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Reduction of Harmonics in 3-Phase Squirrel Cage Induction Motor by using VFD Method

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Abstract: *This project aims to explore and implement effective strategies for the reduction of harmonics in three phase squirrel cage induction motors using the VFD method. By leveraging advanced pulse width modulation (PWM) techniques within VFDs, it is possible to significantly lower total harmonic distortion (THD), thereby enhancing the efficiency and lifespan of the motor. The study includes an analysis of harmonic reduction methods, simulation results, and practical recommendations, with a goal to improve overall power quality and maintain the stable operation of industrial motor drives.Harmonic distortion is a well-known challenge in the operation of three phase squirrel cage induction motors, which are central to many industrial applications due to their robust construction, efficient performance, and low maintenance needs. When these motors are powered using Variable Frequency Drives (VFDs), while variable speed control and energy efficiency are achieved, the inverter switching process inadvertently introduces harmonic components into the current and voltage supplied to the motor. Such harmonics, especially of lower order like the 5th and 7th, can cause increased heating, additional core losses, torque pulsations, and noise, ultimately reducing motor efficiency and lifespan.*

Keywords: VFD – Variable Frequency Drive, Harmonics – Harmonics are unwanted voltage or current components, Motor – Converts electrical power into mechanical movement., PWM – Pulse Width Modulation

I. INTRODUCTION

The 3-phase squirrel cage induction motor is one of the most widely used electrical machines in industrial and commercial applications due to its rugged construction, high efficiency, low cost, and minimal maintenance requirements. It functions on the principle of electromagnetic induction, where a rotating magnetic field in the stator induces a current in the rotor, causing it to turn. Despite its advantages, the performance of this motor can be significantly affected by the presence of harmonics, especially when powered through non-linear sources or in systems involving power electronic converters.Harmonics are voltage or current waveforms that are integer multiples of the fundamental frequency (usually 50 Hz or 60 Hz). These distortions are typically introduced by devices such as inverters, rectifiers, and switching power supplies. In induction motors, harmonics can cause a range of issues, including increased heating, reduced efficiency, torque pulsations, vibration, and even premature failure of the motor. Moreover, harmonics can lead to power quality problems in the electrical grid, such as voltage distortion, resonance, and interference with communication systems.

II. PROBLEM STATEMENT

Squirrel cage induction motors are extensively used in industrial and commercial applications due to their simplicity, durability, and cost-effectiveness. However, their performance can significantly degrade when subjected to electrical disturbances, particularly harmonic distortion. Harmonics are generated by non-linear loads, including the power electronic devices commonly used in motor control systems. These harmonic components distort the sinusoidal nature of supply voltage and current, leading to several operational issues such as increased I^2R losses, overheating of the motor windings, derating of the motor capacity, torque pulsations, and reduced power factor.Variable Frequency Drives

(VFDs) are widely adopted for controlling the speed and torque of induction motors. However, if not properly designed, they too can contribute to harmonic distortion due to the switching nature of their inverter sections. Therefore, the key challenge lies in optimizing VFD systems with appropriate filtering and modulation techniques to minimize the harmonic impact on the motor.

III. LITERATURE REVIEW

Researchers have analysed the generation and impact of harmonics on motor behaviour using both analytical models and practical experiments. For instance, dynamic and steady-state models that incorporate effects such as skin effect, magnetic saturation, and stray loss have been developed to quantify efficiency drops and performance changes in motors powered by VFDs. Experimental comparisons between motors supplied with sinusoidal versus VFD-fed waveforms validate these effects and underscore the need for harmonic reduction strategies.

