TECHNIQUES APPLIED IN ELECTRICAL POWER DISTRIBUTION FOR SOUNDING ROCKETS

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Abstract. *Nowadays the Sounding Rockets, developed by the Space and Aeronautical Institut, can be divided into subsystems related to the functions performed by themselves. One of those subsystems is called by On board Electrical Networks, which may be typically subdivided into Service Electrical Network, Telemetry Electrical Network and Safety Electrical Network. During the phase of tests, pre-launching and launching, these networks are associated of electrical and mechanical mode in the rocket structure. In order to have those integrated networks successfully in supporting the tasks foreseen for the mission, in normal condition and during fault condition, that is necessary to employ techniques to distribute the electrical power that are likely to on board application. Within that context this work presents a set of techniques applied to electrical power distribution for launching rockets. That set of techniques aims to keep the power supply dedicated to the circuits submitted to the condition of occurrence of the first fault to ground. Also those techniques are dedicated to limit the consequences of occurrence of the first fault to ground among electrical networks that change signals to each other. The proper results obtained during the simulation of those techniques on computational modeling developed to represent part of the sounding rocket electrical power, show that the proposal presented in this work is likely to the proposed purpose.*

Keywords: *Electrical system, Techniques for power distribution, On board electrical network, Sounding rockets.*

1. INTRODUCTION

Nowadays the Sounding Rockets, developed by the Space and Aeronautical Institute, can be divided into subsystems related to the functions performed by them. One of those subsystems is called by On board Electrical Networks, which may be typically subdivided into Service Electrical Network (SEN), Telemetry Electrical Network (TEN) and Safety Electrical Network (SAEN) (Palmério, 2002). The Figure 1 shows an example of Sounding Rocket called by VSB-30, which uses these networks.

There are mainly in the Service Electrical Network (SEN) equipments responsible for: i) storing and supplying electrical power, ii) distributing power into the rocket and iii) performing the sequence of events, safety and pyrotechnic events actuation during the rocket flight phase.

In the Telemetry Electrical Network (TEN) are specifically located equipments that performs: i) conditioning, ii) acquisition, iii) codification and iv) signal irradiated transmission to the on ground station.

Safety Electrical Network (SAEN) is compounded basically by equipments that perform functions of: i) reception, ii) decode, iii) command, iv) actuation of order to remote destruction, that one is specifically employed in the hypothesis of occurring anomaly during the flight that be able to compromising the foreseen trajectory, and v) transmission, which is dedicated to the function of rocket traceability through ground radar.

During the phases of tests, pre-launching and launching those three networks are associated to the electrical and mechanical mode in the structure of the mentioned rocket. On that condition they are named of Integrated Electrical Networks (IEN).

In order to have these three integrated networks successfully in supporting the tasks foreseen for the electrical system operation, in normal condition and during fault condition, that is necessary to employ, as a minimum, techniques to distribute the electrical power that are likely to on board application and able to complying simultaneously with the referenced conditions of operation.

Figure 1. Rocket VSB-30 launching at Alcantara's Launching Center

2. OBJECTIVE OF THE WORK

The objective this work is to establish the more relevant techniques that must be considered in the definition of architecture applied to the on board electrical power distribution system for sounding rockets.

These techniques will allow that the Integrated Electrical Networks (IEN) be able to:

i) To keep the electrical power supply for the circuits submitted to the condition of occurrence of the first fault to ground.

ii) To carry out the transference of electrical signals to each other, in a such way that the occurrence of a fault in a determined network does not be able to causing direct consequences in the operation of another network and vice-versa.

3. PROPOSED TECHNIQUES

In order to have an Integrated Electrical Networks (IEN) of a sounding rocket that be able to keep the power supply dedicated to the circuits submitted to the condition of occurrence of the first fault to ground and to perform transference of electrical signals to each other, in a such way that the occurrence of a fault in a determined network does not be able to causing direct consequences in the operation of another network, that are proposed the utilization of the following techniques:

i) To distribute electrical power, specifically, through of grounding scheme that be capable of keeping the electrical power supply under condition of occurrence of the first fault to ground.

ii) To install, strategically, galvanic isolators in the circuits that accomplish the transference of signals between electrical networks. These techniques are presented with more details in the items 3.1 and 3.2 following.

