Control Of Inverter Compressors

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Abstract: The bill for the cost of electricity production in most countries is very high, and therefore these countries tend to develop ways to save electricity consumption. Refrigeration and air-conditioning devices are among the highest devices that consume electricity, so the general trend is how to reduce the consumption of these devices. The main component of electricity consumption is the compressor. This paper deals with the types of fixed-speed and inverter-operated compressors, as well as the types of electric motors that operate on DC and those that work on variable current, and the traditional control methods in air conditioning systems and those that use modern methods to save energy.

Index Terms: compressors, inverter compressors, dc motor, AC motors, PWM, inverter

1 Introduction

The phenomenon of high temperatures in most countries, especially the Arab Gulf states, where the temperature in the summer months exceeds fifty degrees Celsius, makes the use of air conditioners very necessary in buildings and cars, so that it prevents work at noon times due to the intense heat and this leads to electricity consumption at record levels Where the electricity consumption of air conditioners in homes represents about ninety percent of the total electricity consumption. As a result, most air conditioning companies tended to replace traditional air conditioners with air conditioners using the inverter to reduce electricity consumption, saving about fifty percent of electricity consumption from traditional air conditioning systems. The air conditioning system is a system responsible for cooling the air in the specified place. The compressor is the main element in the refrigeration circuit, which consumes the most energy. The refrigeration circuit consists of the compressor, expansion valve, condenser and evaporator.

- The compressor works to increase the pressure of the refrigerant from low pressure to high pressure, which results in a high temperature of the refrigerant.
- The condenser is a heat exchanger whose purpose is to transfer heat from the refrigerant to the atmospheric air to convert the refrigerant from the vapor state to the liquid state. The refrigerant is in a liquid state of high pressure and high temperature.
- Expansion valve reduces the pressure of the condenser to the evaporator pressure, as well as controls the flow rate of the refrigerant to the evaporator, and then the refrigerant turns into a refrigerant in a mixture of low pressure and low temperature.
- The evaporator is a heat exchanger whose purpose is to transfer heat from the space to be cooled to the refrigerant passing through the evaporator tubes, and the refrigerant after that is in the form of vapor with low pressure and low temperature. The figure_1 below shows the components of the circuit.

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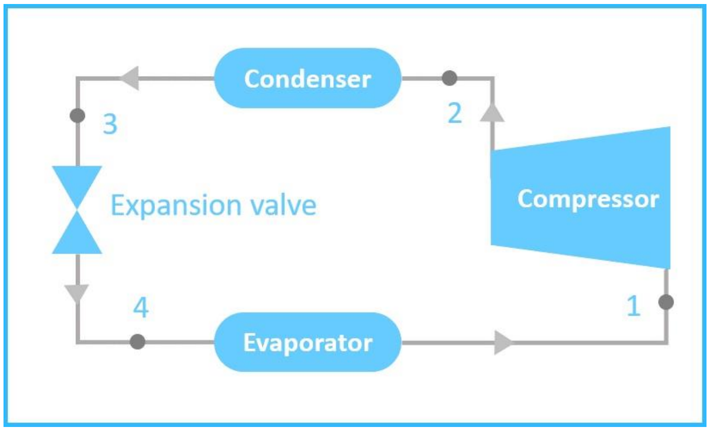

Fig1: *Refrigeration Circuit*

The electrical circuit of the air conditioner mainly controls the compressor, condenser fan and evaporator fan as shown in the figure_2 below

