Conception and Implementation of Single and Simultaneous Two Diodes Open Faults Automatic Detection and Localization Algorithm in Six Diodes Three Phase Rectifier Bridge

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Abstract

The faulty performance of six diodes three phase rectifier is studied under one and two simultaneous open-diodes conditions. This rectifier is feeding a resistive load. The rectifier three phases currents zero harmonic components and their maximum and minimum values are used as diagnostic indices. A knowledge algorithm is based to get information on which IGBT is in open-switch fault condition. This algorithm testing shows that the system could not only detect the open-switch fault, but also identify the faulty switches. Presented simulation results confirm the effectiveness of the proposed methodology.

Key Words: Six Diodes Three Phase Voltage Rectifier, Fault Diagnosis, Alternative Current, Zero Harmonic Component, Min and Max Value

1. Introduction

Automatic fault detection of electric machines and drive systems is a challenging task that has recently attracted increasing attention. An intelligent regime of online condition monitoring leading to fault identification, fault location, and fault-severity evaluation represents the far goal. Precise diagnosis and early detection of incipient faults help avoid harmful, sometimes devastative, consequences of the fault. Repair requirements and the time frame could be preset based on the automatic diagnostics, which reflects lower cost. Temporary remedial actions, which allow the machine to continue running under fault, are firmly based on the online diagnostics and highly recommended for fault-tolerant systems.

Certain procedures are to be followed in order to achieve the automatic diagnosis mission. Studying system performance under specific fault conditions, and comparing it to healthy performance, yields one or more characteristic waveforms that could identify the fault. Features extracted from the characteristic waveform(s) are used as input date to the online diagnosis process.

Various techniques for open-switch fault detection in voltage source inverter (VSI)-fed pulse width-modulation (PWM) asynchronous motor drives were presented in [1]. Monitoring voltages at key points of the system, and comparing them to respective references could successfully diagnose the fault. Temporary remedial actions under similar faults on permanent-magnet (PM) synchronous motor drives were prescribed for fault-tolerant operation [2]. A converter topology with eight switches helped the machine produce more torque under fault than the classical six-switch configuration.

Expert systems, artificial neural networks (ANNs), fuzzy and adaptive-fuzzy systems, and genetic algorithms (GAs) represent the modern AI tools, which have been used in the area [3,4]. Adaptive neuro-fuzzy inference systems (ANFIS) are composed of fuzzy inference systems implemented in the framework of adaptive networks [5]. Pattern classification through learning, nonlinear mapping, and utilization of human expertise are examples of the powerful features of ANFIS. New and

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promising research horizons in the area of motor fault detection could be explored using fuzzy inference systems implemented on neural architectures [6].

Tahar Bahi, Mohamed Fezari, George Barakat and Nasr Eddine Debbache [7], Friedrich W. Fuchs [8] used a localization domain illustrated by seven patterns built with the stator Concordia mean current vector. One pattern corresponds to the healthy domain and the remaining six patterns are linked to the state of each inverter switch.

All works mentioned previously study the case of one open-switch fault condition. Case of simultaneous two open-switches fault is not widely studied.

The present work introduces a simple diagnostic technique for one and simultaneous two open-switches faults on the inverter bridge of voltage-source inverter (VSI)-fed three phase balanced load. Healthy and faulty system where simulated in PLECs/MATLAB program. Fault impact on each one of the three phases currents mean values and maximum and minimum values are observed to conceive the appropriate diagnosis algorithm based on the value and the polarity of both the currents mean values and maximum and minimum values under fault condition. This technique testing shows its effectiveness in detecting and locating the open-switch fault and even the simultaneous ones.

Implementation of the proposed method should be straight forward on a processor loaded with three currents sensors.

2. Studied System

The six diodes three phase balanced rectifier feeding resistive load considered in this work is presented in (Figure 1). The system consists of the following components:

(1) DC resistive load of 270 Ω;
(2) Main power supply balanced sinusoidal voltages rms values of 47 V and frequency of 50 Hz;
(3) Three current sensors.

3. Simulation

The system was modelled using a PLECS/MATLAB program.

