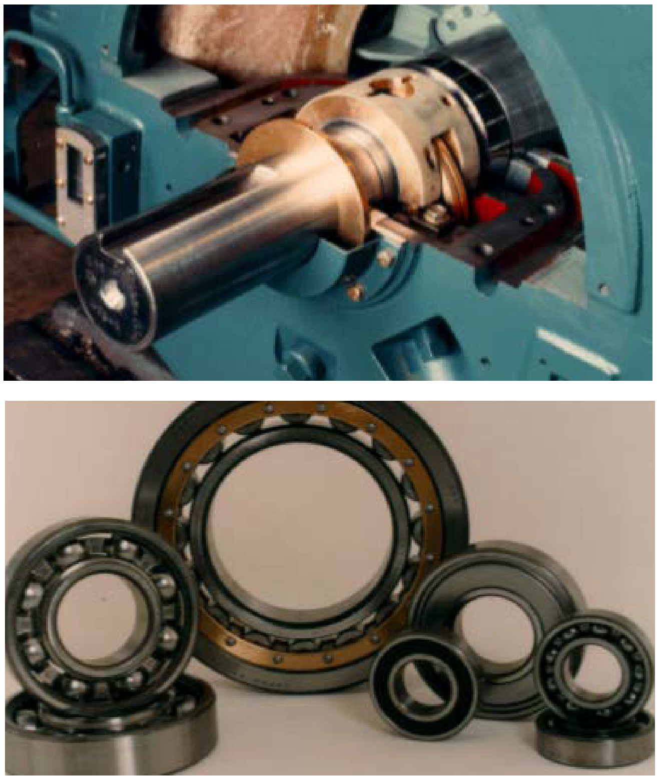


Figure 2: Mechanical components in a motor, and/or compressor, affected by lubrication conditions

An electrical starting system that maintains a constant frequency of electricity supply to the motor (D.O.L., Y-Δ, Solid State Soft Starter, Part Winding Starter) subjects the moving parts to maximum acceleration during the starting phase of the component.

In contrast, an inverter uses the continuous frequency change of the supply current as its main control variable, thus allowing the acceleration to be modulated gradually. This reduces the effect of poor lubrication during the transition stage, as well of the mechanical stresses induced by high starting torque.

Main benefits of Inverter

2. Electrical Benefits

The electrical benefits of using an inverter are in three categories:

a) Starting current is minimised
b) High value of the motor power factor
c) Reduction of total power absorbed in kVA at full load

a) Starting current is minimised at high current absorption, even for only fractions of a second, can cause complications in an electrical network, including a drop in voltage and disturbance of sensitive electronic components. Sometimes an electrical panel's magnetic protection can even cause a motor to switch off immediately, because of the magnetic-thermal overload.

The value of the starting current of an electric motor is usually evaluated as a percentage of its Full Load Ampere (FLA) value.

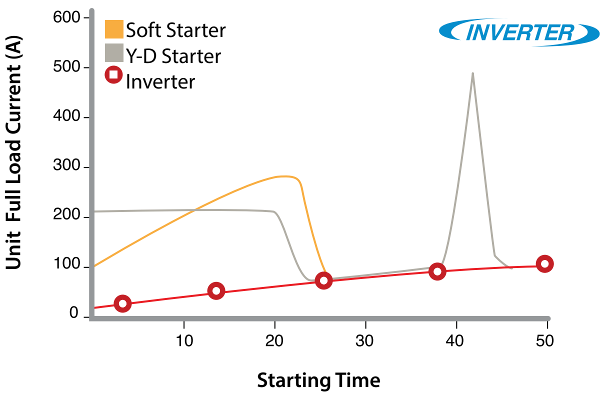
The starting solutions for electric motors are mainly: D.O.L., Y-Δ, Soft Starter, Part Winding, Autotransformer and Inverter.

Of these, only an inverter can vary the input frequency of an electric motor, while all the others act exclusively on the value of the voltage. This is their main limitation in minimising the starting current. Table 1 compares the starting current values, as percentages of the FLA, guaranteed by the various starting solutions listed above.

When an inverter - sometime referred to as Variable Frequency Driver (VFD), controls a compressor motor, there is no current inrush during compressor starting.