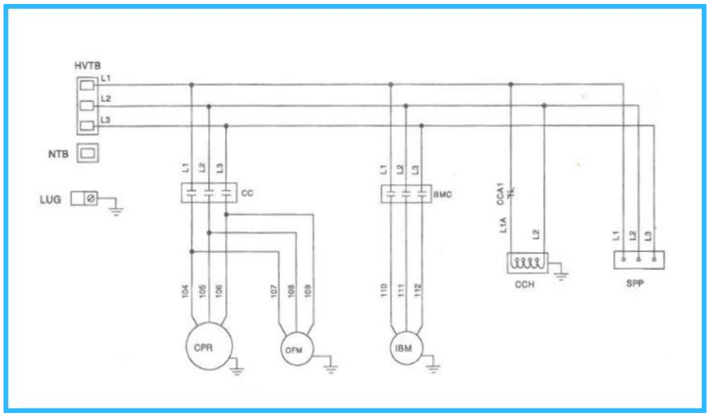

Fig2: *Power Circuit of Air Conditioner*

The temperature of the place is controlled by the thermostat, which turns on or off the air conditioner according to the desired temperature. For example, if we want to cool the place to a temperature of 20 degrees Celsius, the thermostat is set to this degree and the air conditioner works until this temperature is reached, then separates and when the temperature rises above 20 degrees Celsius, the thermostat turns the air conditioner on again and so on. The electrical circuit consists of two parts, the first is called the power circuit, which is concerned with connecting the high power of the compressor, fan and heater, and the other part is called the control circuit, which is concerned with controlling the start or stop in the event of a fault in the mechanical or electrical circuit using multiple protection devices for air conditioning and refrigeration devices as shown in the figure3 below.

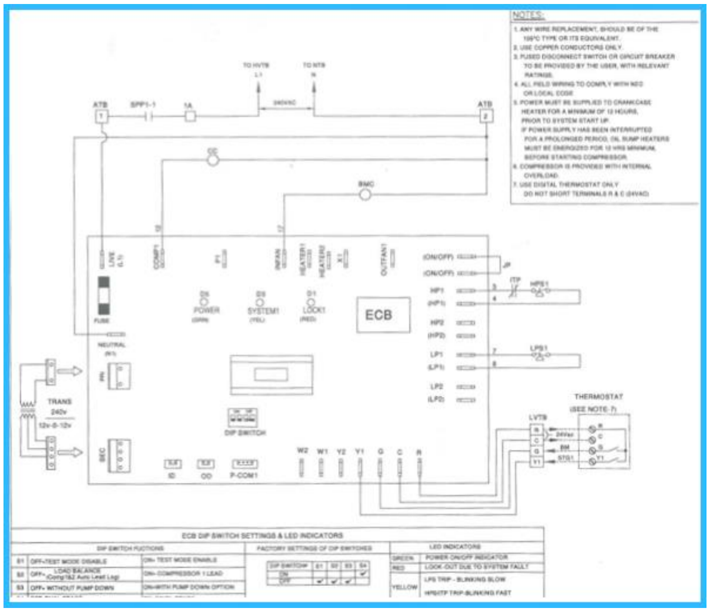

Fig3: *Control Circuit of air conditioner*

2 COMPRESSORS

Compressors in the refrigeration industry are divided in terms of the method used for the compression process into positive displacement compressors (where the compression process takes place as a result of reducing the volume of gas or steam inside the compressor, which raises its pressure, such as reciprocating, rotary and screw compressors) and dynamic compressors (in which the centrifugal compression process takes place This type includes centrifugal compressors). The focus will be on positive displacement compressors in this research.

2.1.1 Reciprocating Compressors

Reciprocating compressors are the most common compressors in the field of refrigeration, and these compressors are used with both halocarbons and ammonia systems. The reciprocating compressor, as shown in the figure, consists of a piston that moves inside a closed-end cylinder. The end of the cylinder is known as the cylinder head and usually contains a coolant inlet and outlet valve to and from the cylinder.