Phases currents waveforms in normal operating condition are presented in (Figure 2) and (Figure 8).

3.1 Proposed Method Principle (Change Detection of Phases Currents)

Simulation results under both normal and faulty conditions will be used to conceive the diagnosing algorithm based on currents zero harmonic components and their maximum and minimum values and their polarities. Normal operating condition is characterized by, theorically, a nil zero harmonic component value. That is due to the symmetric currents wave forms thus their currents zero harmonic components values are nil (Figure 2). In open diode fault operating condition, currents wave forms are

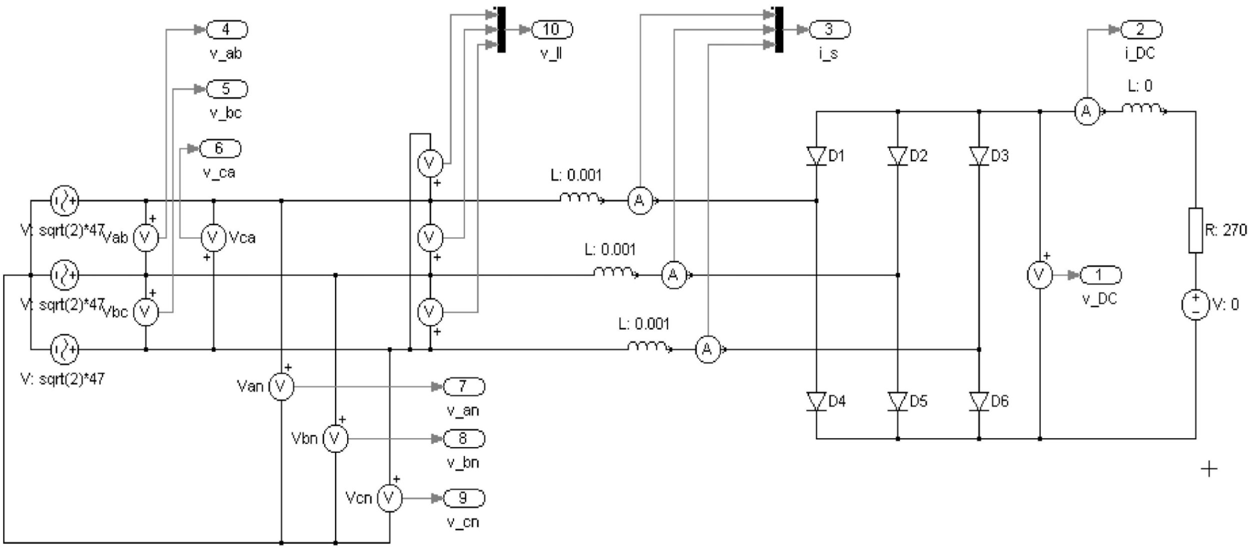

Figure 1. Schematic diagram of the drive system.

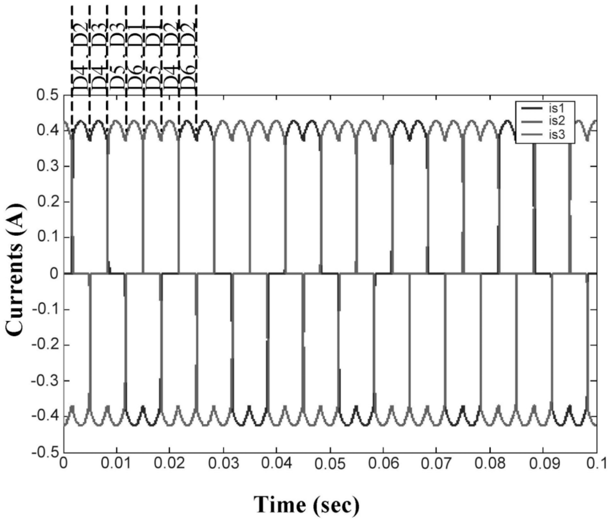

Figure 2. Phases currents waveforms (is1, is2, is3) in safe operating condition.

asymmetric and thus their currents zero harmonic components values are not nil (Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7).