3.1. Electrical Power Distribution

The electrical power systems are classified based on: i) Live Conductors Scheme and ii) Grounding Scheme (ABNT, 2004). The Live Cables Scheme considers, specially, the nature of the used equipment that is supplied by the electrical system, in other words, if it is configured like three-phases, two-phases, single-phase etc. In the Grounding Scheme is given great importance, mainly, to the way of power supply neutral connection and the relation between the loads cases and the grounding reference. Depending on how those connections are performed, it can be obtained three types of conventional grounding schemes, which are named by TN, TT and IT.

Based on the characteristic of electrical conductibility and mechanical frame defined for the structural components of a sounding rocket, can be only considered the implementation of the IT and/or TN schemes.

Concerning to the mentioned grounding schemes, only the IT does not need to interrupt the electrical supply to the load, when its circuit is submitted to the first single-phase fault to ground (Hofheinz, 2000).

The IT grounding scheme does not have any point from the electrical power supply (L+ or L-) directly grounded, nonetheless, the exposed metallic parts, including parts of the loads (cases, structures and others) supported by that scheme, it must be connected in the grounding reference. The Figure 2 presents the electrical model of this grounding scheme.

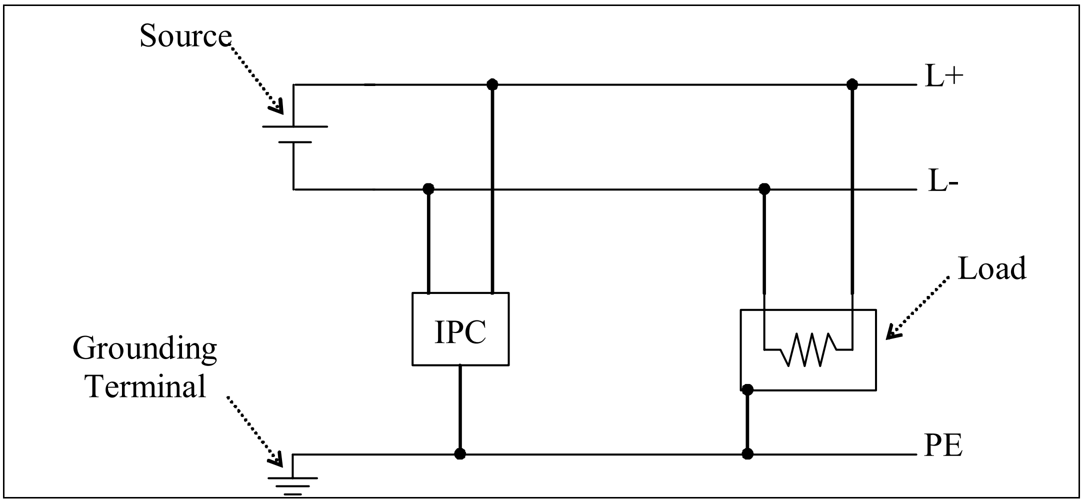

Figure 2. IT Grounding Scheme Diagram

On the Figure 2, the nomenclatures have the following meaning:

Source, electrical power source in direct current.
L+, positive line of voltage source in direct current.
L-, negative line of voltage source in direct current.
PE, protection cable.
IPC, Insulation Permanent Controller.
Grounding Terminal, defined by cable or a set of cables embedded under the ground and electrically connected to the earth.

The loads supplied by IT Grounding Scheme must not have any connection between any their power supplies lines and the respective cases, structures and others. The occurrence of just one single-phase fault to grounding, on IT Grounding Scheme, it will probably cause a low intensity flow of current, just because the value of the fault path resistance is high. The Figure 3 shows an example of the fault path resistance, in steady state, to the IT scheme.

