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Fault Detection Techniques for Variable Frequency Drives and its Structured Components

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Abstract: Variable Frequency Drives (VFDs) are essential instruments in modern industrial systems, providing precise control over motor speed in various industrial applications and improving energy efficiency. Faults in VFD's can lead to costly downtime and reduced productivity. This paper presents precise fault detection technique for VFDs and its technical components providing flawless step by step method for quick access of faulty parts / items and time saving in testing methods. Experimental results demonstrate the effectiveness of the proposed approach in accurately detecting faults in IGBT, SCR, choke, capacitor, power card, control card, firing card, CT card and its causes like temperature over voltage and current, aging, atmosphere and bearing wear etc. The proposed methodology offers Cold test and hot test methods applied on common technical machines using oscilloscope and multi-meter.
Keywords: VFDs, Fault detection, Cold / Hot test, SCR / IGBT, Choke, Capacitor, Power Card, Control Card, Firing & CT Card.

I. INTRODUCTION

The main job of an engineer is to resolve the problem associated with apparatuses quickly and to facilitate the work of industry with minimal breakdown. This research paper is about the exact technique of detecting faults in VFD step by step. Significances of faulty VFDs are reduced efficiency and downtime of industries product, workforce burdening the commercial issues. The variable frequency converter supplies a regulated amount of mains AC power to a standard 3 phase induction motor to control the motor speed. A variable frequency drive broadly comprises of converter section which rectifies mains AC voltage into DC voltage, after which this DC voltage is converted into AC through inverter section with a variable amplitude and frequency to match the load demand [1]-[5]. Variable Frequency Drives are largely classified into three clusters [5].

1) Voltage-Source Inverter (VSI): The most common type, which uses a diode circuit to convert AC to DC, with a capacitor to store energy
2) Current-Source Inverter (CSI): In CSI VFDs, the inverter section is supplied by a current-regulated DC source rather than a voltage-regulated one. They are less common than VSI VFDs and are typically used in specialized applications.
3) Pulse Width Modulation Inverter (PWM): PWM VFDs control the output voltage and frequency by modulating the width of voltage pulses using high-frequency switching devices such as Insulated Gate Bipolar Transistors (IGBTs). They provide precise control over motor speed and torque and are widely used in various applications.

a) Some of the applications of VFDs [11] depicted are stated as under:

- *Mechanical and electrical industries:* VFDs are used in servo systems, control systems and spindle speed regulation.
- *Industrial applications:* VFDs are commissioning in control pumps, compressors, fans, blowers, extruders, roller coasters, and mechanical bulls.
- *Commercial applications:* VFDs are employing for flow control and volume in tanks, and in HVAC systems for fan and pump balancing, equipment monitoring, and cutting equipment energy usage.
- *Food and beverage industry:* VFDs are used in conveyors, filling machines, capping machines, wrapping, and cutting processes.
- *Paper and pulp industry:* VFDs control conveyor systems, pump operations, and regulate the flow and pressure of liquids.
- *Marine applications:* VFDs are used for propulsion, shaft power generation, thrusters, and other marine applications.

b) There are many motives to adjust the motor speed by Variable Frequency Drive [9]. Some of these are portrayed below:

- Save energy and improve system efficiency
- Convert power in hybridization applications
- Match the speed of the drive to the process requirements

- Match the torque or power of a drive to the process requirements
- Improve the working environment
- Lower noise levels, for example from fans and pumps
- Reduce mechanical stress on machines to extend their lifetime
- Save peak consumption to avoid peak-demand prices and reduce the motor size required

c) Safety precautions [10] must be followed during the testing and checking of faulty VFDs at workplace are as under:

- *Electrical Safety:*
  - Lockout/Tagout (LOTO): Implement LOTO procedures to ensure the VFD is de-energized and cannot be inadvertently restarted while maintenance or repair work is being carried out.
  - Test for Voltage: Before working on the VFD, verify that it is de-energized by using a voltage tester.
  - Proper Grounding: Ensure the VFD and associated equipment are correctly grounded to prevent electrical shock hazards.
  - Use of Personal Protective Equipment (PPE): Wear appropriate PPE such as insulated gloves and safety glasses when working with electrical components

- *Mechanical Safety:*
  - Machine Guarding: Ensure that any rotating parts driven by the VFD are adequately guarded to prevent accidental contact.
  - Proper Installation: Follow manufacturer guidelines for VFD installation to prevent mechanical hazards such as vibration or overheating.
  - Lockout/Tagout of Mechanical Systems: Secure mechanical components to prevent unintended movement during maintenance activities.

