DEVELOPMENT OF A LOW COST DIAGNOSIS AND ALERTS SYSTEM FOR FAULTS IN ELECTRONIC UPS SYSTEMS USING GSM LINK

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***Abstract* – The industrial processes expansion become very complex the electronic systems. The costs of not planned stops are so high that a project for fault detection and fault isolation has been very important. The advances in the Information Technologies allow that one people through a mobile phone has instantaneous access to an information in practically any place of the world. This work proposes the development of a system that reduces the time where an UPS system it is remained in the period after-faults until the maintenance. In this period, depending on the fault, part of the components still is in full operation, however, if to keep them thus for a long time will be compromise all system. The developed device analyzes the behavior of the equipment and detects some types of faults. After that it transmits through one GSM link the detected fault.**

***Keywords* – Fault detection, Fault diagnosis, GSM link, Supervisory System.**

I. INTRODUCTION

Power electronic devices are more, and more, presents in the industry, commerce, hospitals, and others, although, some times, imperceptibles for the population in general. However, the reached advances in the last decades are notables, in drives and motion control, in the energy conversion, amongst others. Even with the new technologies, control laws, redundancy, had not hindered that these devices presents some kind of fault. Thus, the identification and fault localization become important for the decisions, preventive or correctively.

In the last years many researchers had searched improvement in the identification, insulation and faults compensation, in the power electronics area.

Firstly [1] proposes the use of rules based on intelligent systems to fault diagnosis in voltage-fed inverters. Through a database a mechanism makes the supposition of the system conditions, beyond the status of the protection circuit.

In [2] the authors had made a methodical investigation of faults modes of voltage-fed Inverter system for induction motor drives. Through this study it is possible to determine components problems in the steady state and to contribute for the improvement of protection systems projects.

Another work using a data-base model was considered by [3]. This study is based on the current vectors trajectories analysis and instantaneous frequencies during the PWM (Pulse Width Modulation) inverters faults.

An investigation of different detection and fault identification techniques in the power switches in voltage-fed drive systems is proposed in [4]. A system where besides detecting and isolating the faults in voltage fed inverters it makes the compensation, reconfiguring the system through a tolerant fault strategy control is presented in [5].

The fault definition was established in [6], like "*a defect in a point or region in a circuit or component*". Considering this, is possible to propose for the work definition two fault categories. The first one where the fault leaves the equipment or device inoperative, and another one where the equipment continues operating, in inadequate form, supplying the loads.

No planned stops in production systems can results in high unnecessary costs, besides involving lives or important information. In hospitals or datacenters the use of UPS is essential, guaranteeing reliability to the system loads.

Independently of the considered reliability parameters, UPS faults for example, are adverse, being able to happen at any time. Actions of corrective maintenance they must be taken, for that the equipment does not continue in inadequate operating mode.

This work objectives the development of a device that reduces the time where an UPS system it is remained in the after-fault period until the maintenance. In this period, depending on the fault, part of the components still is in full operation, however, if to keep them thus for a long time will be compromise all system.

Two different types of faults in UPS systems had been studied, the rectifier and the inverter faults. The inverter faults in general produce damages so significant, resulting in inevitable stopped of the equipment. The rectifier faults produce less significant damages. Is possible in some cases maintaining the UPS operation (in inadequate mode) but, without interruption. This paper analysis the diagnosis faults without the UPS operation interruption.

The procedure used to fault diagnosis is the acquisition of the voltages, and to process that in the microcontroller, identifying or not the fault. In fault occurrence, it transmits the detected fault and equipment number by GSM link.

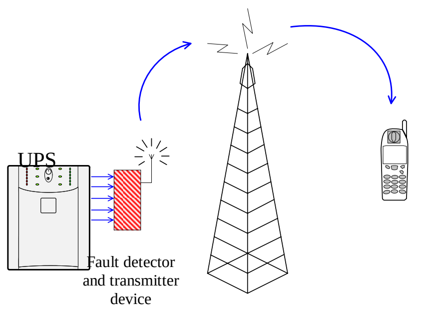


Fig. 1 Basic diagram operation of the proposed device.