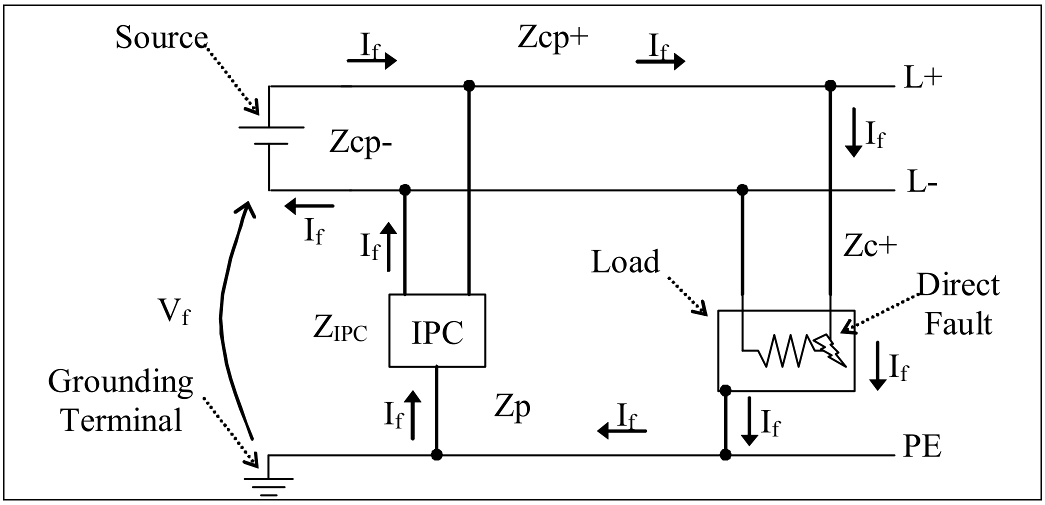

Figure 3. Path of the fault current in the IT

On the Figure 3, the nomenclatures have the following meaning:
- If, current caused by the direct fault.
- Vf, voltage caused by the direct fault.
- Zcp+, resistance in the main cable segment, positive line.
- Zc+, resistance in the load cable segment.
- Zp, resistance in the protection cable segment.
- Z_{ICP}, internal resistance in the Insulation Permanent Controller.
- Zcp-, resistance in the main cable segment, negative line.
- Direct Fault, fault with negligible contact resistance.

Typically the value obtained specifically with the sum of the involved cables impedances in the fault path is low. Nonetheless, the resistance defined by the IPC on that sum is high. That last characteristic allows that the IT Grounding scheme does not need to interrupt its power supply when occurs a fault to the ground.

Based on this capacity of non-interruption, the identification of one single-phase fault to ground on IT Grounding Scheme is performed by mean of Insulation Permanent Controller (IPC). That type of device identifies one fault by system insulation value analysis, however it does not inform the exactly point of origin of this fault. The fault identification can be performed by mean of equipment for faults searching.

The occurrence of second fault on IT Grounding Scheme, that involves another line power, is a situation that must be avoided or to have their effects mitigated through protection.

All electrical components of this IT Grounding Scheme must be designed considering the possibility of occurring overvoltages caused, mainly, by occurrences of faults or interferences in the electrical system.

The TN scheme has a point from its power source directly grounding, being the cases of the loads connected to that same point by mean of conductors (Cotrim, 1985). This TN scheme can be implemented in three different versions, it means, TN-C, TN-S e TN-C-S. The complementary letters define that, respectively: i) the neutral cable is also used for cases connection, ii) the functions of neutral and protection are guaranteed by separated cables and iii) the functions of neutral and protection are combined in the same cable at the beginning of the circuit and starting from a determined point the functions of neutral and protection are separated in two different cables.

Based on the necessity of establishing the electrical connection among all mechanical parts that compounds the structure of sounding rocket, by way dedicated to this goal, it was chosen the implementation of TN-S Grounding Scheme, where this scheme is necessary. The Figure 4 presents the electrical diagram of TN-S Grounding Scheme.

