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Reduction Of Harmonics In VFD's Which Are Used To Drive Solar Water Pumping Systems

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Abstract— *This paper presents the apt solution for reduction of harmonics in VFD that drives an ac water pump that is energized by solar energy. This water pumps can be used in Agriculture, Livestock Farming, Drinking Water Supply, Swimming Polls and Resorts. The key point of our approach is the usage of passive filters to reduce the harmonics in VFD and improve the life of AC pump driven by Solar that requires less energy for its operation. This water pump can serve as an energy solution as it delivers energy to the pump depending on the requirement. Besides this, Using VFD has more advantages like better process control, Low maintenance costs, Control of process temperature, pressure or flow without the usage of separate controller unit. Thus providing the best alternate way to run ac water pumps using solar energy.*

I.INTRODUCTION

Today, it is the known fact of increasing need of electricity because of various reasons like increase in the population, increase in the number of devices that depend on the electric power. This power is produced from various sources like fossil fuels (coal, petroleum, etc), natural gas, oil, etc. This in turn would impact a lot on environment in the form of global warming, acid rains, sea level rise, and glacier disappearance.

India's total installed capacity is 211 GW at present of which about 70% of the energy production is from fossil fuels followed by natural gas and oil. To meet its energy demands India is dependent on imports of fossil fuels which would be a huge burden on the society. Therefore there had been increased focus on developing alternate sources of energy like solar, nuclear and wind energy.

Among the alternate sources of energy solar energy constitute to a large extent. India's theatrical solar potential is about 600 TW [1] which is very large compared to total consumption. So the government has laid an emphasis on development of Solar energy as a part of that it tend to install about 20 GW solar power by 2022. Even though the installation cost to harness Solar Energy is costly the maintenance cost is very low compared to conventional sources of energy. Added to this the energy production by means of solar would be eco-friendly whereas the energy by fossil fuels would result in the emission of CO_2 which had a bad impact on the environment.

Solar energy can be used in following applications like Home Lightening Systems, Street Lightening Systems, Solar Power Packs i.e. both On-Grid and Off-Grid applications, Solar Fencing, Solar Water Pumps i.e. both AC and DC pumps, Solar Chargers, Solar Study Lamps, Solar Lanterns and the list goes on. The approach to harness the solar energy for energizing water pumps can be done in three steps. The manufacturing of solar cells from silicon that is available in the earth's crust then manufacturing of the solar modules from the solar cells and finally designing a VFD to drive an AC water pump

II. MANUFACTURING OF SOLAR CELLS

Silicon is available in the earth's crust in the form of sand i.e. SiO_2. The first step in this process involved here is purification of Silicon from the sand. This can be done by removing the oxygen from SiO2. For this purpose SiO2 is placed into an electric arc furnace where a carbon arc is then applied to release the oxygen. The products formed are carbon dioxide and molten silicon. This simple process yields silicon with one per cent impurity, useful in many industries but not the solar cell production industry.

The 99 per cent pure silicon is purified even further using the floating zone technique. A rod of impure silicon is passed through a heated zone several times in the same direction. This procedure "drags" the impurities toward one end with each pass. At a specific point, the silicon is deemed pure, and the impure end is removed. The pure silicon can be in the form of granular or chunk polysilicon. There are two types of solar cells depending on the raw material used for the preparation of silicon wafers. Mono Crystalline solar wafers are cut from the single silicon ingot or boule of silicon whereas Poly Crystalline solar wafers are cut from the silicon ingot which is made up of different crystals.

The process of conversion of Mono crystalline silicon to Ingot involves a process called Czochralski process**,** [2] whereas for multicrystalline silicon, the poly-silicon material is melted and cast into bricks.

The mono-crystalline silicon ingot is then slice into wafers. As for the poly-crystalline silicon, the silicon brick is first diced into bars and then sliced into wafers. Hence Poly crystalline wafers exist in perfect square and Mono crystalline wafers does not exist in perfect shapes. Usually they are cut at the edges. The Wafers thus formed are checked for quality, treated with KOH, etched at the sides and a layer of SiN is deposited on the cell surface to reduce reflection and improve power output. Silver electrodes and an aluminium layer are screen-printed on the front and back of the cell respectively. The cell is completed when ceramic powder is bonded to the cell surface through a high-heat process called sintering. The overall process of manufacturing a solar cell is shown in the Fig.1.[3]