II. MAIN FAULTS IN POWER DEVICES

The power devices function has being intensifying with the development of the applied technologies. The expansion of industrial processes has taken the systems very complex. The costs of not planned stops are so high, that projects for detection and fault isolation becomes economically viable [3]. The protection of the drive systems is normally projected to prevent damages of the converter switches [5]. The Fig. 2 shows a typical voltage-fed inverter block diagram of protection project.

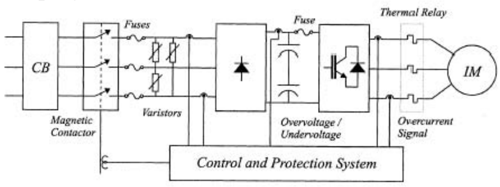


Fig. 2. A block diagram of a typical voltage fed inverter protection project.

The project includes surge and sags prevention circuits for DC Link, as well as, inverter over-current. The fuses protect the inputs against over-currents and a thermal unit protects the machine to overheat. The circuit breaker (CB) interrupts the input current in the case of system overload [5].

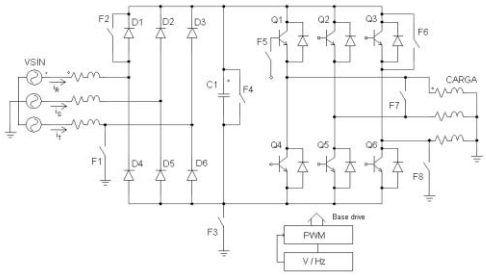


Fig. 3 Fault modes in a voltage-fed inverter.

In Fig. 3 the fault modes in a voltage-fed inverter are presented. Only some type of faults can be considered as relevant to this study, being able to be excluded the fault referring to the load and DC link, which had the form that the system protection project was be realized [2]. Therefore remain 4 type of faults, assigned as: (F1) Short-circuit (SC) between an input phase and the ground; (F2) SC in a rectifier diode; (F5) switch open base; and, (F6) SC in the switch inverter.

These four fault modes can be subdivided in two: rectifier faults (F1 and F2) and inverter faults (F5 and F6). Other faults had been added to the system project (protection system faults).

A. Rectifier Faults

The two fault rectifier modes have a characteristic in common, in the two situations the current addition in one or more phase's results in the damage of one or more input fuses.

1) Short-circuit between an input phase and the ground (F1)

The simulated circuit for this fault is presented in Fig. 4 and the input currents in the Fig. 5. Due to the "R" phase current increase the diode it is break, making with that the system works in two phases. The DC link capacitor is projected to permits a typically ripple lesser than 5%, this value will increase (Fig. 6). In operation mode, each diode loads 50% more current average that working in 3 phases (Fig. 7).

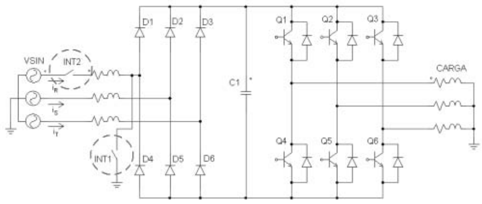


Fig. 4 Simulated circuit for (F1).

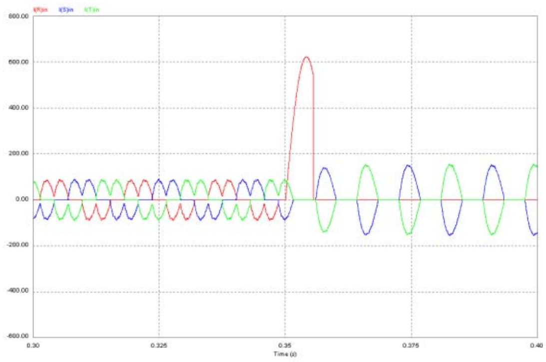


Fig. 5. Simulated input currents.