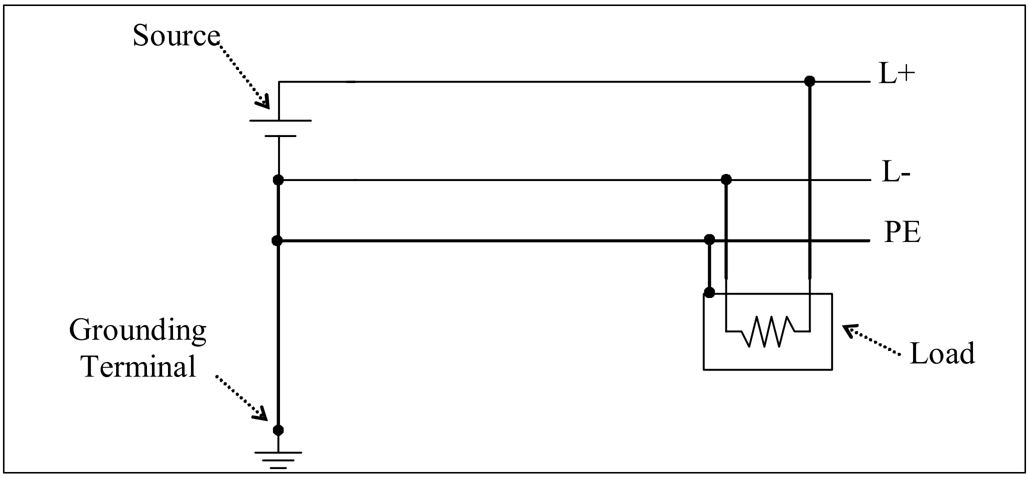

Figure 4. TN-S Grounding Scheme Diagram

On the Figure 4, the nomenclatures have the same meaning of those ones mentioned in the Figure 2.

The mode that single-phase faults to grounding are eliminated in the TN Grounding Scheme is through protection trip of the supplier circuit submitted to fault condition. The advantage of TN Grounding Scheme is the quick identification of the circuit under fault, which can be observed by the stop of operation due to protection trip. The great disadvantage is the removal of a circuit in operation that can compromise the process in which that circuit is included. The Figure 5 shows an example of fault current path, in steady state, for the TN-S scheme.

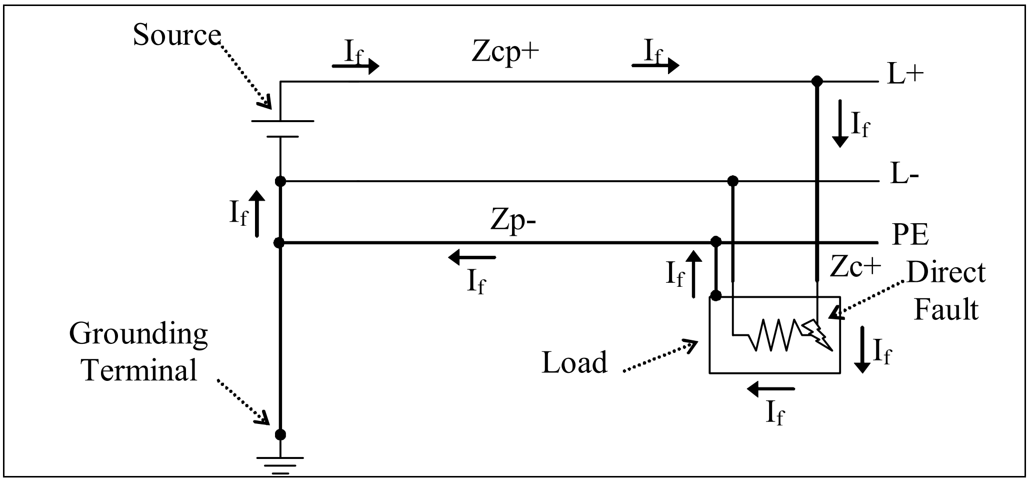

Figure 5. Fault current path in TN

On the Figure 5, the nomenclatures have the same meaning of those ones mentioned in the Figure 3.

Considering the statistics, the most frequent fault in electrical systems, independently of the grounding scheme adopted, is the single-phase to ground (Kindermann, 1992).

Among conventional grounding schemes, the IT scheme is the only one that does not need to interrupt the power supply circuit when is submitted to single-phase fault to ground. The characteristic of immunity is a great advantage of the IT scheme relatively to the TN scheme. The IT scheme disadvantage is in the way of identifying the circuit under fault. That identification is performed through the Insulation Permanent Controller (IPC) and with the measurements of differential current in the several circuits that compounds the electrical system. The Figure 6 presents an example for implementation of IT Grounding Scheme in electrical networks of unmanned rocket.