Diode D1 is the only path for negative part of phase 1 current is1. If D1 is in open switch fault case, negative part of is1 will disappear (Figure 3) making is1 nil. In this case, there will be a temporary open phase 1 case. Current will flow from phase 2 to phase 3 and vice versa (Figure 3). When current flows from phase 2 to phase 3 (D5 and D3 are conducting), line voltage vs12 is applied on R-L load instead of vs12 that is applied if D1 is operating normally (D5 and D1 are conducting). vs12 makes current is2 getting its new form that is different than its form where D1 is operating naturally. It is clear that is2, in D1 faulty condition, is asymmetric and its negative part is bigger than its positive part. The same remark is observed on phase 3 current (is3). Thus is2 and is3 will have negative dc components. So, when D1 is open faulty switch, is1 will have positive dc component while is2 and is3 will have negative dc components

A change in phase currents waveforms is defined as the instant at which a sudden increase or decrease is observed in zero harmonic components values of three phases currents. A change is considered to have occurred in three phases values when they exceed or falls below a given band (± 0.03 A).

Using zero harmonic components values may not be sufficient to make difference between one open-diode fault of an upper diode of one leg and simultaneous two open-diodes fault of lower diodes of other legs. In both cases, one phase current zero harmonic component is of a sign that is different from the other two phases currents zero harmonic components (Figure 3) and (Figure 4). As remarked on (Figure 3) and (Figure 4), the phase 1 current has a positive DC offset while phase 2 and phase 3 currents DC offsets are negative in both cases of D1 open

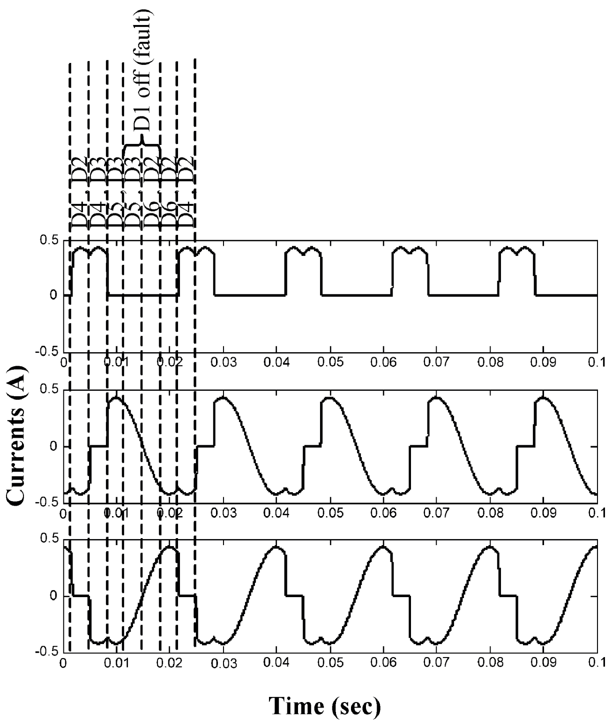

Figure 3. Phases currents waveforms (is1, is2, is3) in open fault operating condition of D1.

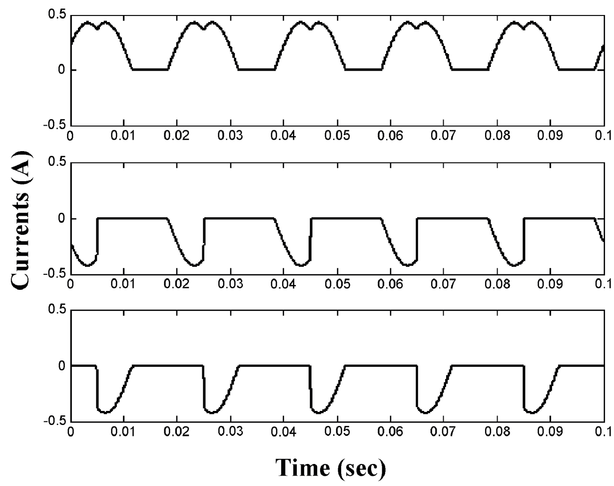

Figure 4. Phases currents waveforms (is1, is2, is3) in simultaneous open fault operating condition of D5 and D6.

switch fault and simultaneous D5 and D6 open switches fault (Figure 3), (Figure 4) and (Figure 9).