- *HVAC Safety (for HVAC applications):*
  - Ventilation: Ensure proper ventilation around the VFD to dissipate heat generated during operation.
  - Fire Prevention: Take measures to prevent the risk of fire, such as avoiding the accumulation of combustible materials near the VFD.

- *Training and Procedures:*
  - Training: Provide comprehensive training to personnel on the safe operation and maintenance of VFDs, including emergency procedures.
  - Written Procedures: Develop written procedures for VFD maintenance and emergency response, and ensure they are easily accessible to personnel.
  - Risk Assessment: Conduct a risk assessment before starting work to identify and mitigate potential hazards.

- *Emergency Preparedness:*
  - Emergency Shutdown Procedures: Have procedures in place for quickly shutting down the VFD in the event of an emergency.
  - Emergency Response Plan: Develop an emergency response plan that includes procedures for evacuating personnel and contacting emergency services if needed.

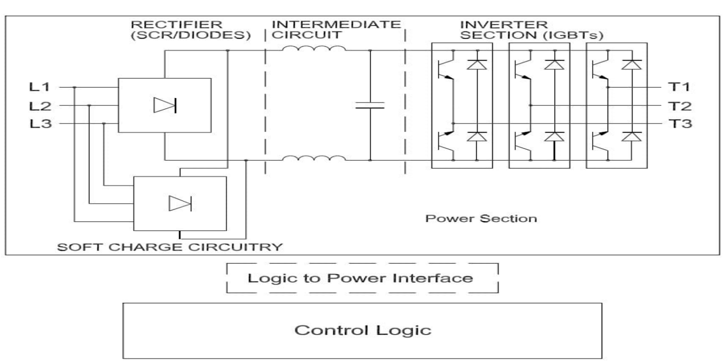

Fig.1 Internal Control Logic Of VFD

d) The variable frequency converter [7]-[9] Fig.1 is divided into four main modules:

- Rectifier (Firing card, SCR)
- Intermediate circuit or Dc link (Choke, Capacitor)
- Inverter (Power card, IGBT, CT)
- Control and regulation (Control card)

e) Following steps for testing and checking of faulty / dented unit are observed for rapid access [6], [12].

- *Steps of Testing:*
  - Cold test (oscilloscope diode drops, multi-meter through test)
  - Hot test (oscilloscope pulse generates and power panel testing)

- *Fault checking step:*
  - Checking VFD
  - Checking high power components
    - IGBT
    - SCR
    - Capacitor
    - Choke

- *Checking low power components:*
  - Firing card
  - Power card
  - Control card
  - CT card

II. CHECKING OF VARIABLE FREQUENCY DRIVE

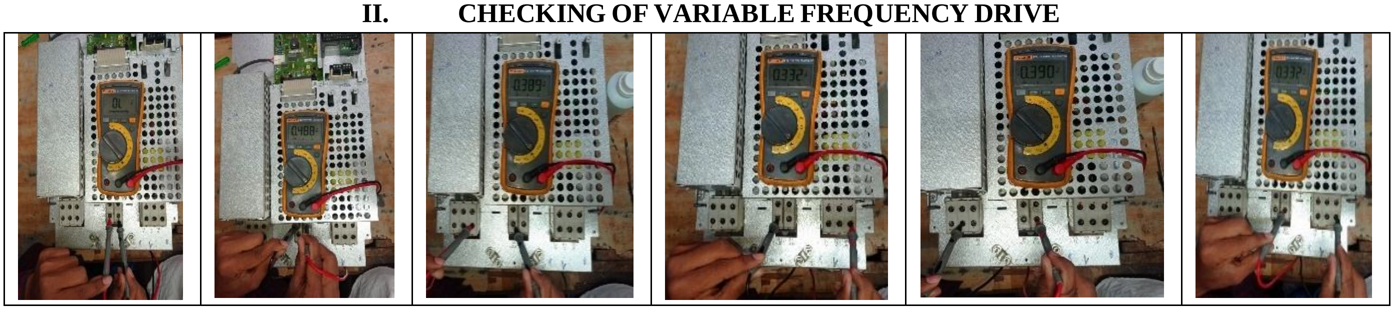

Fig.2 Cold test (Diode testing) of VFD

When do diode test, diode is open and voltage drop between 0.3 to 0.7, if the value is <0.3 and >0.7 then VFD are faulty. Testing the VFD using a multi-meter or similar tool when the drive is not under load or operating conditions Fig.2.