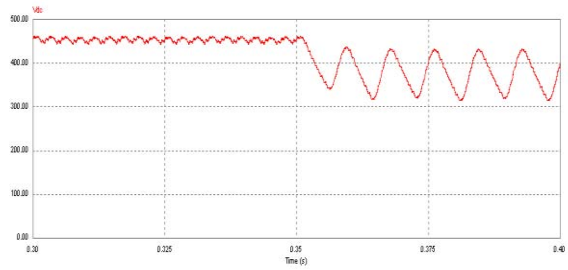


Fig. 6. Simulated DC link ripple increase.

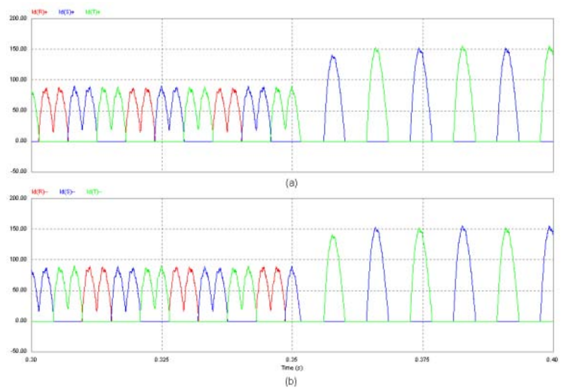
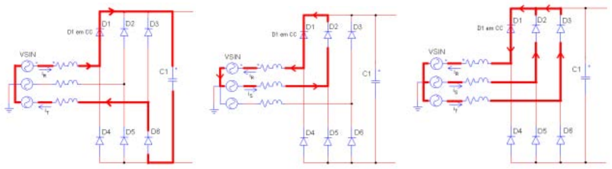


Fig. 7. 50% Average Current Diodes Increase (a) D1, D2 e D3 (b) D4, D5 e D6.

2) Short circuit (SC) in a rectifier diode (F2)

In Fig. 8 (a) is presented the normal conduction for a definite period, however, already with the D1 diode in SC. In the Fig 8 (b) the D2 diode enters in conduction due the input voltage to be larger that positive DC link. Thus, a SC current circulates between “R” and “S” phases. Finally, in the Fig. 8 (c) when D3 enters in conduction a symmetrical SC occurs enter the 3 phases of the power supply.



(a) {b] (c)

Fig. 8. Fault modes for rectifier diode in SC.

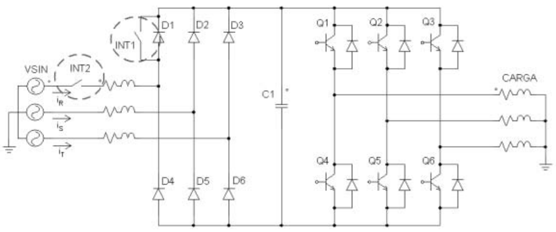


Fig. 9. Simulated circuit for (F2).

The simulations in the PSIM™ had been carried out through for F2 (see Fig. 9). Two inputs currents increase, of this form, for the simulation first the interrupter (INT1) is closed, characterizing the SC, and soon after the interrupter (INT2) is open characterizing the fuse’s rupture (see Fig. 10).

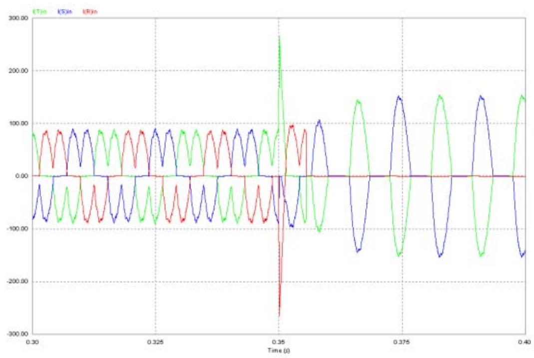


Fig. 10. Input currents.

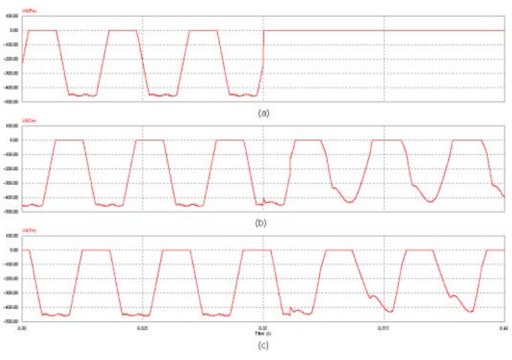


Fig. 11 Reverse diode voltage in the rectifier bridge (a) D1, (b) D2, (c) D3.

