Power Quality Improvement in Variable Speed Drives

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Abstract- **Energy conservation is necessary because with the ever increasing demand, need for electrical power can only meet by conserving electrical power in addition to installation of new generating units.A major portion of electrical power in a plant is consumed by electric drives. Selecting a higher efficiency pump will reduce power consumption, but by improving the design of pump and controlling the interaction between the pump and the system would achieve greater improvement.A Variable Frequency Driveoffers a very good response to pumping system. The speed control of induction motor using VFD can save energy according to affinity law. Thus the consumption of electrical energy is depends on the load requirement. Reduces the flow with VFD, motor consumes very less power. This type of fluid flow control is common in industry, wide spread application of variable frequency drives with power electronics area can help in large energy conservation. Thus the variable frequency drive serves both in case of speed control of motor as well as energy savings. The main objective of this proposed research work is to design, model, simulate and implement an improved power quality VFD for mitigating the power quality problems in variable speed drives used in different applications.**

Index Terms- Energy conservation,electric drives,Variable Frequency Drive.

I. INTRODUCTION

In the past years, various control methods has been employed to enhance the flexibility and consistency of manufacturing processes such as controlling the speed of the equipment, changing gear ratios or pulleys, and using hydraulic drives. In many cases, motors are controlled by means of a valve that regulates the flow of fuel or a vane that controls the airflow while the speed of the motor itself remains unchanged.

Conventional methods, such as controlling motor by switching it on and off in two-speed motors are inefficient ways that wastes a huge amount of energy. One of the main reasons that make motor drives popular is that they save energy by changing the speed of an electrical motor and control the power that is fed into the machine. Furthermore, using motor drives reduce the amounts of carbon dioxide emissions by millions tons per year

A variable speed drive (VSD) is a device that regulates the speed and rotational force, or output torque of mechanical equipment. Some examples of mechanical equipment that incorporate with VSD technology are pumps, fans, compressors and conveyors. There are many types of equipment currently in use that needs to be retrofitted because they are running inefficiently; however, manufactures are introducing VSDs technology to save the losses of mechanical equipment. VSD increases efficiency by allowing motors to be operated at the ideal speed for every load condition. In many applications VSDs reduce motor electricity consumption by 30–60%. The potential for electrical motor energy savings is enormous since motor systems use more than 60% of the electrical power consumed by industry. There are millions of motors in industries and offices around the world employed in a wide variety of applications such as motors, pumps, conveyors, ski lifts, sawmills and hospital ventilation systems. They can effectively improve the process efficiency particularly where flow control is involved. Currently, VSD is the most effective controller and energy saver for mechanical machines in industries. Modern VSDs are affordable, reliable, flexible, and offer significant electrical energy savings through greatly reduced electric bills.

Almost all the industrial processes require adjustment for normal operation and optimum performance. Such adjustments are usually accomplished with a VSD. They are an important part of automation and help to optimize the process while reducing investment costs, energy consumption, energy cost and greenhouse gas (GHG) emissions. Most motors are designed to operate at a constant speed and provide a constant output. The benefits of applying VSDs are in both productivity improvements and energy savings in pumps, fans, compressors and other equipment. VSDs installation increases energy efficiency, saves energy consumption, improve power factor and process precision, soft start up and over speed capability. They also eliminate throttling mechanisms and frictional losses affiliated with mechanical or electromechanical adjustable speed technologies and expensive energy-wasting. Other benefits of VSDs include prolonging the life of the equipment, by adjusting motor speed to meet load requirements. Generally, energy savings translate into cost savings and reduction in GHG emissions for a given level of production

II.VARIABLE SPEED DRIVES

Nowadays, technology requires different speeds in many applications where electric motors are used. Electric motors using traditional control methods have mainly two states; stop and operate at maximum speed. In most motor installation, motors are sized to provide the maximum power output required. If the rotational speed is constant at its maximum value to provide the maximum designed load, the power input to the motor remains constant at the maximum value. However, if the load decreases, significant energy savings can be achieved when the rotational speed of the motor is decreased to match with the load requirement [16]. Nevertheless, the majority of motors operate only at 100% speed for short periods of time. This often results in many systems operating inefficiently during long periods of time. Consequently, there are significant energy losses during the operation time. System loss reduction can be achievable by installing VSD systems to match the speed of the motor with the related load. VSD has become very popular because of their advantages over traditional control methods. By using VSD, the speed of a motor or generator can be controlled and adjusted to any desired speed.

Besides adjusting the speed of an electric motor, VSD can also keep an electric motor speed at a constant level where the load is variable. There are several terms used to describe devices with capability of controlling the speed

1. Variable frequency drive (VFD) that uses power electronic components to control the motor speed by changing the frequency of input power of the motor.
2. VSD that control the speed of either the motor or the equipment driven by the motor (fan, pump, compressor, etc.). This device can be electrical or mechanical.
3. Adjustable speed drives (ASD) are devices that use both mechanical and electrical means to control the motor speed.

VSD with optional control panels

There are different reasons for using VSDs. Some applications, such as paper making machines, cannot run without them while others, such as centrifugal pumps, can benefit from energy savings. In general, VSDs are used to match the speed or torque of a drive to the process requirements as well as save energy and improve efficiency.

VSDs and VFDs are electronic devices, which match motor speed to the required speed of the application. The output voltage and frequency are determined by input power of the motor. Most motors can benefit from VSD to provide different frequency outputs; whether the speed of the drive is set manually by an operator or automatically by a control system.