Therefore, another parameter is introduced to make the difference between one open-diode fault of an upper diode of one leg and simultaneous open-diode fault of lower diodes of other legs. This parameter is the maximum values of currents.

In case of D1 open switch fault, maximum values of phases 2 and 3 currents (is2 and is3) are positive (Figure 3). But, in case of simultaneous D5 and D6 open switches fault, maximum values of phases 2 and 3 currents (is2 and is3) are nil (Figure 4).

In general, in case of one open-diode fault of a diode linked to the negative pole of DC load of one leg, maximum values of the other phases, linked to safe legs, currents are positive (Figure 3). But, in case of simultaneous two open-diode fault of the diodes linked to the positive pole of DC load of the other two legs, maximum values of the other phases, linked to these legs, currents are nil (Figure 4).

In case of one open-diode fault of a diode linked to the positive pole of DC load of one leg minimum values of the other phases, linked to safe legs, currents are negative (Figure 5).

In case of simultaneous two open-diode fault of the diodes linked to the negative pole of DC load of two legs, minimum values of phases, linked to these legs, currents are nil (Figure 6).

Currents zero harmonic components are calculated by using the discrete variable-frequency FFT calculation block in Simulink/Matlab with sample time of 0.0001s and input signal (phase current) frequency of 50 Hz.

4. Experimental Results

The experimental system consists of the following components:

(1) DC resistive load of 270 Ω;
(2) Main power supply balanced sinusoidal voltages with rms values of 47V and frequency of 50 Hz;
(3) Three current sensors;
(4) Acquisition system of sampling time of 0.00005 seconds and display interface in Labview (detection algorithm was implemented in Labview program).

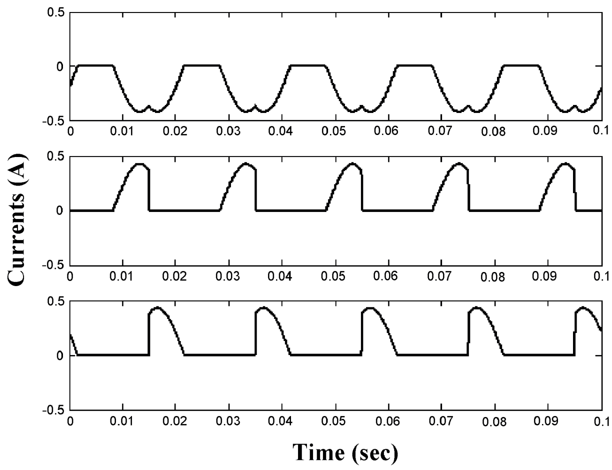

Figure 6. Phases currents waveforms (is1, is2, is3) in simultaneous open fault operating condition of D2 and D3.

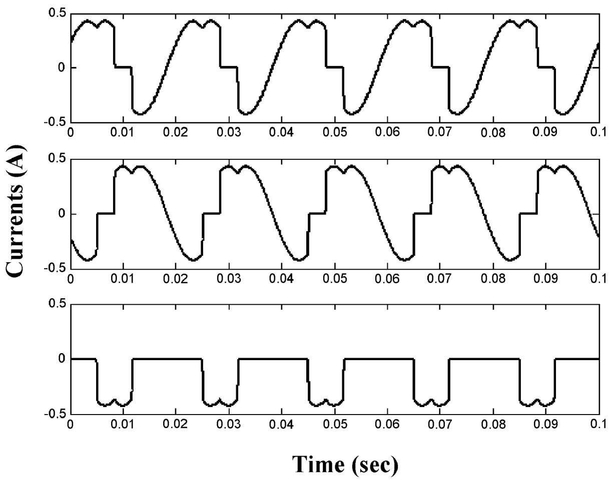

Figure 5. Phases currents waveforms (is1, is2, is3) in open fault operating condition of D6.