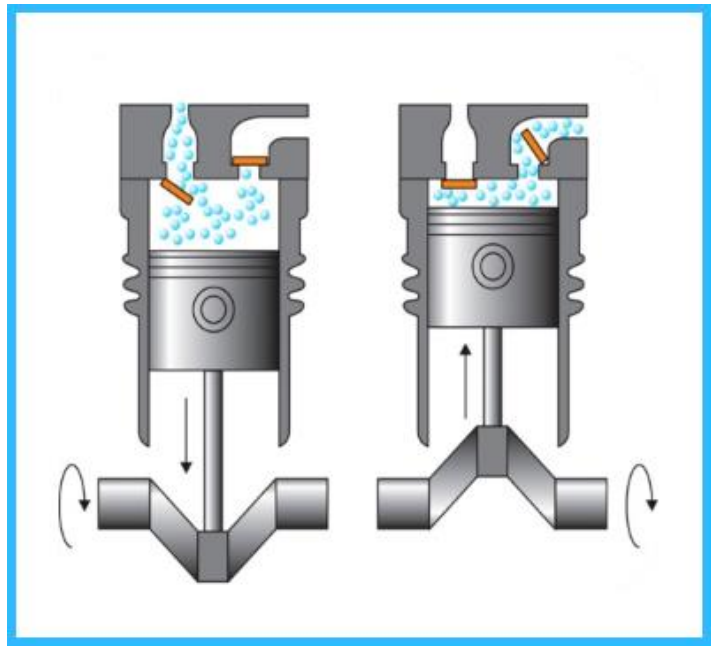

Fig4: *Reciprocating Compressors*

Reciprocating compressors are used in many refrigeration applications. These compressors are available in the market with capacities ranging from 90 watts to more than 120 kilowatts.

2.1.2 ROTARY COMPRESSORS

It is one of the divisions of positive displacement compressors, where this displacement is produced as a result of rotational movement instead of the reciprocating movement. Rotary compressors are divided into single-vane and multi-vane compressors, and are characterized by their small size, higher rotation speed, and better efficiency than reciprocating compressors. Rotary compressors consist of an external cylinder, a piston ring, a shaft directly connected to a cam, a sliding vane and an ejection valve. The external cylinder represents the outer body of the compressor and contains within it the annular piston, drive shaft, cam, vane and sliding under the influence of a spring that makes the tip of this vane permanently centered on the surface of the annular piston. Refrigerant in the drive of the parcel. The refrigerant vapor is drawn from the compartment towards the intake port, while the vapor is compressed into the compartment toward the exhaust port.