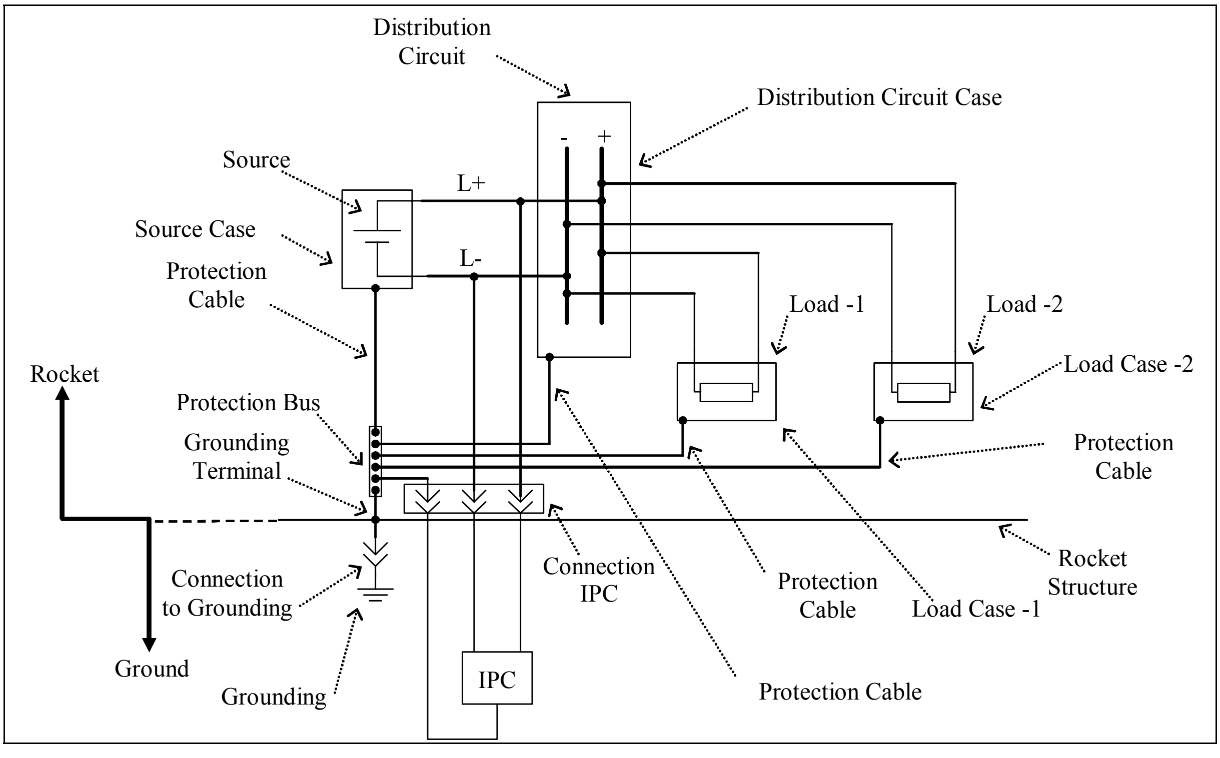

Figure 6. IT Scheme applied to on board network

The Figure 6 shows the installation of Insulation Permanent Controller (IPC) on ground, condition that prevents the acquisition of related information with the behavior of the on board electrical system insulation during the rocket flight phase. On this condition is necessary to carry out tests in the electrical network that will be installed in the rocket, with the presence of IPC, to simulate the flight condition and this way to identify the behavior of the insulation on that condition.

3.2. Galvanic Separation

The goal of galvanic separation is to establish galvanic isolation among electrical systems that operate in separated mode, however they are susceptible of being associated at the same net that can be exposed to a electrical potential difference able to damaging an equipment or to cause undesirable interferences for the system operation.

For on board space applications can be identified electrical networks configurations, that are implemented with different grounding schemes and that have the necessity of performing the transference of electrical signals to each other. The Figure 7 shows an example of circuit (Cts) that has no galvanic separation, nevertheless it has as function to perform the transference of signals between two electrical networks that adopt IT and TN Grounding Scheme respectively. On that figure the electrical network that adopts the IT scheme provides analogic signal that is proportional to the level of voltage reached by the F2 power supply to TR transmitter, trough Cts circuit. On normal operation condition, the absence of galvanic separation in the Cts circuit causes limited interference between the electrical networks. Prevailing on that situation the nominal currents that flow by the circuits (I_{n1}, I_{n2} e I_{ts}).

