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A Brief Analysis of Ac Drives and Its Importance in Automation

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***Abstract*: -- This paper explains the description and operation of AC Drives (Variable Frequency Drive, VFD). The various benefits, applications, types and ratings of VFD are also studied in this paper. The use of VFD has been increased dramatically in the recent past over a wide range. This paper provides the basic understanding of how AC Drives are being used in the field of automation.**

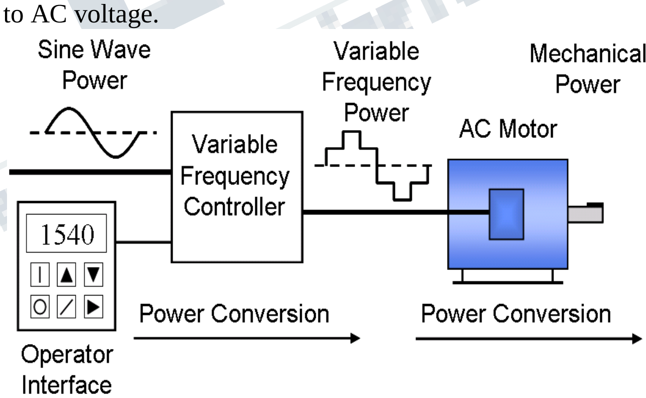
I. INTRODUCTION

A variable-frequency drive (VFD) (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage. The AC drive industry is growing at a very fast rate and it is now the duty of every technician and maintenance personnel in the field to keep installation of AC drives running smoothly. The principle of AC drives is to change the speed of AC motor by varying the voltage and frequency of the power supplied to the AC motor. The ratings, volts/hertz ratio, of the motor must be maintained so as to maintain proper power factor and reduce excessive heating of the motor. This is the reason why VFDs are being installed so frequently. VFDs have a wide range of application and are used from the small appliances to the largest of mine mill drives or compressors. Around 25% of the world's electrical energy is consumed by the conventional electric motors that are used in industrial applications. But by using VFDs in centrifugal load service a whole lot of energy could be saved. But the market growth of VFD is still very low and hence the relatively small global market penetration for all applications. This lack of market penetration sheds light to the significance of energy efficiency improvement opportunities for every new VFD installation.

In recent years, the massive improvement in power electronics technology has reduced the cost and size of VFDs. This in turn have improved the performance through various advances in semiconductor switching devices, various simulation and control techniques, and also the control of hardware and software, in other words, improvement of VFDs by power electronics have helped improve power electronics itself.

BASIC WORKING PRINCIPLE OF AC DRIVES

1. AC drives are basically used for the speed control of squirrel cage induction motors, which are used in various processing plants for mainly two reasons: heavy & rough use and low maintenance throughout its life.
2. AC drive controls the speed of ac motors by varying the output voltage and frequency through a combination of power electronics devices.
3. AC drive constitutes the combination of rectifier and inverter units. The rectifier unit converts the AC voltage to DC voltage and the inverter converts that DC voltage back to AC voltage.



CONSTANT V/F RATIO OPERATION

All AC drives maintain the output voltage - to - frequency (V/f) ratio constant at all speeds for the reason that follows. The phase voltage V, frequency f and the magnetic flux ϕ of motor are related by the following equation:

$$V = 4.444\, f N \phi_m$$

or

$$V/f = 4.444 \times N \phi_m$$

Where, N = number of turns per phase.
ϕ_m = magnetic flux

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If the same voltage is applied at the reduced frequency, the magnetic flux would increase and saturate the magnetic core, significantly distorting the motor performance. The magnetic saturation can be avoided by keeping the ϕm constant. Moreover, the ac motor torque is the product of stator flux and rotor current. For maintaining the rated torque at all speeds the constant flux must be maintained at its rated value, which is basically done by keeping the voltage - to - frequency (V/f) ratio constant. That requires the lowering the ac motor voltage in the same proportion as the frequency to avoid magnetic saturation due to high flux or lower than the rated torque due to low flux.

II. SYSTEM DESCRIPTION AND OPERATION

A VFD consists of the following three main sub-systems: AC motor, assembly of the main drive controller, and drive/operator interface.