Table 1

Type of starting solution	Starting current as % of FLA
Direct on line (D.O.L.)	600-800 %
Part Winding	400-500 %
Auto-transformer	400-500 %
Y-Δ(Star-Triangle)	200-300 %
Solid State Soft Starter	200-300 %
Inverter	NO INRUSH CURRENT



In the example of an inverter chiller equipped with more compressors:
when the first compressor starts the unit, in-rush current is equal to only a few amperes. When another compressor starts, the unit in-rush current is never higher than the running amperage of the electrical motors already working. So for instance in a refrigerant compressor equipped with a 180 kW electrical motor, the Y-Δ in-rush current is more or less 700 A; but with an inverter it is equivalent to the stand-by current (which is basically zero).

Main benefits of Inverter

b) High value of the Power Factor (PF)

Any electric motor that creates and maintains a rotating magnetic field inside the motor absorbs two distinct powers:

- ACTIVE power, measured in kW and used to supply mechanical work
- REACTIVE power, measured in kVAR (kiloVolt-Ampere-Reactance) which creates the internal magnetic field

The "vector sum" of these two powers is called Total Power and is measured in kVA (kiloVolt-Amperes), where A indicates the total and effective current absorbed by the motor. This is used to calculate the crosssection of the power conductors to be installed.

The ratio between the ACTIVE (kW) power and the TOTAL (kVA) power, as indicated in the equation (3), is called the Power Factor (PF).

An electric motor necessarily absorbs REACTIVE power to sustain the magnetic field inside the motor. With reference to the ACTIVE quota absorbed (kW), the smaller the effective load of the motor, the more reactive power it tends to absorb.

In other words, the Power Factor of an electric motor decreases as its load level decreases, reaching values considerably lower than PF = 0.6 under minimum load conditions.

An increase in the reactive power absorbed is not advantageous in any case because:

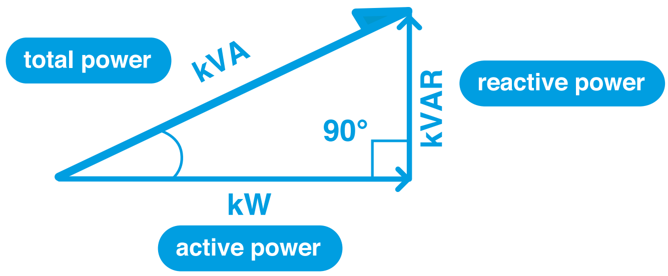


Figure 3: The vector triangle of the powers (ACTIVE, REACTIVE, TOTAL)

EQUATON 3

$$Power\ Factor\ (PF) = \frac{kW}{kVA}$$

- An increase in the effective current absorbed is associated with greater resistance losses (Joule effect)
- A larger cross-section of transformers and power wires is required
- There is a risk of incurring economic sanctions from electricity suppliers, which normally require power factor values of no less than 0.85-0.9 at the supply node.

On the other hand, the installation of an inverter - which contains a DC BUS section including the condensers (capacitive effect) in any load condition - ensures a Power Factor of 0.95-0.97 (Figure 4). An electric motor with an inverter always has a higher re-phasing value than one without an inverter but is equipped with an external battery of re-phasing condensers.

Main benefits of Inverter

The reduced Power Factor of an electric motor and the decreased load issued (which tends to be opposite in the same motor equipped with an inverter) highlights the following:

1. The risk of incurring penalties from the electricity supplier because of non-compliance with re-phasing conditions at the supply point
2. The frequent need to install an external battery of load re-phasing condensers
3. The constantly higher absorption of electricity (A) by the motor, while providing the same output of active power (kW). This causes greater energy consumption and higher annual costs, due to resistance losses in the electrical conductors.

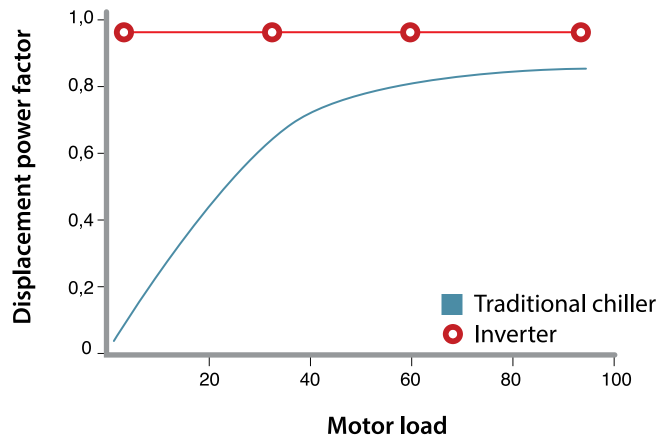


Figure 4: Comparison of the Power Factor between a motor with and a motor without an inverter (400 V)