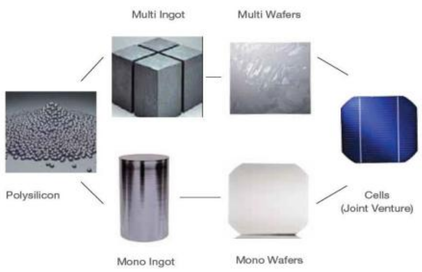

Fig.1. Manufacturing process of Solar Cell

III.MANUFACTURING OF SOLAR MODULES

The solar cells thus manufactured have the ability to produce electricity when sunlight is incident on it. The sunlight consists of photons which excite the electrons that are present on the surface of the solar cell. The electrons are collected at the silver paths that are present on the surface of the cell. The above process of conversion of sunlight to electricity can be termed as Photovoltaic Effect. Such solar cells have some output wattage of around 4 watts, output voltage of 0.5volts. Hence to charge 12 volt batteries considering all the losses we have connect 36 solar cells in series. The cells are available in the standard sizes of 156×156mm. For the manufacturing of solar modules the cells have to undergo following steps.

A .Scribing:

Scribing is the process of engraving on the solar cell so that we can cut the cell depending on the output wattage required. The reason behind this the output wattage of the cell is dependent on the surface exposed to the sunlight.

B. Tabbing:

Tabbing is the process of connecting solar cells in series to get the voltage to desired need. Good tab wire is made out of solid copper coated with solder for easy flow of electrons. The length of the tab wire should be double the length of solar cell. The tab wire is made to solder on the paths that are present on the solar cell. The tabbing process of Solar cell is as shown in the Fig.2.

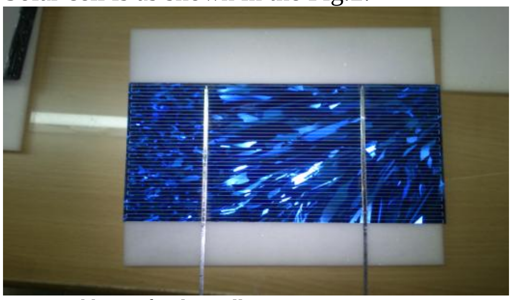

Fig.2. Tabbing of Solar Cells

C. Stringing:

Stringing of solar cells is interconnection of the solar cells electrically for generating larger power. The solar cells which are tabbed are kept in series with each other and made to string with each other by soldering using a copper wire which is coated with tin. The stringing of solar cells to form into module is as shown in the Fig.3.

Fig.3. Stringing of Solar cells

D. Lay Up

The lay-up is done to protect the solar cells from atmospheric conditions. Here we are going to cover the solar panel with glass material on one side to trap the sunlight and boost the solar power. The panel on the other side is covered by tedlar which is made up of polyvinyl fluoride. **EVA** (Ethylene vinyl acetate) is "hot melt glue" and is used to stick the cells to the front glass, and hold the Tedlar to the backside to make it vapour tight.

E. Final Verification

Final Verification is done by looking for any broken solar cells that are stringed together. Checking of EVA, Tedlar, and Glass is done before sent to lamination process.

F. Lamination

The product in lay-up process is brought to laminator machine and kept in laminator to laminate it. The laminator is used to seal the solar panel which is composed of layers into a single component. The laminator in which the lamination process is done is as shown in the Fig.4.

Fig.4. Laminator used to laminate Solar Modules

G. Mechanical Assembly

Mechanical assembly means adding the requisites to the product from the laminator. An aluminium frame is placed around the panel and is made locked by the Solar Module Framing Machine. We then add the junction box to the module..

I. Module Testing

The module that is formed after the mechanical assembly is sent to Module Testing where it is tested using Xenon Flash Lamp. This Xenon Flash Lamp will be switched on for 3milliseconds where the V-I characteristics of Solar Module are plotted in 250 points. Therefore we can get output wattage of the module where we can segregate accordingly.

J. Packing

The tested Solar Module is sent to packing section where it is packed and sent to the customer.

IV. System Design Of VFD

The Solar Modules thus manufactured are used harness the Solar Power from the sun and able to deliver DC power at the output. The DC power can be directly used or can be send to inverter to convert the DC power to AC power and then used. The complete system for solar water pump is as shown in the Fig.6

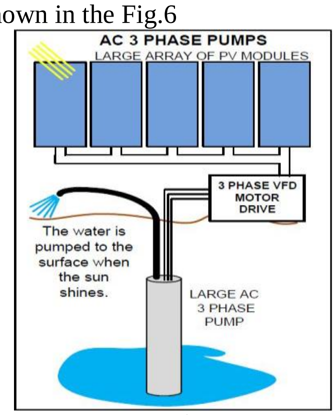

Fig.5. System setup for Solar water pump with VFD

A. Need for emphasis on VFD:

In Industries about 65 % of the energy is consumed by Motor driven applications. So by doing some improvements in system designs we have an opportunity to improve the efficiency and make a significant energy savings. An excellent alternate for this problem is to use adjustable speed or frequency drives instead of using fixed speed drives for their operation. When a motor is driven by a fixed speed motor, the flow may sometimes be higher/lower than the required. This flow is regulated by using a variable frequency drive which controls the rotational speed of the motor by controlling the frequency of the electric power supplied to the motor. Through this method the VFD is able to deliver the only required amount of power to the motor based on the requirement. The power conversion in the VFD can be explained through the Fig.7.