The other obtained results in the simulation for (F2) referring the voltage ripple and the current in the diodes increase are equivalents to the found for (F2). In the Fig 11 the reverse voltage of the diodes are observed. As the reverse voltage of the (a) after remained 350ms in 0V, characterizing the fault.

B. Inverter faults

1) Switch base open (F5)

The inverter switches are normally controlled for isolated amplifiers. Had the Q1 switch to be inoperative, the output “R” phase is connected directly to the positive side DC link through the freewheel diode of the proper switch. Since the phase voltages are balanced with sinusoidal PWM before and after fault, the current phase also will be balanced sinusoidal with an offset (see fig. 12).

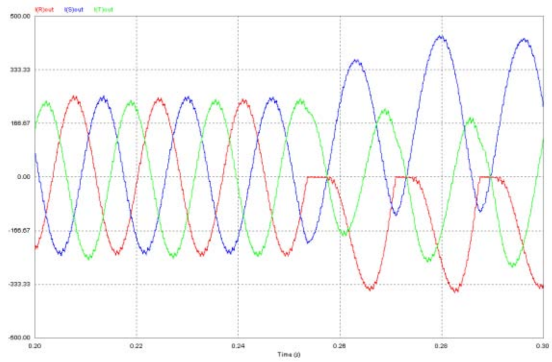


Fig. 12 Inverter output currents in (F5).

2) Short circuit in inverter switch (F6)

This fault imposes extreme problems in inverter switching components, and requires of the protection circuit immediate attention. In this fault the output voltages is fixed in DC link, resulting then, a DC voltage in the load.

C. Protection system faults

Amongst the cited faults, others can be relevant and to leave the UPS inoperative. They are related to the supply of electric energy, including the fuses and contactor.

III. GSM

A historical briefing of GSM system is mentioned by [10], relating that the development of a cellular mobile system for all the Europe, using digital technology, started in 1982.

The GSM is differentiated of its predecessors being that the voice canals are digital, what means that this is seen as a "second generation" system.

Observing the presented data in [11] is possible to perceive the increase of this technology. In June of 2002 the participation of the GSM in Brazil was of 0,12%, already in June of 2006 it was of 58,55%. The table 1 shows the evolution of technology GSM, new generations and respective data-communication speeds.

TABLE I

GSM Evolution Technology

Spectrum	Actual: 900 e 1800 MHz (Europe) 1900 MHz (EUA)			New: 1900/2100 MHz	
Generation	2 G	2,5 G	2,5 / 3 G	3 G	
Technology	GSM	GPRS	EDGE	WCDMA (UMTS)	HSDPA (WCDMA)
Data Rate máx. (Kbit/s)	14,4	171,2	473,6	2.000	14.000
Data Rate mean (Kbit/s)	-	30 - 40	100 - 130	220 - 320	550 – 1.100

Fonte: Teleco[5].

A. M2M – Machine to Machine

The term M2M is new, translates the new tendency, where the machines "talk" with other machines through wireless networks. The Sony Ericsson™, defines M2M as an "*electronically controlled machine with transmits information quickly, with more precision and a low effective cost*".

B. The GSM system

The data communication system in the GSM network is divided in three types:

a) CSD: is a point-to-point simple connection.

b) GPRS: is a data package network connection. Once connected the system is always "online" being able to data transfer immediately, the costs is only made on the data transmitted without considering the connection time. As the GPRS is compatible with protocol TCP/IP, the GSM operator's allocate one gateway for the internet.

c) SMS: is the sending and receiving small text messages service (150 to 1609 characters).

The last has been chose because the payment is realized through the messaging sending.