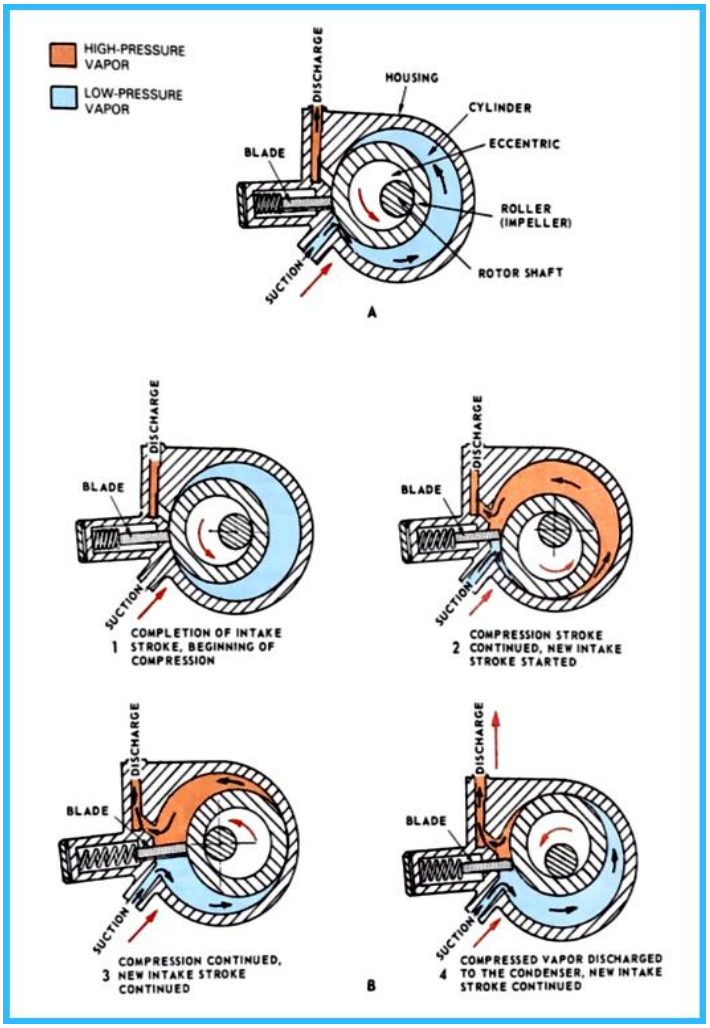

FIG5: *ROTARY COMPRESSOR*

Continuing the movement of the annular piston, the volume of steam in the space towards the expulsion decreases as a result of the positive displacement of the piston, which raises the pressure value. The two types of rotary valve do not need an intake valve, but the intake is continuous, and this is useful in reducing the noise arising from the intermittent intake process. A single-vane compressor needs an ejection valve, but a multi-vane compressor does not need an ejection valve because the ejection is done by passing the vane over the ejection valve.

2.1.3 Scroll Compressors

scroll compressors mainly consist of two interlocking scrolls, one of which is fixed and the other is moved by an eccentric arm that moves along a circular boring to compress the refrigerant. The intake steam is sucked from the evaporator output and enters the compressor at the far end of the scroll and the compressed vapor of the refrigerant media exits from the screed via the open outlet at the center of the fixed scroll. Between the two spirals there is always a point of contact at the entrance and at the exit, each of which is hermetically closed. The closed space is constantly decreasing, and thus intermediate vapor is compressed to cool, and this leads to its exit from the exit hole in the center of the fixed scroll.

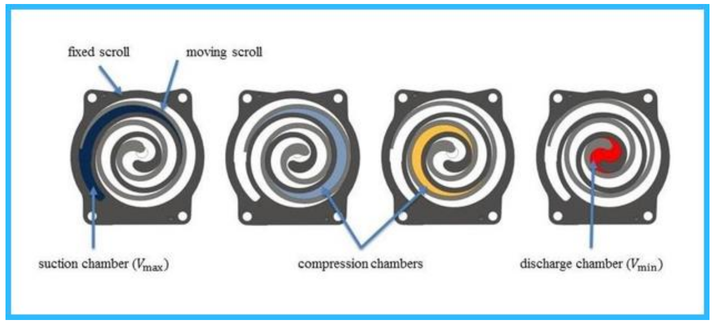

Fig6: *Scroll Compressor*

The figure shows the method of withdrawing and compressing the refrigerant. This compressor offers several advantages, continues and constant pressure, no valves required due to the flange-controlled pressure principle, only a small number of moving components, suitable efficiencies at high rotational speeds and low relative speed compared to piston compressors.

2.1.4 Screw Compressors

These compressors are considered rotary compressors and are characterized by ease of design and operation, durability, long life, small size and high efficiency as shown in the figure below. These compressors provide large cooling capacities from 20 tons to 300 tons. This compressor consists of a male and female screw rotor, a container cylinder for the two rotors, a refrigerant intake connection and a refrigerant vapor ejection connection to the exhaust line. In addition to safety and control devices.

Fig7: *Screw Compressor*

The refrigerant vapor enters from the intake connection and fills the spaces between the two rotors and the outer cylinder by rotating the male rotor and then the female rotor. The refrigerant between the two rotors and the cylinder is shifted forward, where the volume decreases, causing the refrigerant to compress and move the refrigerant vapor gradually in the direction of the ejection junction where it is pushed out at the ejection pressure.