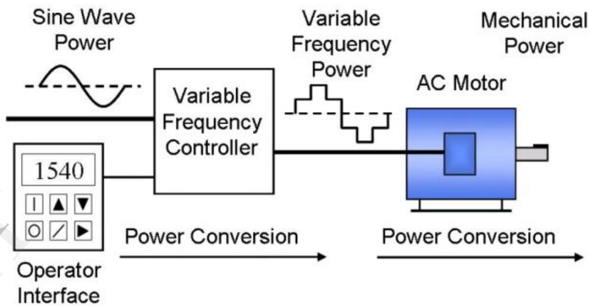

Fig.6. Power conversion involved in VFD

The VFD consists of three subsystems. They are:

- AC motor
- Main Driver Controller Assembly
- Operator Interface

B. AC Motor:

An AC electric motor used for VFD's is generally three phase motor. Sometimes single phase motors are also used but three phase motors are generally used. These offer more advantages over single phase motors.

C Main Driver Controller Assembly:

The Controller used in VFD can be divided into three sections [4] namely rectifier, DC bus and inverter section. The three sections in the VFD are shown clearly in the Fig.8. The voltage on an alternating current (ac) power supply rises and falls in the pattern of a sine wave. When the voltage is positive, current flows in one direction; when the voltage is negative, the current flows in the opposite direction. This type of power system enables large amounts of energy to be efficiently transmitted over great distances.

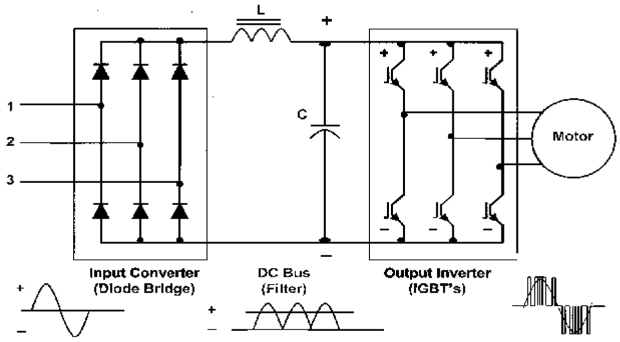

Fig.7. Three sections of VFD

The rectifier in a VFD is used to convert incoming ac power into direct current (dc) power. One rectifier will allow power to pass through only when the voltage is positive. A second rectifier will allow power to pass through only when the voltage is negative. Two rectifiers are required for each phase of power. Since most large power supplies are three phase, there will be a minimum of 6 rectifiers used appropriately, the term "6 pulses" is used to describe a drive with 6 rectifiers. A VFD may have multiple rectifier sections, with 6 rectifiers per section, enabling a VFD to be "12 pulse," "18 pulse," or "24 pulse."

Rectifiers may utilize diodes, silicon controlled rectifiers (SCR), or transistors to rectify power. Diodes are the simplest device and allow power to flow any time voltage is of the proper polarity. Silicon controlled rectifiers include a gate circuit that enables a microprocessor to control when the power may begin to flow, making this type of rectifier useful for solid-state starters as well. Transistors include a gate circuit that enables a microprocessor to open or close at any time, making the transistor the most useful device of the three. A VFD using transistors in the rectifier section is said to have an "active front end."

After the power flows through the rectifiers it is stored on a dc bus. The dc bus contains capacitors to accept power from the rectifier, store it, and later deliver that power through the inverter section. The dc bus may also contain inductors, dc links, chokes, or similar items that add inductance, thereby smoothing the incoming power supply to the dc bus. The final section of the VFD is referred to as an "inverter." The inverter contains transistors that deliver power to the motor. The "Insulated Gate Bipolar Transistor" (IGBT) is a common choice in modern VFDs. The IGBT is a three-terminal power semiconductor device primarily used as an electronic switch and in newer devices is noted for combining high efficiency and fast switching. The IGBT uses a method named "pulse width modulation" (PWM) to simulate a current sine wave at the desired frequency to the motor.