C. Communication Devices

The GSM modems or GSM modules are very similar equipment to the cellular devices. These devices have a friend and easily graphical user interface. The modules have only one serial communication. All the commercial modules are compatible with serial communication and AT commands. As well as, in the mobiles phones for the functioning a SIMcard is required.

The Fig. 13 presents a module for embedded applications by SIEMENS™.

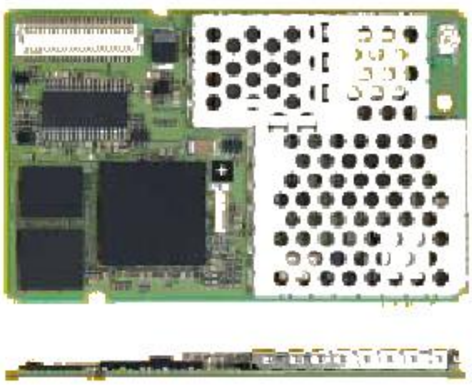


Fig.13: Siemens Mobile MC35 Embedded Module

D. AT commands

AT is an acronym proceeding from the English language, *attention*, which also can be translated as "ringing code". This code is used by great part of the commercial modems.

For example:

ATD12345 → dials for the number 12345;

AT+CSMS → selects message service;

AT+CMGS → send a message.

IV. FAULT IDENTIFICATION

A. Acquisition points

Five different points had been chosen in the UPS rectifier to make voltage signals acquisition (see Fig. 14).

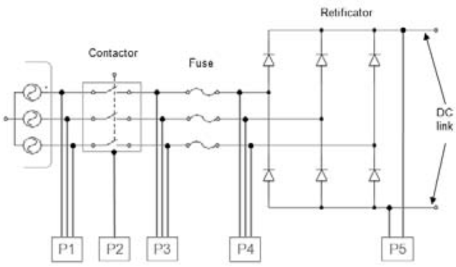


Fig. 14 Acquisition points for voltage signals.

B. Fault identification in the contactor

The contactor can have one of its terminals with defect, or still a mechanical obstruction, hindering the closing those contacts. Through P2 it can be verified if the coil is being energized. Still, through the comparison of P1 and P3 it is possible to detect some defect in the contacts of the contactor.

C. Fault identification in the fuse

The fuse faults normally occurs of SC in one of the phases, or SC in the diode, when the nominal current is substantially increased, being the sufficient to leading the rupture of one or more fuses. The comparison points for the detection of the imperfections are P3 and P4.

D. Faults identification in the rectifier diodes

1) Short circuit diode

Through the reverse diodes voltage is possible to detect when a fault occurs.

2) Open diode

When the diode is opened beyond the reverse voltage applied, appears a positive voltage due the polarization of the other circuit diodes (see Fig. 15).

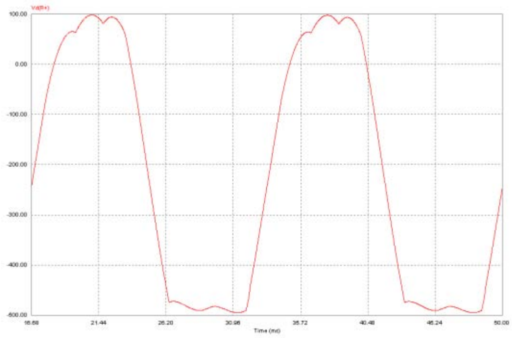


Fig. 15 Voltage in an open diode.

V. PROJECT

A. The proposed system

In the Fig. 18 is presented the block diagram of the proposed system.