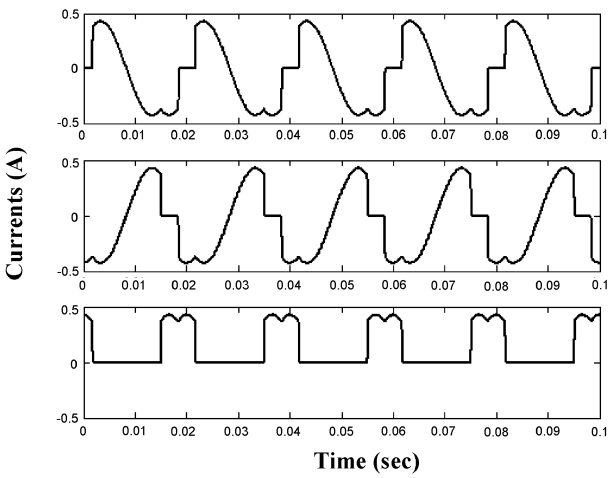

Figure 7. Phases currents waveforms (is1, is2, is3) in open fault operating condition of D3.

Different cases of open diode fault condition are classified in Table 1.

The important remarks from this table to be noted are:

In case of one leg one open-diode fault of a diode linked to the negative pole of DC load, current mean value of phase linked to that leg will be positive and currents mean values of the other phases, linked to safe legs, will be negative as shown in (Figure 3), (Figure 7), (Figure 10) and (Figure 12).

In case of one leg one open-diode fault of a diode linked to the positive pole of DC load, current mean value of phase linked to that leg will be negative and currents mean values of the other phases, linked to safe legs, will be positive as shown in (Figure 5) and (Figure 11).

If the simultaneous faulty diodes are linked to the negative pole of DC load, currents mean values of phases

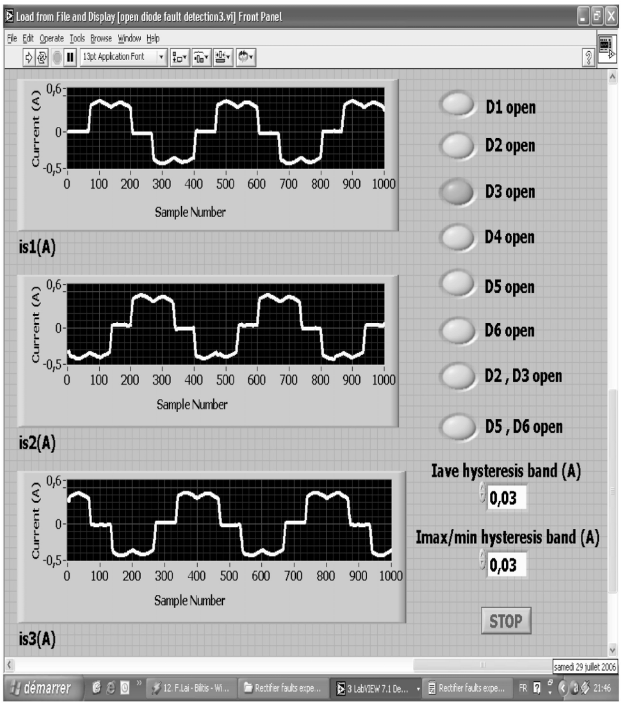

Figure 8. Diagnostic system outputs in safe operating condition via Labview interface.