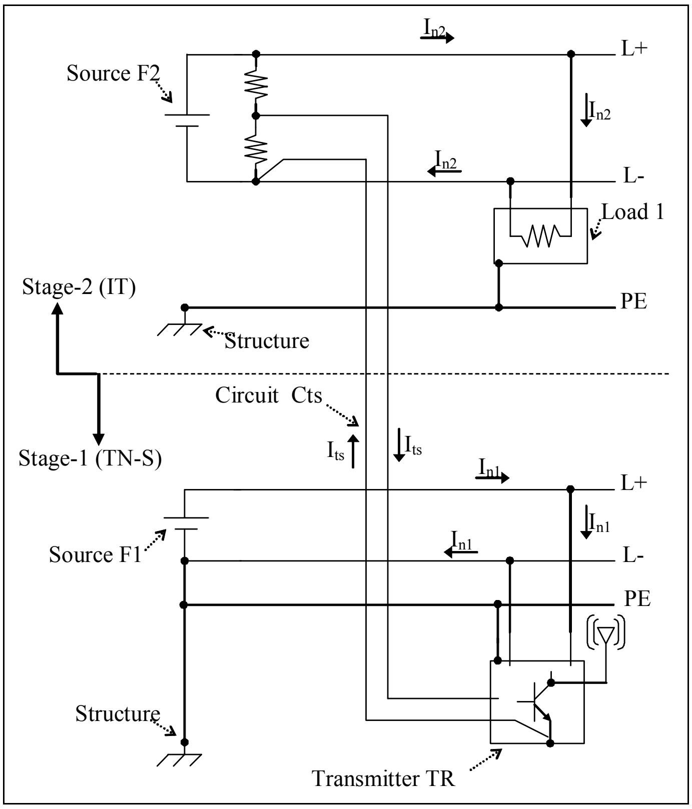

Figure 7. Signals transference without galvanic separation

Considering the hypothesis of occurring the single-phase fault to the case of the Load 1, which is supported by the electrical network that adopts the IT scheme, it will be established a condition to allow the short-circuit current flow (I_f) between the components of electrical networks as showed in Figure 8.

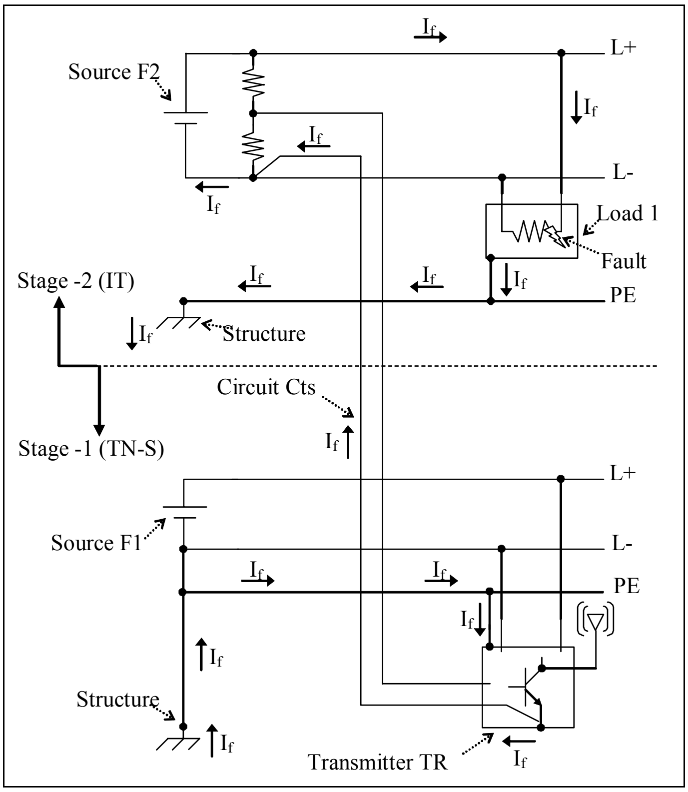

Figure 8. Fault path between the electrical networks

The Figure 8 shows a situation in which the occurrence of fault in an electrical network has enough capability of generating undesirable consequences in another one. In order to minimizing those consequences, the installation of a galvanic separator is proposed. The Figure 9 illustrates an example of a circuit that uses a galvanic separator to perform the transference of signals between the involved electrical networks.