Our Contribution**:**

1. Filter Installation: We installed filter along VFD
2. Transistor: We used IGBT in VFD

IV. METHODOLOGY

A Variable Frequency Drive (VFD) operates by converting a fixed-voltage, fixed-frequency AC power supply into a fully controllable AC output whose frequency and voltage can be adjusted to regulate the speed and torque of an electric motor. The process begins when the AC input from the electrical mains enters the VFD. This AC power is first directed to the rectifier stage, which typically uses diodes or controlled semiconductor devices to convert the alternating current into direct current. The rectification process produces a pulsating DC output, which is not yet suitable for motor control. Therefore, the DC is passed into the DC link—or DC bus—where filtering components such as capacitors and reactors smooth out voltage ripples, stabilize the energy flow, and store electrical energy temporarily. This smoothing is essential because a clean and stable DC supply ensures reliable operation of the next stage and reduces electrical stress on downstream components.Once the DC link has conditioned the power, the stabilized DC is fed into the inverter section. The inverter is the core of the VFD and uses advanced power electronic switches, commonly IGBTs, that are turned on and off at very high speeds using Pulse Width Modulation (PWM). By modulating the width and timing of these switching pulses, the inverter reconstructs a new AC waveform from the DC input. Unlike the original mains supply, this reconstructed AC waveform can have its frequency and voltage precisely controlled. Adjusting the output frequency allows the VFD to control the speed of the motor, since the motor's rotational speed is directly proportional to the frequency of the input power. Similarly, the voltage is varied in proportion to frequency to maintain an optimal voltage-to-frequency (V/Hz) ratio, ensuring proper torque production and preventing overheating or magnetic saturation of the motor.These electronic control circuits continuously analyze feedback signals from the motor—such as current, speed, load demand, and temperature—and use this information to generate accurate PWM patterns for the inverter. They also manage user-defined parameters like acceleration and deceleration rates, direction of rotation, speed setpoints, and protection limits. In addition, the control system provides essential protections, including over-current, over-voltage, under-voltage, ground fault, and over-temperature safeguards, ensuring safe and sustainable operation. Ultimately, the inverter's controlled AC output is delivered to the motor, allowing it to run at the desired speed and torque with high efficiency and smooth performance. This capability not only improves energy efficiency by matching motor speed to load requirements, but also enhances process control, reduces mechanical stress, and extends the lifespan of the motor and connected equipment.

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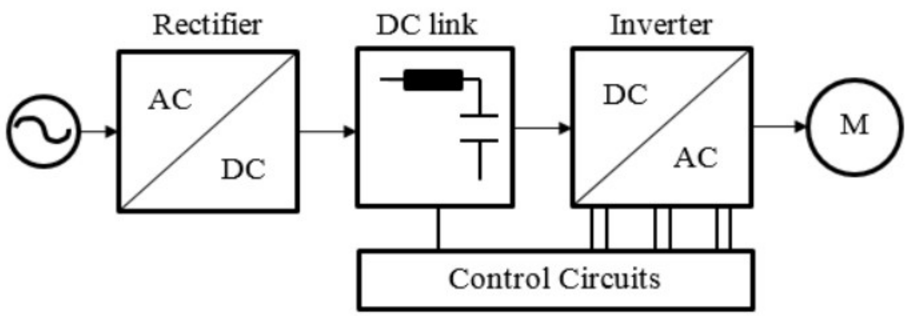
V. BLOCK DIAGRAM



COMPENTS USED

1. VFD
2. MCB
3. Potentiometer
4. Digital Tachometer with sensor
5. Switches
   - ON / OFF switch
   - Forward / Reverse switch
6. UVW terminals

VI. COMPONENTS DESCRIPTION

Variable Frequency Drive [VFD]:

A VFD (Variable Frequency Drive) is an electronic device used to control the speed and torque of an AC motor by varying the frequency and voltage of the electrical supply. It converts fixed-frequency AC power (usually 50 or 60 Hz) into variable-frequency AC power, allowing precise control of motor operation. A VFD consists mainly of three parts: a rectifier, a DC link, and an inverter.The rectifier converts incoming AC to DC, the DC link smooths the voltage, and the inverter converts DC back to AC at the desired frequency. By adjusting this output frequency, the VFD controls motor speed efficiently. It also provides soft starting and stopping, reducing mechanical stress and extending motor life.VFDs are widely used in pumps, fans, conveyors, compressors, and HVAC systems. They help achieve energy savings, improve process control, and reduce maintenance costs. Modern VFDs include features like protection circuits, digital control panels, and communication interfaces for integration with automation systems. Overall, VFDs play a crucial role in enhancing efficiency and performance in industrial and commercial motor applications.