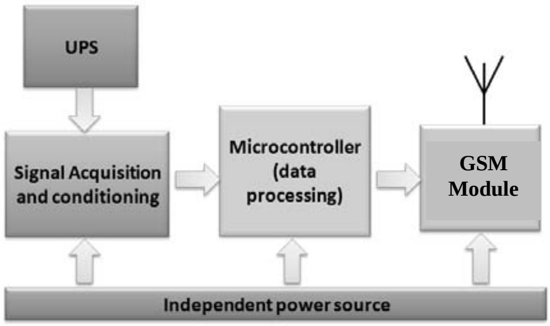
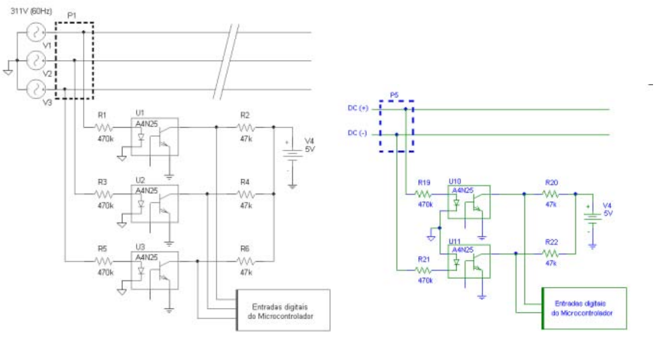


Fig. 16 Block diagram of the proposed system.

B. Signal Acquisition and conditioning circuits

The signal conditioning circuit is basically composed with optic couplers, separating the circuit proposed of the power electronic circuits. A peak detector is connected in the P2 point.



(a) (b)

Fig. 17: Acquisition signals circuits. (a) P1 P3 and P4 (b) P5

C. Experimental Results

Some tests had been carried out using a digital oscilloscope allowing the output signals visualization. With these results is possible to get the parameters that are used in program algorithm. A practical example can be observed in Fig. 17, where “R” phase is approximately 10.4ms in high logical level and 6.25ms in low logical level.

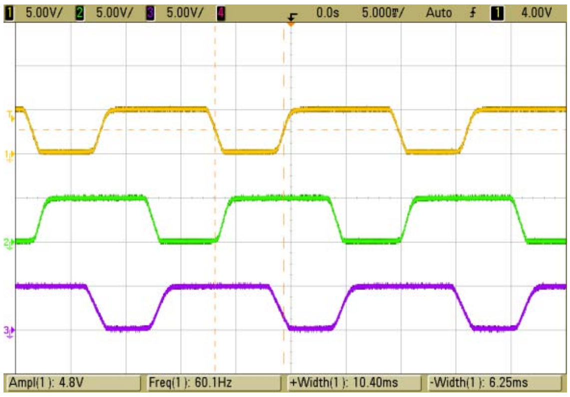


Fig. 17 Input voltages for P1 acquisition point normal mode.

In Fig. 18 shows the result of the interruption (emulated) of the "R" phase fuse, is possible to determine that the signal of channel 1 ("R" phase) practically keeps a fixed value.

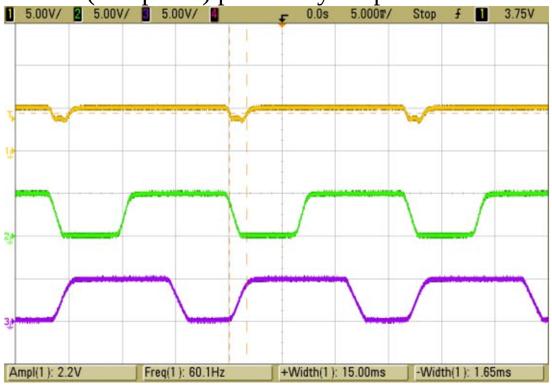


Fig. 18 Input voltage for P1 fuse in the R phase damage.

Still it is possible to verify in Fig 19 ripple caused in DC Link due to interruption of the same fuse (in phase "R").

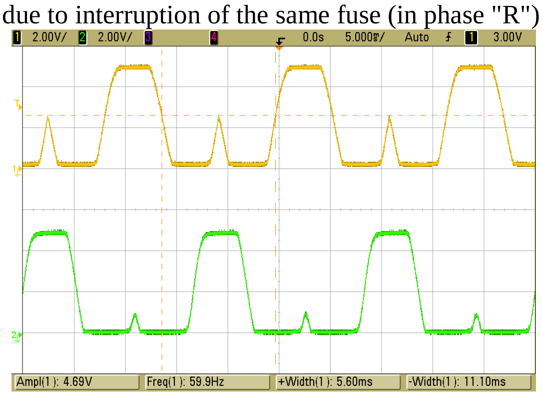


Fig. 19 Ripple in P5 (DC link) caused by a fuse damage.