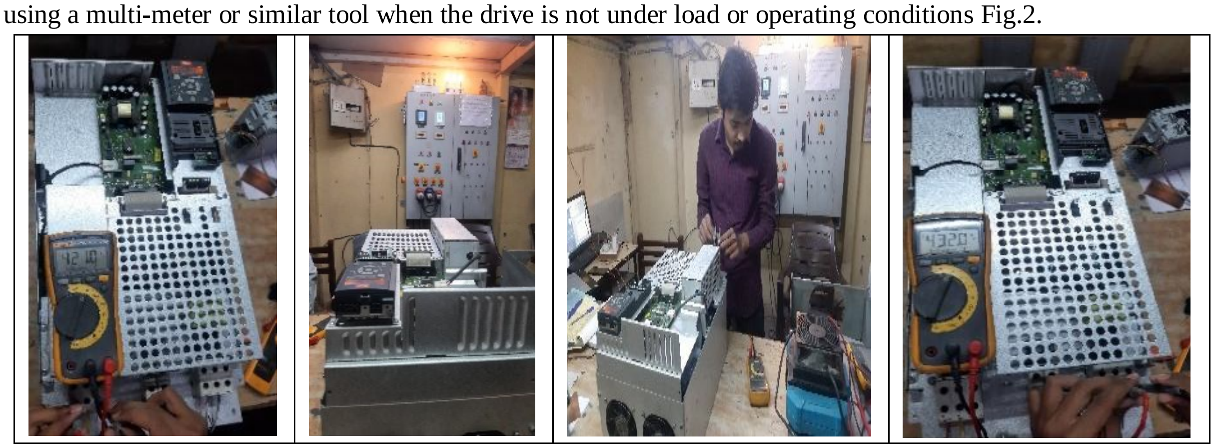

Fig.3 Hot test (power panel through) of VFD

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When supply is on, input value on that time is 421V and output value must be 432V. If drive is faulty then alarming signal is generated in display and drive gets trip Fig.3.

If drive test is getting clear indications on these hot and cold testing criteria then there is no need to move on next step and drive is ready to work. If any kind of defect occurs in this test, then all components inside it have to be checked in turn. First checking is high power components of VFD. If any power component is faulty or defective during the check process then that component is replaced with new component and drive starts working as usual. Below are the easy fault detection methods, that professionals and engineers are used to make drives fault-free.

III. CHECKING HIGH POWER COMPONENTS

A. IGBT Test:

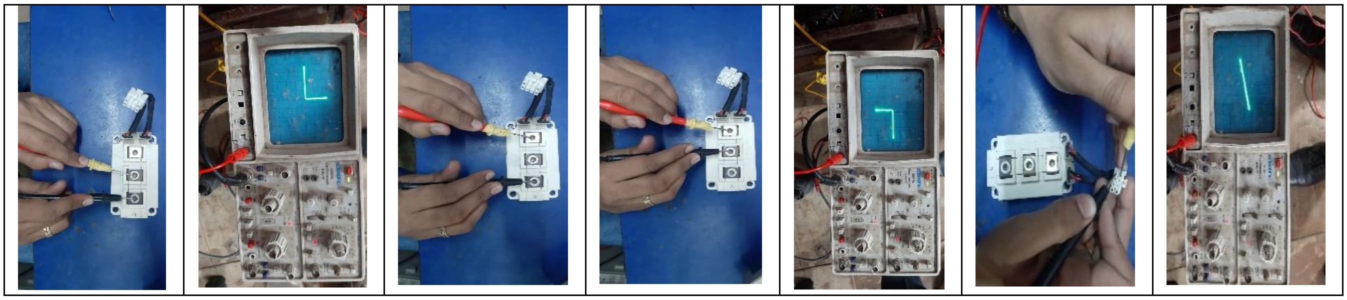

Fig.4 IGBT Cold Test Through Oscilloscope

When do diode test, diode voltage drop must be between 0.3 to 0.7, if the value is <0.3 or >0.7 then VFD is faulty. Pattern is generated by the oscilloscope when IGBT is measured by a probe of a multimeter, this pattern will not show or differently show if there is a fault in the IGBT Fig.4.