2.1.5 inverter Compressors

Any compressor of refrigeration compressors consists of two basic parts, the first is the mechanical part, and there is no change in this part, whether in fixed-speed compressors or inverter compressors, and this does not negate the continuous development of mechanical parts to obtain the highest efficiency for these compressors. The second is the electric part, which is an electric motor that moves the mechanical part to drive the coolant in the circuit. This motor can be a DC motor, or an AC motor. it is controlled by an electronic circuit or a micro-controller, which is called the inverter. It controls the speed from 0% to 100% according to the cooling requirements and according to the efficiency of the control circuits and the quality and efficiency of the compressor. When the compressor needs more power, the inverter gives more power. When it needs less power, the inverter gives out less power. With inverter technology, the compressor is always on but consumes less or more power depending on the temperature of the inlet air and the level set in the thermostat. The speed and power of the compressor are adjusted appropriately. This allows for more accurate cooling and most importantly significant energy savings. Most air conditioners that come with inverter technology use rotary compressors instead of reciprocating compressors. Rotary inverter compressors have a shaft with several blades attached to it. This shaft of blades rotates inside the cylinder housing to simultaneously push and compress refrigerant through the cylinder. Although the concept of the variable speed compressor remains the same, different manufacturers use some subtle differences in their inverter. These types of compressors include but not limited to. The compressor is a Dual/Twin Rotary Inverter type shown below.

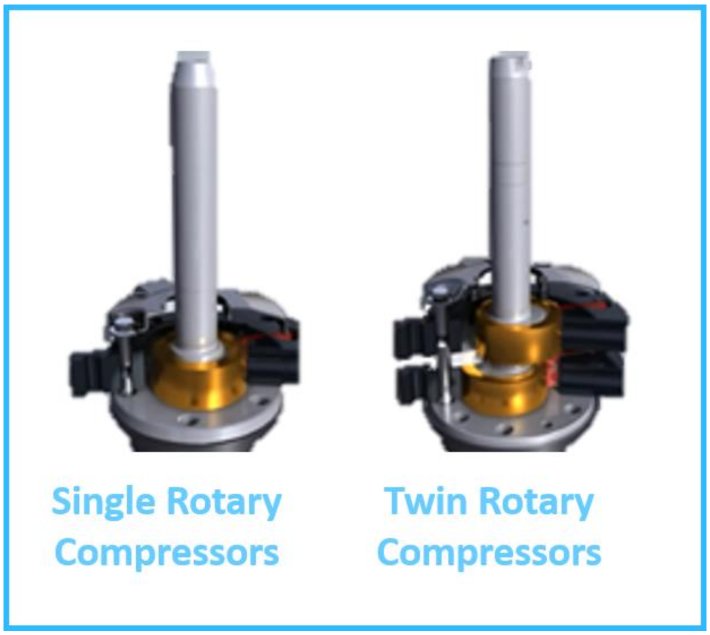

Fig8: *Dual/Twin Rotary Inverter Compressor*

Dual Inverter Air Conditioners often come with a BLDC motor that helps achieve a wider range of operating frequency which helps in faster and accurate cooling. Variable speed single-cylinder rotary compressor which works on the principle of single-rotating compression. It has been observed that this design generates a lot of vibrations and therefore increases in noise levels due to shaft rotation during alternating current operation especially at full load. But using the twin-rotary compressor design, two rotary compressors are operated with a phase difference of 180 degrees in the timing of mutual compression, resulting in more stable operation. The torque boost makes it possible for the compressor to operate from just 700 rpm to a frequency of 8000 rpm. Therefore, the 1.5 ton alternating current payload with double rotor inverter technology can be varied from 0.3 tons to 1.8 tons. Air-conditioning manufacturers compete to develop compressors, so you find each company prefers its own compressor and uses it in its applications.

3 Speed Control of Motors

The electric current is divided into two types, the first type is the constant current, which is denoted by DC, and it is characterized as being of constant intensity and uniform direction, meaning that it flows in one direction only. The direct current is generated from batteries, solar energy systems, or rectifier circuits that convert alternating current into direct current. It is used in many applications that use electronic systems. The other type is alternating current, which is symbolized by AC, and it is defined as an electric current that periodically reverses its direction and oscillates back and forth 50 or 60 times per second, depending on the electrical system used. Hence, it is variable in intensity and variable in direction. And alternating current has several types, including sinusoidal alternating current, sawtooth alternating current, triangular alternating current, and square alternating current, and each type has its own characteristics and advantages. The most used type is sinusoidal alternating current, which is generated from power plants and transmitted through electrical networks to residential areas and factories, its value is reduced by using electrical transformers and connected to homes by electric cables. The alternating current can also be divided into single phase current used for lighting and electrical appliances with low capacities such as household appliances. A three-phase current is used for high-capacity devices such as central air conditioners, elevators, or machines in factories.