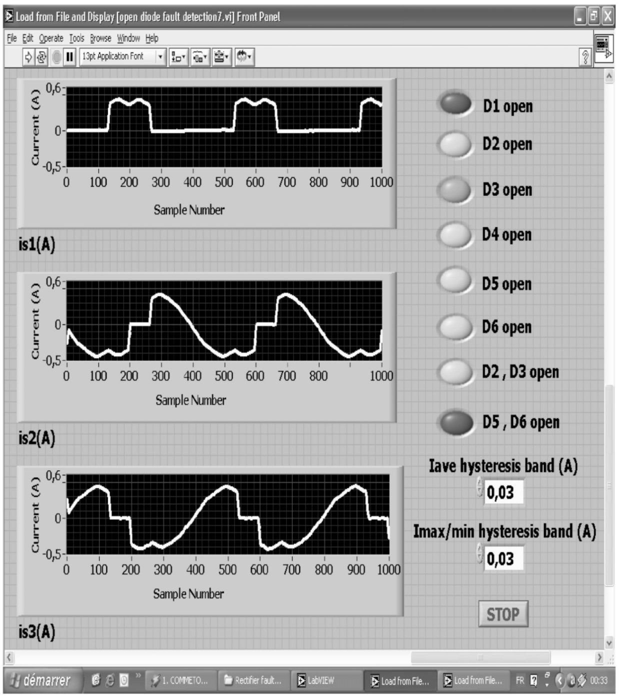

Figure 9. Diagnostic system outputs in open diode D1 fault operating condition via Labview interface (algorithm based on phases currents DC offsets, faulty detection).

Table 1. Phases currents mean values and their Max, Min values polarities corresponding to faulty open circuit diode

Faulty Device	is123 zero harmonic component polarity			is123 Min Values polarity			is123 Max Values polarity		
	Phase1	Phase2	Phase3	Phase1	Phase2	Phase3	Phase1	Phase2	Phase3
D1	positive	negative	negative	nil	negative	negative	positive	positive	positive
D2	negative	positive	negative	negative	nil	negative	positive	positive	positive
D3	negative	negative	positive	negative	negative	nil	positive	positive	positive
D4	negative	positive	positive	negative	negative	negative	nil	positive	positive
D5	positive	negative	positive	negative	negative	negative	positive	nil	positive
D6	positive	positive	negative	negative	negative	negative	positive	positive	nil
D 5,6	positive	negative	negative	nil	negative	negative	positive	nil	nil
D 4,6	negative	positive	negative	negative	nil	negative	nil	positive	nil
D 4,5	negative	negative	positive	negative	negative	nil	nil	nil	positive
D 2,3	negative	positive	positive	negative	nil	nil	nil	positive	positive
D 1,3	positive	negative	positive	nil	negative	nil	positive	nil	positive
D 1,2	positive	positive	negative	nil	nil	negative	positive	positive	nil

linked to legs of faulty diodes will be positive and current mean value of the other phase, linked to safe leg, will be

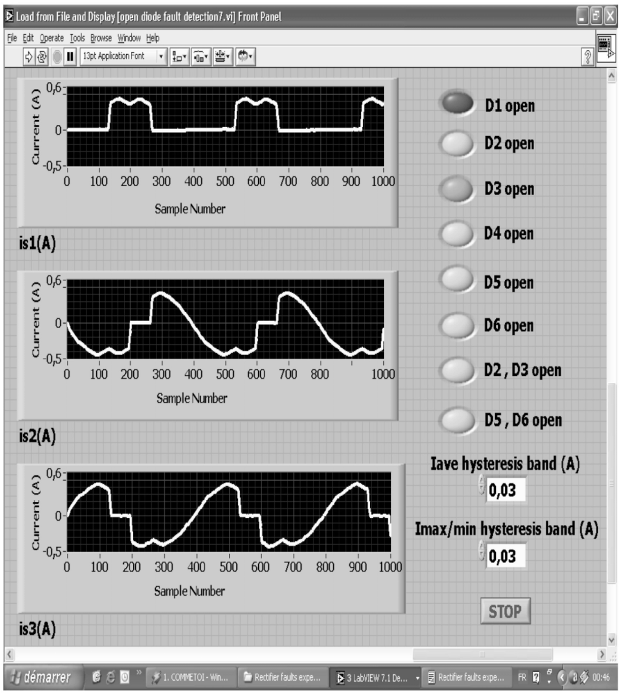

Figure 10. Diagnostic system outputs in open diode D1 fault operating condition via Labview interface (algorithm based on phases currents DC offsets and their maximum and minimum values, correct detection).