1) AC Motor

A three-phase induction motor is generally used as the AC electric motor used in a VFD system. Apart from the preferable three phase motor, sometimes ingle phase motors can also be used. In some situations, various synchronous motors might have some advantages, but three-phase induction motors are most suitable and are generally the most economical in this field. Motors designed for fixed-speed operations are often used in VFDs.

2) Main Drive Controller

The VFD controller consists of three power electronic units which helps in back and forth conversion: the Rectifier unit, DC Bus and the Inverter unit.

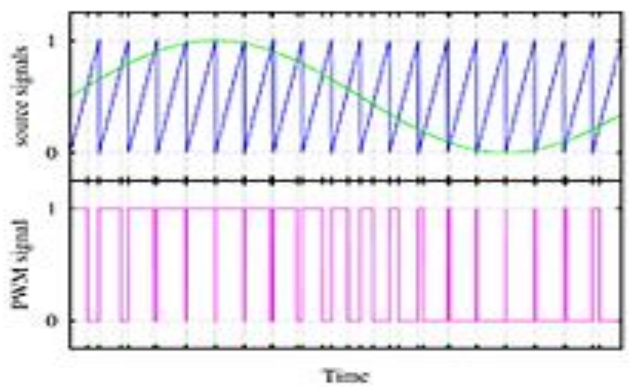
The supply voltage is passed through the rectifier unit, where the three phase supply gets converted into DC supply. The DC bus unit is simply a filter section where the harmonics generated due to the AC to DC conversions are filtered out. The third and final section consists of an inverter section comprising of six IGBTs, where the harmonic free DC supply is being converted to quasi sinusoidal wave of AC supply. This supply is then fed to the AC motor connected to it. The working principle of the AC motor states that the synchronous speed of motor (rpm) is dependent upon frequency. Therefore by varying the frequency of the power supply through AC drive we can control the synchronous motor speed:

Speed (rpm) = {Frequency (Hertz) x 120} / No. of poles

Where:

Frequency = Electrical Frequency of the power supply in Hz.
No. of Poles = Number of electrical poles in the motor stator.

Thus by varying the frequency supplied to the motor, we can directly adjust the speed of an AC motor. The other alternative to control the speed of AC motor is to change its no. of poles, but this change would result in physical change of the motor, which is impractical. The variable frequency and voltage of output required to change the speed of AC motor is obtained by PWM VFDs which produces pulses of changeable widths which are then combined to obtain the exact waveform required.



3) Drive/Operator Interface

The operator interface provides full authorization to an operator so as when to start or stop the motor and also full control over the operating speed.

Additional operator control functions might include reversing, and switching between manual speed adjustment and automatic control from an external process control signal. The operator interface basically offers an alphanumeric digital display as well as indication lights and meters to provide essential information about the drive operations.

Referring to the accompanying chart, drive applications can be categorized as single-quadrant, two-quadrant, or four-quadrant; the chart's four quadrants are defined as follows:

- Quadrant I -- Driving or motoring forward accelerating quadrant with positive speed and torque
- Quadrant II -- Generating or braking, forward braking-decelerating quadrant with positive speed and negative torque
- Quadrant III - Driving or motoring, reverse accelerating quadrant with negative speed and torque
- Quadrant IV - Generating or braking, reverse braking-decelerating quadrant with negative speed and positive torque.

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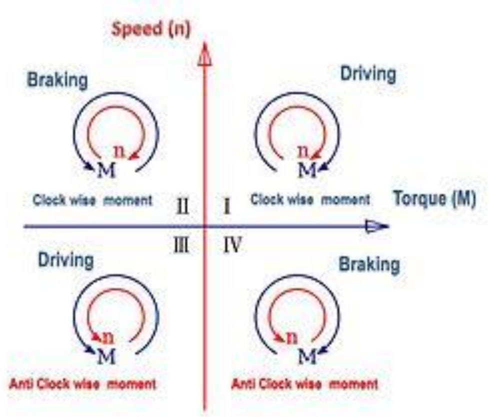