The interruption of the D1 diode also was emulated in the circuit, being shown the waveforms Fig 20, where channel 1 represents phase "R", channel 2 the positive DC Link and the channel 3 negative DC link. The Ripple present in the unbalanced positive DC link 180º of phase "R" can be observed and in the negative DC link he remains unchanged.

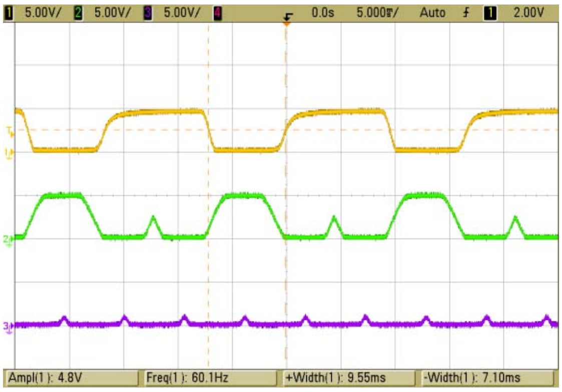


Fig. 20 Scope for P4 and P5 when the interruption of D1 diode.

A microcontroller PIC 18F452® realizes the processing, verifying when has system imperfections. In Fig. 21 is showed the processing circuit prototype.

After the data processing for the circuit and the faults detects the same, is directed to a serial port. Further than GSM module it is possible also to read these data through a PC microcomputer. If this computer will be connected to the internet it can directly send the data by a SMS service eliminating the necessity of a GSM module and reducing still more the application cost.

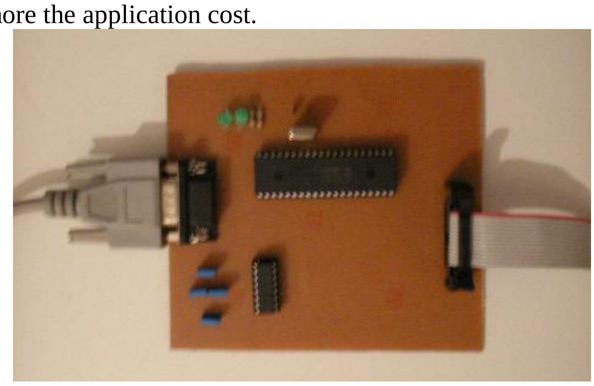


Fig. 21 First prototype of data processing circuit connected in a GSM module.

The system has been connected in a three phase rectifier and a F2 fault is emulated (D1 diode in short-circuit). The proposed system detects a fault and sends a SMS message. This message has shows in Fig. 22(a) and 22(b).

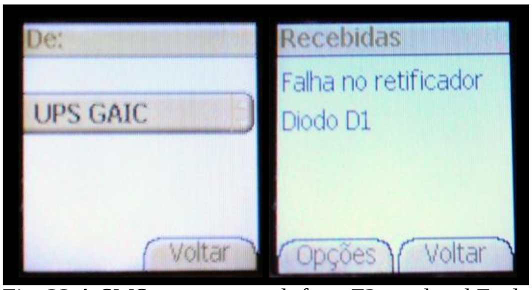


Fig. 22 A SMS message result for a F2 emulated Fault.

VI. CONCLUSION

The diverse referring studies to the identification, insulation and faults compensation in the power electronic devices, directly reflect the concern with the systems reliability. In some cases when fault in the UPS systems occur, your functioning continues of inadequate form. The redundant UPS systems is an option, however, possess a relatively high cost to solve this type of problem, since it uses two identical equipments. Another option, that is the main objective of this work, is decreasing the time where the UPS operates in an inadequate form, transmitting the defect for the maintenance in the instant after fault. Thus, it also reduces the damages risk of internal machine components. Therefore the time that will function with defect will be reduced. Is possible to carried out, the imperfections diagnosis, in an UPS using low cost components. The mobility system guarantee is provided by GSM module. The SMS message in all realized tests shows has a good alternative for simplified supervisory systems.

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