3.1 Speed Control of DC Motor

A DC motor is mainly composed of two parts, the stator of the motor and the rotor that rotates and produces the movement. The stator consists of a pair of fixed permanent magnets that produce a uniform and constant magnetic flux inside the motor, and the rotor consists of individual electrical coils connected to each other in a circular configuration around their metal body producing a north pole, then a south pole, then a north pole, and so on.

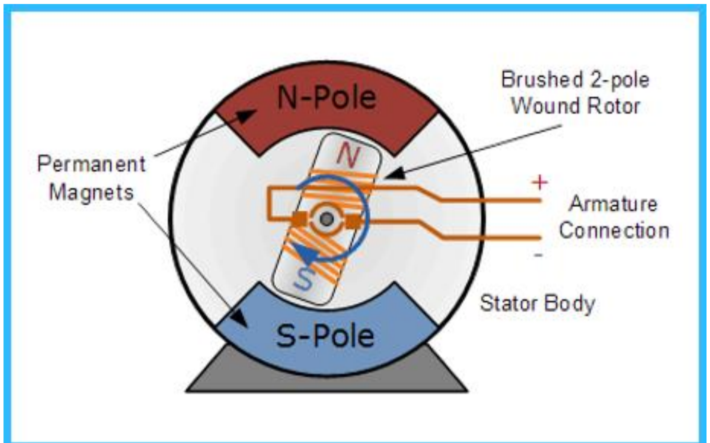

Fig9: *DC motor*

he rotational speed of a DC motor depends on the interaction between two magnetic fields, one of which is prepared by a permanent magnet and the other by an electric magnetic rotational and by controlling this interaction we can control the speed of rotation. By controlling the current flowing through the windings of the rotor magnetic flux will be produced resulting in strength or weakness and therefore faster or slower speed. The simplest control method is to use a variable resistance connected to the rotor, but this method generates a lot of heat and energy losses.

Fig10: *Speed Control of DC motor*

One simple and easy way to control a motor's speed is to regulate the amount of voltage across its terminals and this can be accomplished using "pulse width modulation" or PWM. , the PWM speed control works by turning the motor on in a series of "ON-OFF" pulses and changing the duty cycle, the fraction of time the output voltage is "ON" compared to when it is "OFF". , of the pulses while keeping the frequency constant. The power applied to the motor can be controlled by changing the width of these applied pulses and thus changing the average DC voltage applied to the motor terminals. By changing or adjusting the timing of these pulses, the speed of the motor can be controlled. The figure_11 below illustrated PWM control.