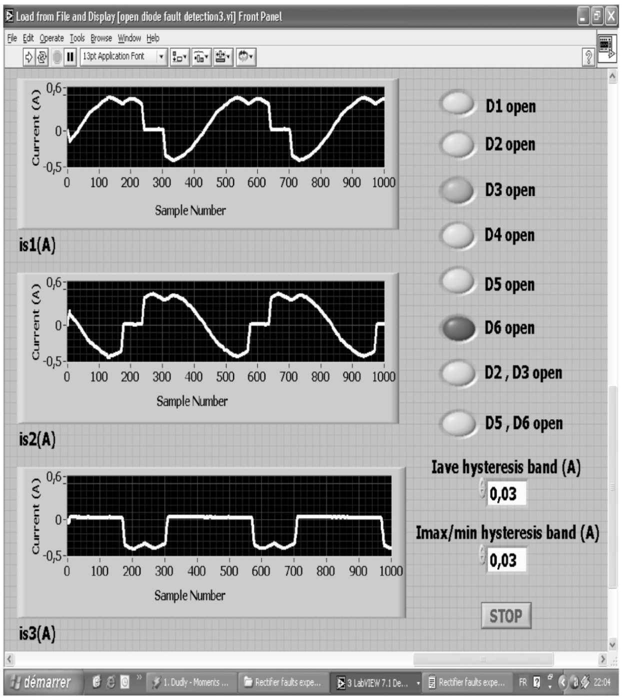

Figure 11. Diagnostic system outputs in open diode D6 fault operating condition via Labview interface.

negative as shown in (Figure 6) and (Figure 14).

If the simultaneous faulty diodes are linked to the positive pole of DC load, currents mean values of phases

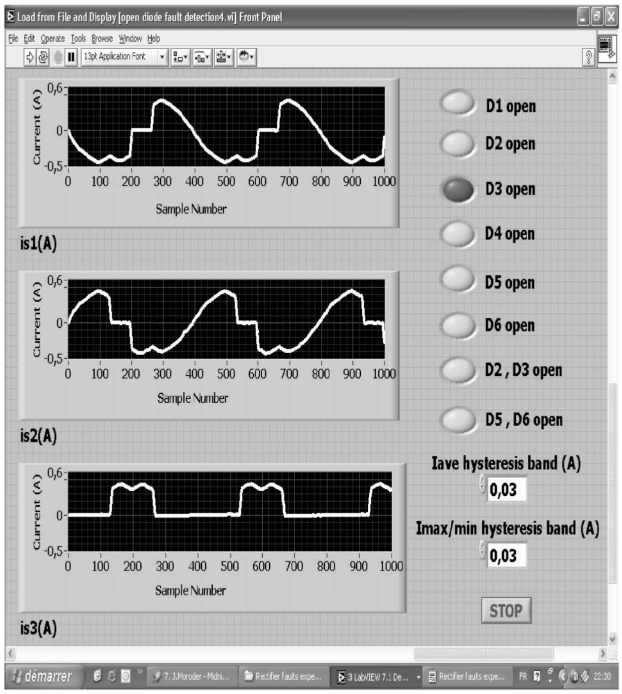

Figure 12. Diagnostic system outputs in open diode D3 fault operating condition via Labview interface.

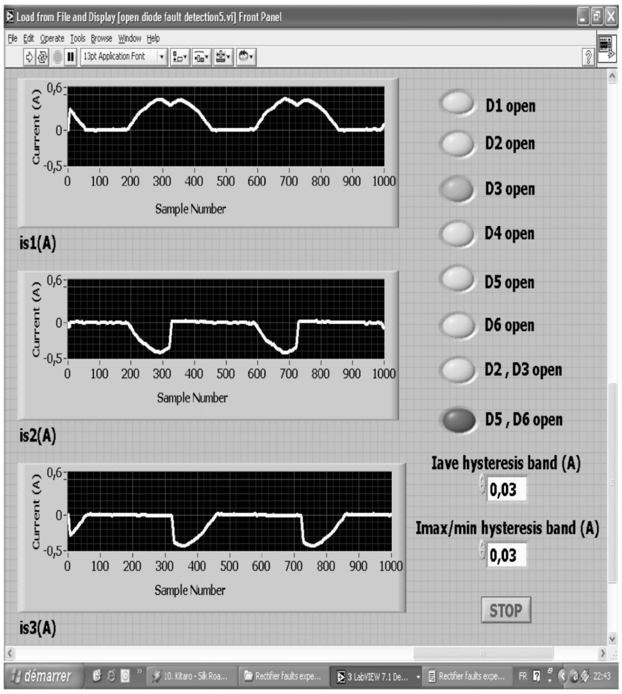

Figure 13. Diagnostic system outputs in simultaneous open diodes D5 and D6 fault operating condition via Labview interface.