c) Reduction of total power absorbed in kVA at full load

Because the inverter always maintains a higher Power Factor in the electric motor compared with the effective active power absorbed, the current absorption is minimised, both at partial motor load and also at nominal load conditions (100%).

The decrease in the nominal current for normal functioning also reduces, by the same percentage, the Total Power absorbed by the refrigerator. This is quantified, in the case of three-phase load, by equation (4).

This benefit is of even greater importance in installations where it is not possible to request increased power supply - perhaps because of the transmission saturation of the local electricity grid.

EQUATION 4

$$Total\ Power\ (kVA) = \sqrt{3} \cdot V \cdot I$$

3. Energy efficiency

Undoubtedly, one of the main benefits of an inverter controlled device such as a fan, pump or compressor is the significant annual energy savings achieved.

Continuous variation in the rotation speed of the electric motor fine-tunes the power supplied by the component activated by the motor, adjusting it to the effective load demand.

The modulation of the electric motor speed reduces the capacity supplied by the activated mechanical component, such as the chiller's compressor, and delivers high energy efficiency throughout all load variations (0-100%), especially when compared with mechanical adjustment systems, such as slide control valves, or the fixed bypass orifices activated by solenoid valves.

4. End-user benefits

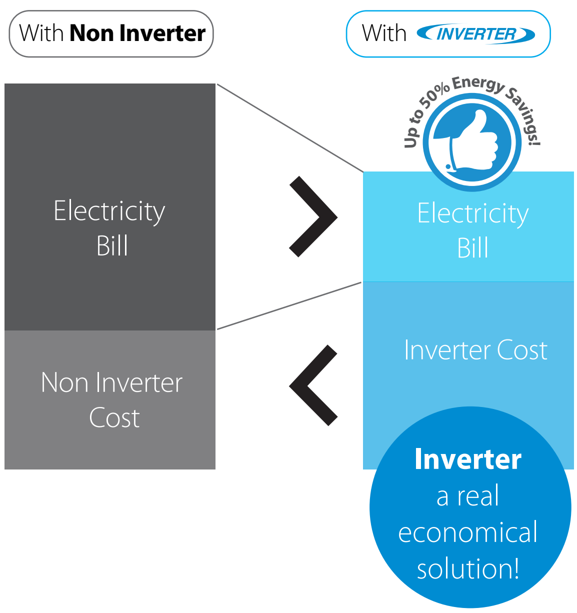
Comfort: Inverter-controlled air conditioning systems continuously adjust their cooling and heating output to suit the temperature in the room, thus improving comfort levels. The inverter reduces system start-up time, so the required room temperature is reached more quickly. As soon as the correct temperature is reached, the inverter ensures that it is constantly maintained.

Energy efficiency: Inverter-controlled products run most efficiently at partial loads, resulting in lower energy consumption than other systems as they only need the power necessary to match the load. This results in reduced annual energy consumption. An inverter controlled air conditioning system, for example, monitors and adjusts the ambient temperature whenever needed, so energy consumption drops up to 50% compared with a traditional on/off system.

Cost savings: Lower energy consumption delivers cost savings and can also reduce the impact of rising energy prices on their bottom line.

Reduced carbon emissions: By improving efficiency, companies can benefit from significant carbon emission reductions.

Intelligent controls maximise benefits: Daikin control units provide absolute control of a system and can be integrated easily with communication modules to provide end-users with a total management solution. These units offer a simple, user-friendly set of controls that allow programming and monitoring every aspect of a system's operation, providing a long-term record for use by maintenance engineers. Intelligent controls reduce usage and improve energy efficiency.



To make real savings, always compare total cost, including operation cost.

Inverter will help you to save money!

DAIKIN

The Daikin INVERTER Difference

Reduce your electricity bill with Smart Technology

Think Smart, think Green,
Think Daikin Inverter!

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Daikin Middle East and Africa

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