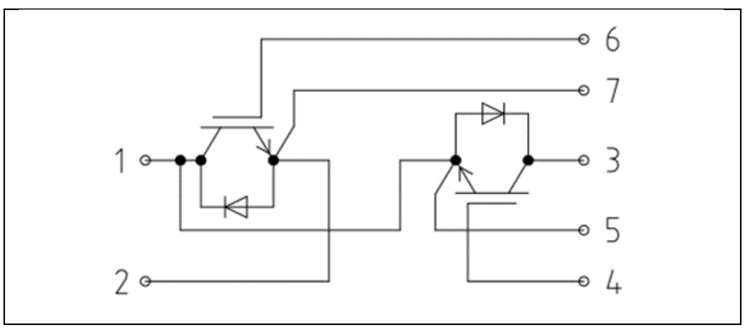

Fig.5 Circuit diagram of IGBT Module

B. SCR Test:

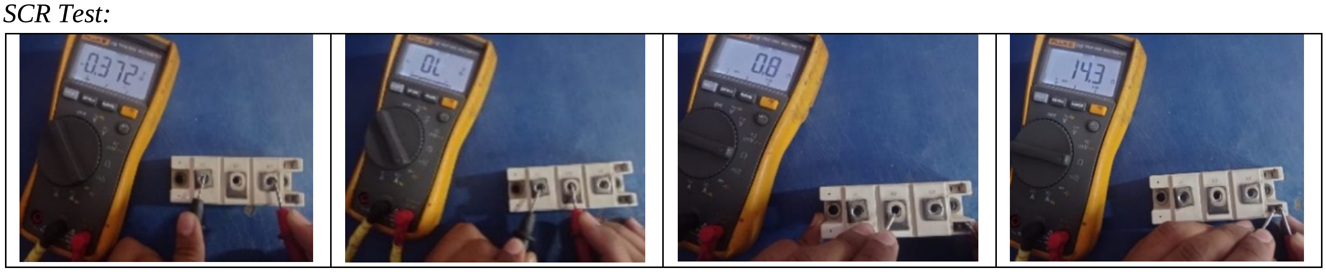

Fig.6 SCR Cold Test Through Multi-meter

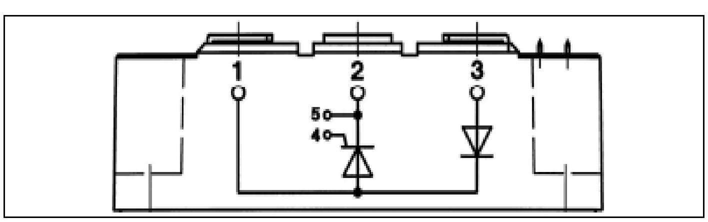

Fig.7: SCR Module

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When do SCR test, Diode voltage drop is 0.372V, multi-meter probe put at number1 (anode) and 2 (cathode). SCR is open and output shows over limit. Number2 and 5 are commonly linked because this area is near by firing zone and its value is 0.8Ω, gate resistance value is 14.3Ω between gate and cathode (number 4 & 5). If other value is detected than specified value as above then SCR is declared as faulty Fig 6.

C. Capacitor Test:

When 104V DC power is supplied to two capacitors, half of the value 52V supply in capacitor1 and the rest of 52V supply must show in capacitor2. If capacitor is faulty then unbalanced voltage, between 2 capacitors will indicate on meter. One Capacitor consumes high voltage and other consumes low voltage. The Capacitor is faulty or leaky, who consume high-rate of voltage Fig.8.

Fig.8 D.C. supply through Capacitor test

D. Choke Test:


Fig.9 D.C. Choke Test

An inductor choke, also known as a reactor, is a type of inductor used in VFDs to filter and smooth out the DC voltage and to limit the rate of change of current in the motor windings. When dc supply passes to choke, inductor value L1 and L2 are almost same then Choke are proper. If L1 and L2 value are unequal then Choke is declared as faulty.

Table.1: chart of Voltage, Current, inductor, resistor of choke

D.C. Choke Test				
V_{dc}	L1	L2	$V_{dc(r)}$	I_{dc}
10.15	0.136	0.138	9.87	123
10.38	0.241	0.199	3.93	95
10.35	0.222	0.182	9.92	81

Table-1 shows 1st reading L1 and L2 value are same then Choke are ready to use, 2nd and 3rd reading shows L1 and L2 value are different then choke are faulty.

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IV. CHECKING LOW POWER COMPONENTS

A. Firing Card

When do firing card test multi-meter probes are put on step by step on 3 test-pins of firing card, gate and cathode resistance of 3 pins are same 9.99kΩ, if firing card is faulty then 3 pins resistance shows different value Fig.10.