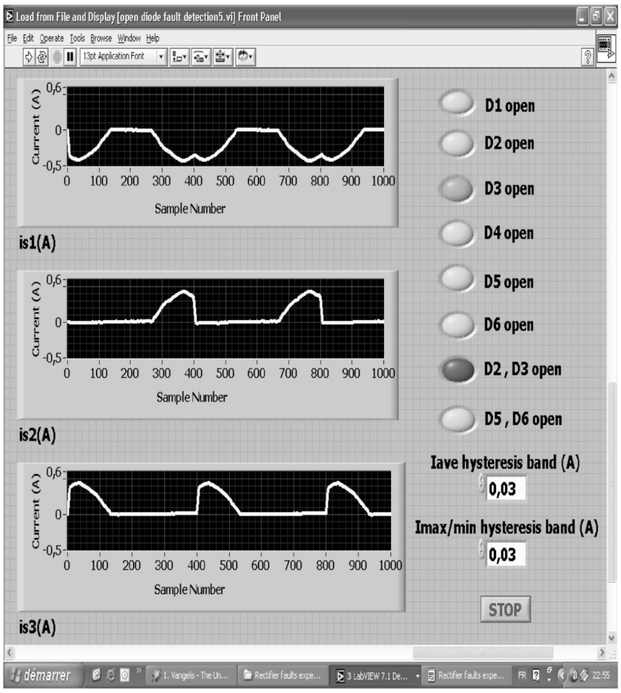

Figure 14. Diagnostic system outputs in simultaneous open diodes D2 and D3 fault operating condition via Labview interface.

linked to legs of faulty diodes will be negative and current mean value of the other phase, linked to safe leg, will be positive as shown in (Figure 4) and (Figure 13).

In both cases, the first cases of one leg one open-diode fault of a diode linked to the negative pole of DC load and the second case of simultaneous other legs faulty diodes are linked to the positive pole of DC load, currents DC offsets present similar characteristics (Figure 3) and (Figure 4), (Figure 10) and (Figure 13). To make difference between these two cases, maximum values of currents of phases are used. If the simultaneous faulty diodes are linked to the positive pole of DC load, maximum values of currents of phases linked to legs of faulty diodes will be nil (Figure 4) and (Figure 13). But in case of one leg one open-diode fault of a diode linked to the negative pole of DC load, maximum values of currents of phases linked to legs of safe diodes will be positive (Figure 3) and (Figure 10).

In both cases, the first cases of one leg one open-diode fault of a diode linked to the positive pole of DC load and the second case of simultaneous other legs faulty diodes are linked to the negative pole of DC load, currents DC offsets present similar characteristics. To make difference between these two cases, minimum values of currents of phases are used.

Simulation and Experimental results show that when the base drive open diode fault or simultaneous two open diode fault are introduced and phases currents are examined as a function of failure mode, there will be six different phases currents corresponding to the individual diode and simultaneous two diodes base drive open-circuit fault. In all six cases, this fault introduces a non-nil zero harmonic component values in three phase currents with polarity specified to each fault condition. Some cases have similar non-nil zero harmonic component polarity. Based always on phases currents, other indices are used to specify each case from the others. These indices are phases currents maximum and minimum values. This technique allows not only individual diode open fault detection but even simultaneous diodes open fault as well.

5. Conclusion

This paper presents systematically the novel simple approach to detect the rectifier faults of one and simultaneous two open switches fault condition. The zero harmonic component values of phases currents as well as their Max/Min values have been used to identify the rectifier faults. Implementation of this technique requires only three currents sensors, signal acquisition system and calculation processor.

The results are extremely important for the monitoring and fault detection of the rectifier in drives system. The work can be extended to other converter configurations or drives.

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Biography

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Manuscript Received: Jul. 8, 2007
Accepted: Jan. 25, 2008