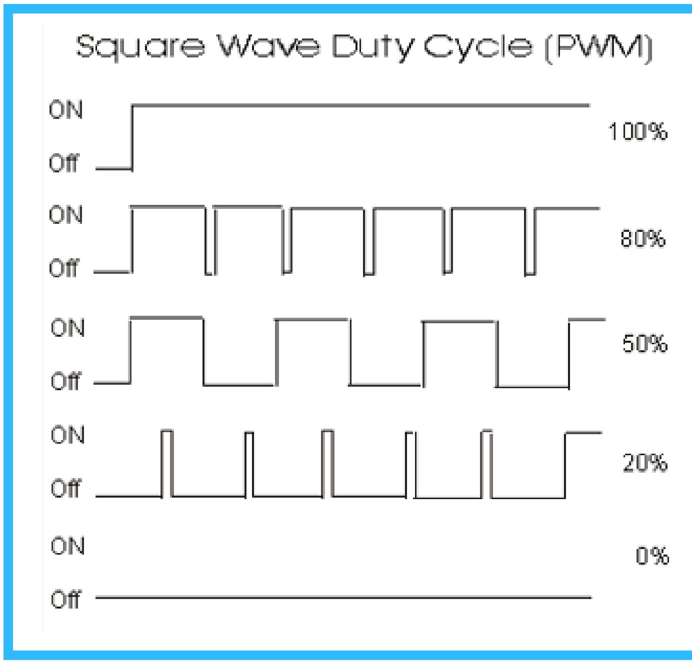

Fig11: *PWM Control*

3.2 Speed Control of AC Motor

There are many types of AC motors, but we will focus on the three-phase induction motor, which has gained wide popularity as it is used in most industrial applications and is characterized by simplicity of installation, cheap price and the least amount of maintenance. They are placed so that they are at an angle of 120 degrees between them inside the ducts made of iron. And the rotor part is iron foil isolated from each other and the coils are copper, or aluminum rods planted inside the rotor part and compartment on both sides with two thick rings. When the stator coils are fed with a three-phase variable current, a rotating magnetic field will be generated that induces a voltage in the rotor and a current will pass through the rotor and generate a magnetic field in it. The magnetic poles of the rotor and the poles of the same rotating field of the stator repel and the different poles attract, and the rotor follows the same direction of rotation of the rotating field. the motor speed is the speed of the rotating field. To control the speed of the motor, it is necessary to control the voltage supplying the motor, changing the number of poles of the stator, changing the frequency, or changing the resistance of the stator. One of the best ways to control speed is frequency converters, which are circuits that convert alternating current to another alternating current, either with the same value or other values. For the following variables, Phase Number (L1, L2, L3), Phase Sequence, frequency, and Voltage. Frequency converters consist of rectifier circuits to convert alternating current into direct current, and then store the direct current in a coil or Capacitor (intermediate circuits) and then converts DC current to alternating current. At this stage, frequency, phase sequence and phase number can be changed. The output voltage can also be controlled. Frequency converters are used to control the speed of AC motors. The block diagram of inverter as in the figure_12 below.

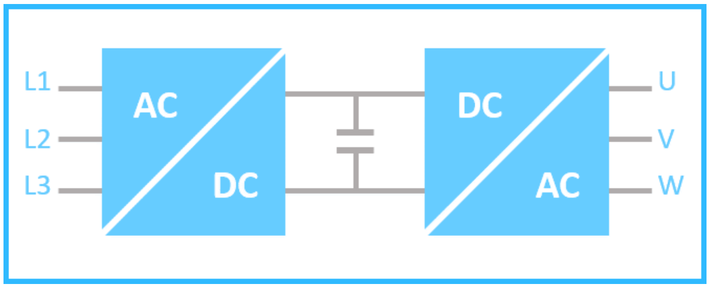

Fig12: *Block Diagram of inverter*

The circuit diagram of inverter as in the figure_ 13 below.