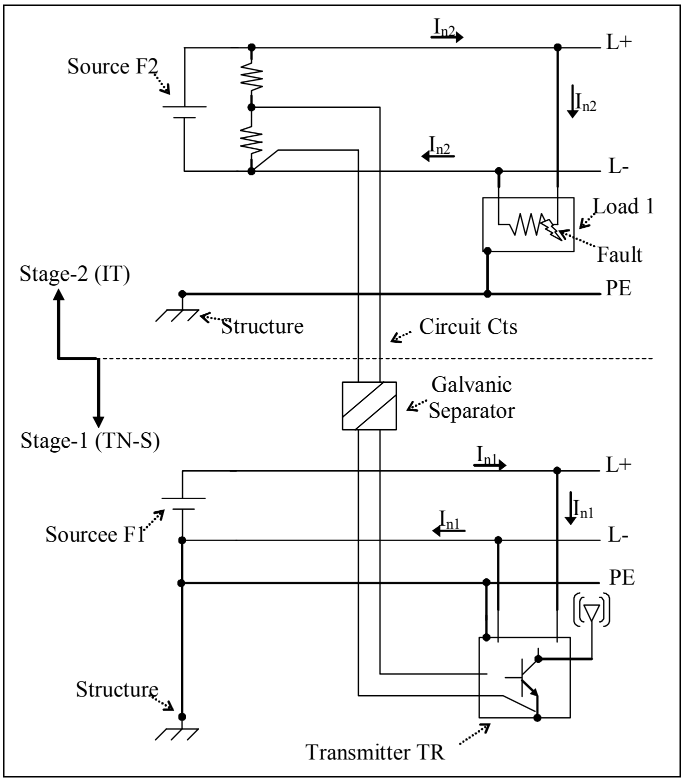

Figure 9. Transference of signals with galvanic separation

On the Figure 9 can be observed that the galvanic separator installation in the circuit of transference of signals (Cts) is able to limiting the consequences created by the occurrence of fault and this way to allow the operation of both electrical networks.

The Figure 10 presents four examples of means to create the galvanic isolation for circuits that perform the transference of signals among on board electrical networks (Mulville, 1998).

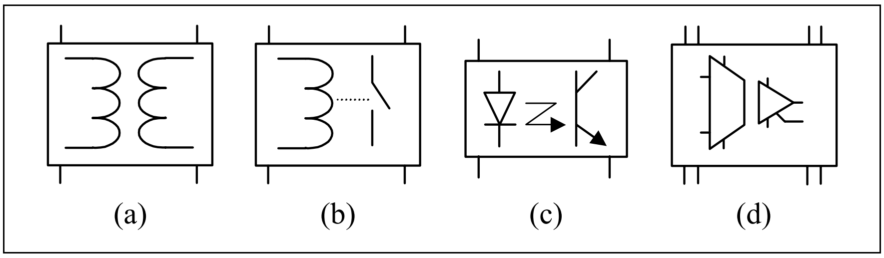

Figure 10. Galvanic Isolators

The transformer, presented in the Figure 10 (a), can be used to isolate the circuits that work with analogic signals of expressive variation during the time. Their dimensions and weight are characteristics to limit several spatial applications.

To isolate digital signals, it starting from alternated or direct current activation, can be employed the relay, Figure 10 (b). The relays have same limits compared to the transformer, however they are robust and of simple implementation in the electrical circuits.

The optical coupler, Figure 10 (c), also isolates digital signals, nonetheless with operation in direct current. In most of applications the weight and dimensions are proper, however the optical coupler has low robustness when compared to relay.

In situations where is necessary to isolate circuits that operate with analogic signals, with low variation during the elapsed time, it can be employed insulation amplifier as showed in Figure 10 (d). These amplifiers present significant dimensions and complexity to be implemented in signals transference circuits.

4. CONCLUSIONS

The utilization of the proposed techniques within this work to implement the Electrical Networks of Sounding Rockets mainly will cause the following positive impacts: i) it will allow that an essential electrical equipment for the rocket operation, that does not have redundancy, operate even with occurrence of single-phase fault to ground, and ii) the path of fault current will be restricted to the electrical network in which that fault was created, avoiding this way the involvement of another electrical systems..

5. REFERENCES

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