D. Operator Interface:

The operator interface provides a means for an operator to start and stop the motor and adjust 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 often includes alphanumeric display or/and indication lights and meters that indicate the operation of the drive. This can be done through PC also by using the software provided by the manufacturer. Every control of motor through VFD can be done via PC.

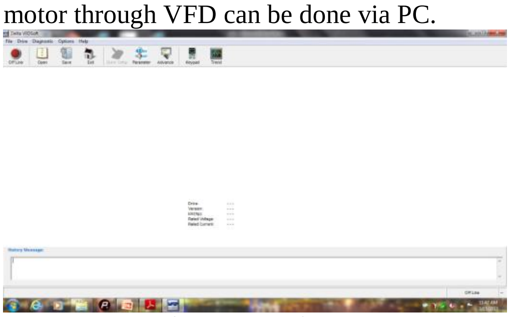

Fig.8: Screenshot of operator interface.

E. Drive Operation:

In starting a motor, a VFD initially applies a low frequency and voltage, thus avoiding high inrush current associated with direct on line starting. After the start of the VFD, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load. This starting method typically allows a motor to develop 150% of its rated torque while the VFD is drawing less than 50% of its rated current from the mains in the low speed range. A VFD can be adjusted to produce a steady 150% starting torque from standstill right up to full speed.

F. Control platforms:

Most drives use one or more of the following control platforms:

- PWM V/Hz scalar control
- PWM field-oriented control (FOC) or vector control
- Direct torque control (DTC).

G. Load torque and power characteristics:

Variable frequency drives are also categorized by the following load torque and power characteristics:

- Variable torque, such as in centrifugal fan, pump and blower applications
- Constant torque, such as in conveyor and displacement pump applications
- Constant power, such as in machine tool and traction applications.[5]

V. REDUCTION OF HARMONICS IN VFD

Harmonic distortion is nothing but a form of electrical pollution that can cause problems if the sum of the harmonic currents increases above certain limits.

A harmonic current is the one with a frequency at a multiple of the fundamental frequency. For example a 100HZ, 150HZ currents are the harmonics on a 50 HZ network. These currents cannot be used by devices and hence be converted into heat.

The harmonic distortion in VFD may cause the following effects. They are

1. Overheating of cables resulting in damage of insulation.
2. Capacitors overheat which leads to explosions due to breakdown of dielectric.
3. Motors get heated up and become noisy. The operating life of motors gets reduced.

Hence reduction of harmonic effects in VFD's is very important.

There are various methods to reduce harmonic effects in VFD's but they are not cost effective and therefore to we presented a cost effective technique for reducing harmonics.

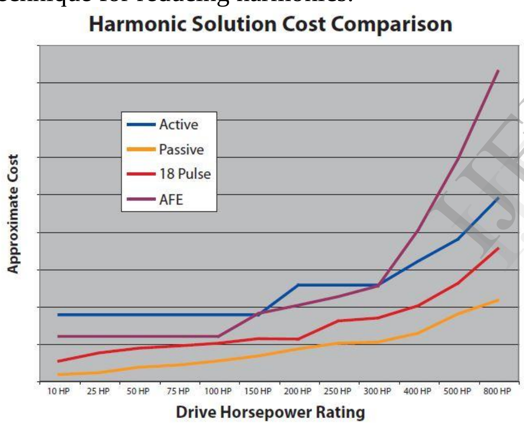

Fig.9: Cost Comparison for various techniques for reduction for Harmonics

Passive Filters and 6-pulse AC Drives

- This is the cost-effective solution at 200 horsepower and below. It may cause a power system resonance condition in some installations. Use caution when applying this type of filter with generator power sources.
- This solution uses a switching rate substantially higher than the network frequency, which effectively reduces the low frequency harmonics.

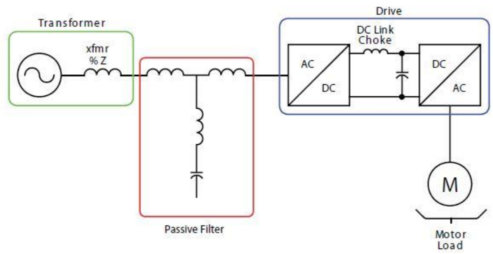

Fig.11: Passive Filter and six pulse drives.

VI. FUTURE SCOPE

Variable Frequency Drives are growing in importance every day as you see them being increasingly used in all kinds of places, not just manufacturing plants and industries, but also in office buildings, warehouses and other commercial places.

The VFD's can be used for regenerative purposes also. VFD can also apply reverse torque and inject the energy back. This application is used in Railway Engines i.e. by the application of brakes we can send back the energy back to the electric line.

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