Components involved in variable frequency drive:

- Rectifier
- DC BUS
- Inverter (IGBT)
- Filter
- Cooling System

Miniature Circuit Breaker [MCB]:

An MCB (Miniature Circuit Breaker) is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overcurrent, overload, or short circuits. It acts as a safety device that interrupts the flow of current when it exceeds the rated limit, preventing overheating and potential fire hazards.Unlike a fuse, which must be replaced after operation, an MCB can simply be reset manually after tripping, making it more convenient and

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reusable. MCBs operate using thermal and magnetic mechanisms — the thermal part responds to prolonged overloads, while the magnetic part reacts instantly to short circuits.

Potentiometer:

A potentiometer is a three-terminal variable resistor used to adjust voltage and control electrical signals in a circuit. It works on the principle of voltage division, meaning it provides an adjustable output voltage between its two ends by moving a sliding or rotating contact called the wiper.When a voltage is applied across the two fixed terminals, the position of the wiper determines how much resistance lies between the wiper and each terminal. By changing the wiper's position, the output voltage varies proportionally — this makes the potentiometer ideal for controlling parameters like speed, brightness, volume, and position.

Digital Tachometer with Sensor:

A digital tachometer is an electronic device used to measure the rotational speed of a shaft or disk in a motor or other machine. It displays the speed in digital form, usually in revolutions per minute (RPM). Unlike analog tachometers that use a needle and dial, digital tachometers provide precise and easy-to-read numerical values.It works on the principle of counting the number of pulses generated by a rotating object within a specific time period. A sensor, such as an optical, magnetic, or Hall-effect sensor, detects each rotation or pulse. The signal is then processed by a microcontroller or digital circuit, which calculates the speed and displays it on a digital screen.

Switches:

ON / OFF switch

Forward / Reverse switch

An ON/OFF switch is a simple electrical device used to control the flow of current in a circuit by turning it on (allowing current to pass) or off (stopping the current). It provides a basic means of controlling electrical appliances, machinery, or electronic devices safely and conveniently.

A forward/reverse switch is an electrical control device used to change the rotational direction of a motor, typically in DC motors or AC three-phase motors. It allows the motor to run in a forward direction for normal operation or reverse direction for applications like conveyors, cranes, and hoists where reversing motion is needed.

U V W Terminals:

The UVW terminals in a Variable Frequency Drive (VFD) are the output terminals that connect the drive to the three-phase induction motor. These terminals supply the variable voltage and frequency power that controls the speed and torque of the motor.In a VFD, the input AC power is first converted into DC using a rectifier circuit, and then this DC is converted back into a variable AC output through an inverter circuit. The inverter uses Insulated Gate Bipolar Transistors (IGBTs) or similar switching devices to produce a three-phase AC output at the U, V, and W terminals.

VII. ADVANTAGES

1. **Reduced harmonics:** VFDs can reduce harmonics, improving the quality of the electrical supply.
2. **Improved equipment lifespan:** VFDs can reduce the strain on equipment, extending equipment lifespan.
3. **Improved power factor:** VFDs can improve the power factor, reducing the strain on the electrical system.
4. **Reduced energy waste:** VFDs can reduce energy waste, as they can optimize motor speed to match load requirements.
5. **Reduced noise:** VFDs can reduce motor noise, as they can operate at lower speeds.
6. **Reduced vibration:** VFDs can reduce motor vibration, as they can operate at lower speeds.

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VIII. CONCLUSION

The study and implementation of harmonic reduction using a Variable Frequency Drive (VFD) for a three-phase squirrel cage induction motor clearly demonstrate the importance of advanced power electronic control in modern industrial systems. Harmonics are one of the major contributors to reduced motor efficiency, overheating, torque pulsations, and premature insulation failure. In large-scale installations where induction motors operate continuously, even moderate harmonic distortion can lead to significant energy losses, equipment deterioration, and increased operational costs. This project addressed these challenges by analysing the behaviour of the motor under normal supply conditions and then evaluating the improvements achieved through the use of a VFD.

IX. FUTURE SCOPE

The future scope of the solar-powered beach cleaning machine includes adding smart features like GPS navigation, autonomous movement, and sensor-based monitoring to reduce human effort and improve accuracy. IoT-based tracking can help record the type and amount of waste collected for better environmental planning. Improvements in battery capacity, solar panel efficiency, and lightweight materials can enhance performance and durability, while adjustable cleaning mechanisms can make the machine effective on different beach conditions.

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