III. AUTOMATION USING AC DRIVES

As the AC drive provides the frequency and voltage of output necessary to control the speed of an AC motor, this is done through PWM VFDs. PWM drives produce pulses of varying widths which are combined to build the required waveform. A diode bridge is used in some converters to reduce harmonics. PWM drives produce a current waveform that more closely matches a line source, which reduces undesired heating. PWM VFD have almost constant power factor at all speeds which is closely to unity. PWM drives can also operate multiple motors on a single VFD. Thus the carrier frequency is derived from the speed of the power device switch remains ON and OFF. It is also called switching frequency. Therefore higher the carrier frequency higher the resolution for PWM contains. The typical carrier frequency ranges from 3KHz to 4 KHz or 3000 to 4000 times per second as compared with older SCR based carrier frequency which ranges from 250 to 500 times per second. Thus it is clear as much as higher the carrier frequency higher will be the resolution of output waveform. It is also noted that the carrier frequency decreases the efficiency of the VFD because it led to increase the heat of the VFD circuit.

IV. BENEFITS

- Efficiency is high and operating cost is low.
- Motor maintenance is maximum.
- Soft starting and stopping as well as smooth speed change of Ac motor can be controlled through linear acceleration and deceleration.
- Accomplishment of multiple motor is easy.
- Quick and accurate torque control is provided by current limit.
- Existing Ac motors accomplish adjustable speed operation.
- Slip compensation provide improved speed regulation.
- AC motors are available in wide variety of mechanical configurations.
- Light weight and compact size of AC motors gives flexibility of machine design.
- High starting torque can be easily and economically provided by IR compensation.
- Suitable enclosures are provided for AC motors which resist corrosion and environmental hazards.
- As same motor can be used for both adjustable speed and constant speed operations, it leads to the requirement of less spare parts.
- Downtime expense gets minimized due to Cutler-Hammer's rugged and reliable design.
- Using extended frequency operation, high speed operation can be economically accomplished.
- No need for a reversing starter as reverse operation is accomplished electronically

V. APPLICATIONS OF AC DRIVE

• Matching the AC Drive to the Motor
PWM and Vector AC Drives are designed in such a way that it can be used with any standard squirrel cage motor. Matching the drive output voltage, frequency and current ratings to the motor ratings is known as the sizing of the drive.

• Output Voltage and Frequency
Most modern AC Drives are designed for use with various voltages and frequencies. Almost any 3 phase motor can be used by adjusting the volts/hertz ratio properly.

• Output Current
With the help of hp ratings of AC motors, an AC drive can be matched with it. However, actual motor current required under operating conditions is the determining factor. If the motor is running at full load, the drive current rating must be as high as the motor current rating. The sum of all full load current rating must be used if the drive is to be used with multiple motors, and adding up of hp ratings will not provide an accurate estimate of the drive needed.

• Motor Protection
Motor overload protection are adjusted as required by the applicable codes. As part of all Ac drives, motor protection is not provided automatically. It might be provided as a standard feature on one model while it might be an optional feature on another.

The direct winding over temperature switch imbedded in the motor windings is the best means of motor protection. As overheating can occur at normal operating current at low speeds, direct over temperature protection is preferred. Most AC drives are equipped with electronic overcurrent protection, such as I2t protection, similar to a conventional overload. Conventional overloads also may be used. In some modern drives, the I2t protection can be configured to protect the motor during low speed operation.

• Motor Winding Damage

The voltage output of AC drives contains voltage steps. In modern PWM drives, the dV/dt of a motor causes can cause very large voltage spikes. Voltage spikes of 1500 volts or more are typical for a 460 volt motor. This can cause the end windings of a Non-Inverter Duty or standard induction motor to fail. This problem gets worse as the cable length from the drive to the motor gets longer. Corrective action is normally required for cables longer than 150 feet.

VI. CONCLUSION

After going through this detail information and study of AC drives, the controlling of speed of AC motor has become possible as well as electrical energy can be conserved. The harmonic change is seen in machine due to frequency variations. With the help of PWM process, the speed of AC motor can be controlled by varying the frequency provided to AC motor. There are also various advantages of Ac drives such as, reduction of noise and vibration, in thermal and mechanical stresses. As the conservation of energy has become an important subject all over the world, so the efficiency is increased, energy consumption and consumption is reduced in order to conserve the energy.

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