VSDs are an efficient and economical retrofit option that should be considered for all variable speed systems. VSDs allow the motor speed to vary depending on actual operating conditions, rather than operating continuously at full speed. Varying speed allows it to match changing load requirements more closely, and because the power draw is proportional to the cube of its speed, reducing speed can save a lot of energy. For example, reducing a fan's speed by 20% can reduce its energy requirements by nearly 50%. Installing a VSD on the fan motor allows the fan to automatically match this reduced capacity, slowing down in response to reduced demand, thereby saving energy

The needs for speed and torque control are usually fairly obvious. Modern electrical VSDs can be used to accurately maintain the speed of a driven machine within ±0.1%, independent of load, compared to the speed regulation possible with a conventional fixed speed squirrel cage induction motor, where the speed can vary by as much as 3% from no load to full load.

III.COMPONENTS OF VSDS

Rectifier

Rectifiers are used to convert alternative current (AC) to direct current(DC). There are two main topologies for medium power rectifier units: the diode and the IGBT rectifiers. The diode rectifier (also known as the six-pulse uncontrolled rectifier) is the most commonly used AC-to-DC power converter to produce a fixed DC voltage. The power circuit of the rectifier consists of six power diodes in a three-phase bridge configuration. This means the DC link voltage is fully depending on the AC supply voltage. Diode rectifiers are non-linear loads and a non-sinusoidal current is taken from the feeding line.

Regulator

Typically a regulator controls the VSD, enables exchange of data between VSD and peripherals, gathers and reports fault messages and carries out protective functions of the VSD

Inverter

Inverters generate an AC by sequentially switching a DC in alternate directions through the load. Nowadays, all inverters are equipped with IGBT components. The structure of IGBT results in a lack of parasitic body diode. Therefore, the IGBT required a freewheeling diode often placed across it. PWM control is widely used for control of the IGBT switches. PWM control consists in rapidly switching on and off the IGBT switches in such a way that pulses with variable width constitute a variable waveform.

IV.VSD IN PUMPING SYSTEMS

Pumping systems account for nearly 20% of the world's energy consumption by electric motors and 25–50% of the total electrical energy usage in industrial facilities. Significant opportunities exist to reduce pumping system energy consumption through smart design, retrofitting, and operating practices. In particular, many pumping applications with variable-duty requirements offer great potential for energy savings. The savings often go well beyond energy, and may include improved performance, reliability, and reduced life cycle costs. Most existing systems require flow control of bypass lines, throttling valves, or pump speed adjustments. The most efficient way is pump speed control. When a pump's speed is reduced, less energy is imparted to the fluid and less energy needs to be throttled or bypassed. Speed can be controlled in a number of ways, with the most popular type of VSD. There are many types of pump prime movers available such as diesel engines and steam turbines, but the majority of pumps are driven by electric motors. Variable speed pumping has become more popular in recent years due to improvements in speed control technology for pumps and the reduction in the initial cost of such devices. A centrifugal pump runs with AC induction motor which is a single speed device due to the fixed frequency of the applied power to the motor. VSD allows the frequency of the power to be controlled and the speed of the motor's shaft to be adjusted.

V.ENERGY SAVINGS THROUGH VSDS

Employing VSD is the best way to reduce energy consumption of electrical motors. Energy consumption of electric motors constitute up to 75% of total plant's energy consumption. About two-thirds of the motors in industry are applied in fans and pumps which do not need constant motor speeds. A small change in motor speed can cause a significant change in energy consumption as shown in Fig. 8. Using VSD systems provide the opportunity to save about 15–40% of the energy and extend equipment lifetime by allowing gentle start-up and shutdown

Study on quantification of energy savings of VSDs has been conducted on San Francisco refinery. VFD installation on the primary feed and product transfer pumps saved energy by reducing losses through flow control valves.

VI.INSTALLATION OF VSDS

Electrically, a VSD is installed in series between the mains electrical supply and the motor. Large VSDs can introduce electrical 'pollution' in the form of harmonics onto the supply which can be detrimental to other equipment; in the UK regulations such as EA Engineering Recommendation G5/4 limit the amount of harmonics that are permitted on the supply; depending on the local circumstances the installer will have to consider installing electrical filters or specify the rectifier type to ensure compliance is achieved.

Most VSDs offer computing intelligence and are able to be connected to a variety of control systems and sensors. A basic VSD will be able to control a motors output in response to a control signal in order to achieve the desired operating condition. In the simplest of applications the VSD will be interfaced to a transducer such as a pressure, or flow rate sensor, and then programmed to maintain a preset value (set point). At the other end of the spectrum advanced VSDs can perform complex process control tasks; they may be interfaced to a number of transducers, implement interlocks and other control functions, and interface with modern computer networks providing real time operating data. Being electronic equipment VSDs are susceptible to damage through dust and humidity ingress, or inadequate cooling.

They should be located near the motor in suitably ventilated enclosures or remotely in a suitably protected area. Larger drives can generate a lot of heat, and this must be removed or the unit will eventually overheat and fail.

VII.CONCLUSION

VSDs are reliable and cost effective means to control the speed of electrical motors. Installing VSDs on electrical motor applications improves the efficiency of the systems and saves a huge amount of energy. They require little maintenance, provide the most energy efficient capacity control, have the lowest starting current of any starter type, and reduce thermal and mechanical stresses on motors and belts. In addition, they protect the motor while keep the process running, reduce pump failure caused by pump cavitations, and reduce maintenance on piping and valves. Applying VSDs to the HVAC systems and compressed air provide excellent opportunities to reduce the energy consumptions. VSDs are an option to match the required loads thus savings energy and improve the economical features of motors.

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