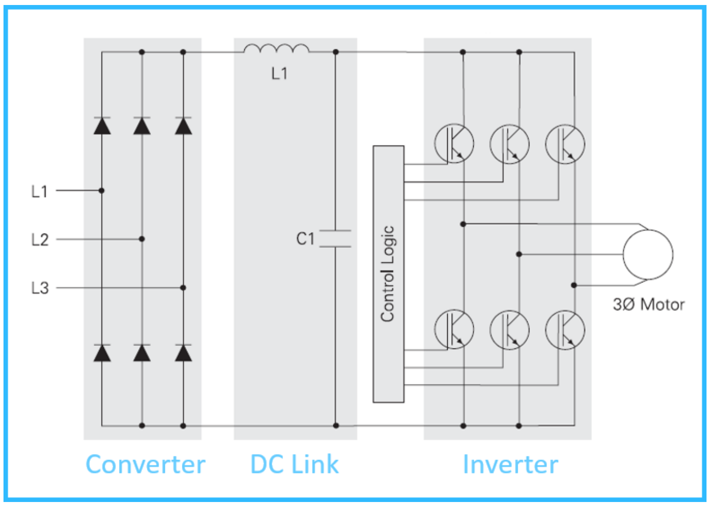

Fig13: *Circuit Diagram of inverter*

One of the control methods used in frequency converters is the Linear Voltage/Frequency method. This method depends on the ratio of voltage to frequency, which is a ratio present in all motors, knowing that increasing the frequency without increasing the voltage will lead to an increase in the magnetizing current as well, leading to a decrease in the stator current, which affects the ability of the motor to handle the load. The second method is to control the flux current (Flux Current Control). The constant current consists of an effective capacity and a passive capacity. The passive power is required to produce the magnetic field through the coils, and the effective power is required to produce the work needed for the load. In this method, the nominal current of the motor is entered. From the list of its information (Name Plate), the processor in the inverter performs mathematical calculations to estimate the magnetic field flux, through the measured effective capacity and the information about the nominal current that has been entered. Thus, through the internal calculations, an attempt is made to maintain the magnetic flux constant. If the information entered about the nominal current is correct and the inverter is set up well, then this method of control will be appropriate, because the inverter senses the actual current of the load and thus the speed control is better stable even when the load changes. The third method is vector control, to control the flux and torque, both the value of the constant current and its phase must be controlled, and that is why this method was called vector control. The processor can imitate the encoder through mathematical calculations of the circuit speed based on this model, and by calculating the voltage and output current, we will get a better dynamic performance of the motor. This method, using complex models, enables the user to obtain the full torque at the few frequencies and 150% of the torque at all speeds. Therefore, the second and third method is more suitable for controlling refrigeration compressors.

4 Conclusion

By comparing the inverter refrigeration and air conditioning technology with conventional systems, we conclude the following:

1- The inverter unit gradually increases its capacity based on the required load, while conventional units start operating with a full load.

2- Inverter technology uses highly intelligent control that regulates compressor speed according to the required cooling load. Conventional units meet the cooling need by using two fixed speeds - zero or maximum speed.

3- The amount of cooling (heating) capacity required depends on the outside temperature and the temperature inside the room to be treated. Outside the temperature varies throughout the year, but also throughout the day, cooling requirements will also vary throughout the year. Only an intelligent system - the inverter - is constantly working to meet specific requirements.

4- Air conditioning units in the Middle East are designed at an outside temperature of 46 degrees, in the winter months the temperature is lower than the design temperature of 46 degrees Celsius, so the cooling load also decreases with the temperature. Inverter technology reacts quickly to this change and reduces the speed of the compressor to save energy. Annual bill with inverter is reduced by 50%.

5- The inverter uses a continuous change of current frequency as the main control variable, allowing the acceleration to be adjusted gradually. This reduces the effect of bad lubrication during the transition as well as mechanical stresses caused by high starting torque.

6- When the compressor is started, the starting current is large for only a few milliseconds, which causes complications in the electrical network, including voltage drops and disruption of sensitive electronic components. It can also cause the motor to stop immediately, the inverter changes the frequency of the voltage feeding into the compressor, while all other methods operate exclusively on the voltage value. The inverter makes the starting current zero and thus does not cause any complications to the electrical network.

7- The power factor required by the Ministry of Electricity is set at 0.85 to 0.9, which requires a capacitor bank to protect the electrical network from the influence of electric motors. The installation of inverters ensures a power factor of 0.95 to 0.97. This feature is of greater importance in installations where it is not possible to order increased power supply.

8- Control units provide the ability to be easily integrated with communication units to provide end users with comprehensive control systems such as building control and monitoring systems, which are currently used in most large buildings or smart homes. These units provide a simple and easy-to-use set of controls that allow programming and monitoring of every aspect of the system's operation.

9- Inverter-controlled air conditioners often operate with high efficiency at partial loads, which leads to lower energy consumption than other systems because they only need the energy needed to match the load. This results in lower annual energy consumption. So, the energy consumption is reduced to 50% compared to the traditional on/off system.

10- Lower energy consumption leads to cost savings and can also reduce the impact of higher energy prices.

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