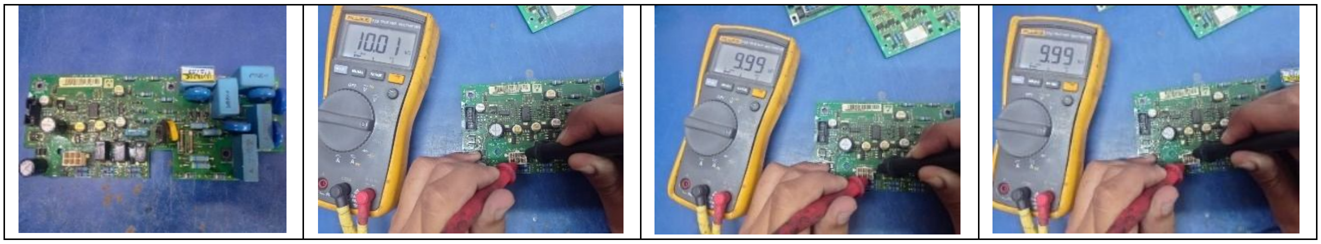

Fig.10 Cold Test of Firing Card

B. Power Card

When supply passes in power card on that time square wave are generated in oscilloscope Fig.11, this shows power card is functioning normal. If power card is faulty then different wave form will display on screen.

Fig.11 Hot Test of Power card

C. Control Card

3-phase power supply is applied to VFD at that time if control card working functionality is normal then display will on and output result will be seen on display. If control card is faulty then display will remain off and output will not be visible on-screen Fig. 12.

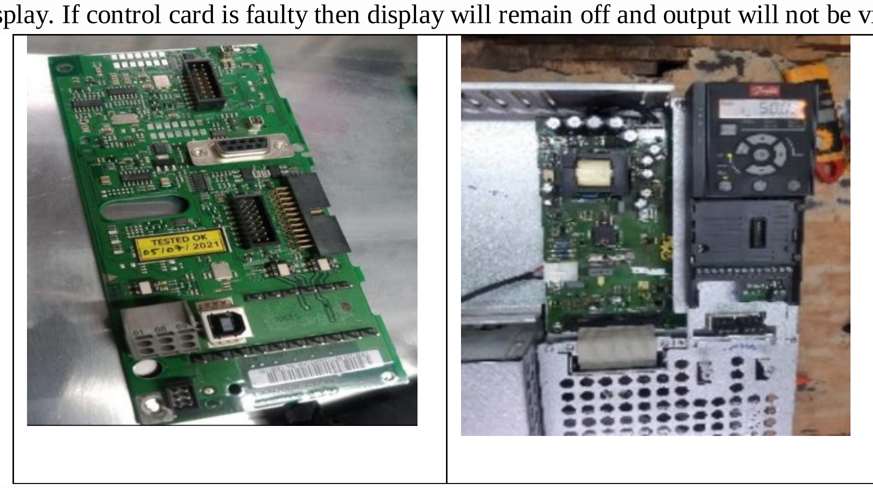

Fig.12 power panel through hot test of control card

D. Current Transformer Card

Power panel through supply is applied to VFD. CT card is ok if the current that appears inside the clamp meter output and the current that appears in the display is the same. If CT card is faulty then current is not same in display of VFD and clamp meter. In upper case Current Transformer card are faulty because clamp meter and display Current are not same Fig.13.

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Fig.13 power panel through hot test of CT card

V. CONCLUSION

Variable Frequency Drives are critical devices in modern industrial systems, providing precise control over motor speed in various industrial applications and civilizing electrical energy resourcefully. Consequences of faulty VFDs are reduced efficiency and disruption of industries product, workforce burdening the commercial issues. This research paper reveals about the exact technique of detecting faults in VFD a bit at a time. Experimental results determine the effectiveness of the proposed approach in accurately detecting faults in IGBT, SCR, choke, capacitor, power card, control card, firing card, CT card. This paper also outlines a step-by-step fault detection method utilizing cold and hot testing methods using oscilloscopes, multi-meter and power panel. Cold tests involve multi-meter testing and oscilloscope diode drop, while hot tests involve power panel and oscilloscope pulse generate. The process includes detailed fault checking steps for high-power and low-power components, ensuring efficient fault detection in Variable Frequency Drive to resolve the problem associated with apparatuses swiftly and to facilitate the work of industry with minimal breakdown.

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