In Fig. 6, the results of the waveforms were superimposed, being possible to observe that the controlled converter drains a negative current to reduce in the input current the peak current required by the non-controlled rectifier.
Fig. 3. Illustration of the waveforms of the output voltages of the hybrid converter (Vout), boost converter (VB), AC input (Vin), the uncontrolled rectifier (VNC) and the halfbridge converter (VHB).

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# Single – Phase Hybrid Converter with Series Voltage Compensation on the DC Bar Applied to Micro grids

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## I - Introduction

The proposition of microgrids emerged in 2002 with the concept of unification of a local low voltage system to different loads, having as main element the sources of distributed generation[1].

Initially in an islanded form, the microgrids emulate the effects of synchronous machines, and through the parallelism of inverters, controlled the levels of active and reactive power in a current system alternating (AC). In AC microgrids, it is interesting to create a new converter topology that aggregates a single structure to the three essentials converters in AC microgrids, defined as grid-feeding, grid-forming and grid-supporting. [2], [3]..

Modern microgrids have an interface with the traditional grid, which may or may not have the bidirectional power flow, but having as main objective the control from the common DC bus. The control can be classified as decentralized, centralized or distributed, with the complexity of communication between elements respectively increasing among these [5]. In general terms, control should be hierarchical in order to guarantee the optimal operating point of each generation subsystem and have a coupling point common that controls the distribution locally and systematized. Since these characteristics are common to a controlled distribution network, differ microgrid, mainly in the control that must be defined in regions [1]

## II – Methodology

Several of the microgeneration sources use converters connected to the power grid to power the DC bus where generators and loads are present, introducing the concept of microgrids, isolated or integrated into the network, and with the aim of locally supplying the demand for loads with nearby sources[16]. In between the factors that can affect the maintenance of voltage in the DC bus of a microgrids can be highlighted the intermittence of renewable sources due to conditions natural resources, the connection and disconnection of loads of greater powers, the connection of excess power generators, and oscillations in the AC power grid in case of connection with it [5].

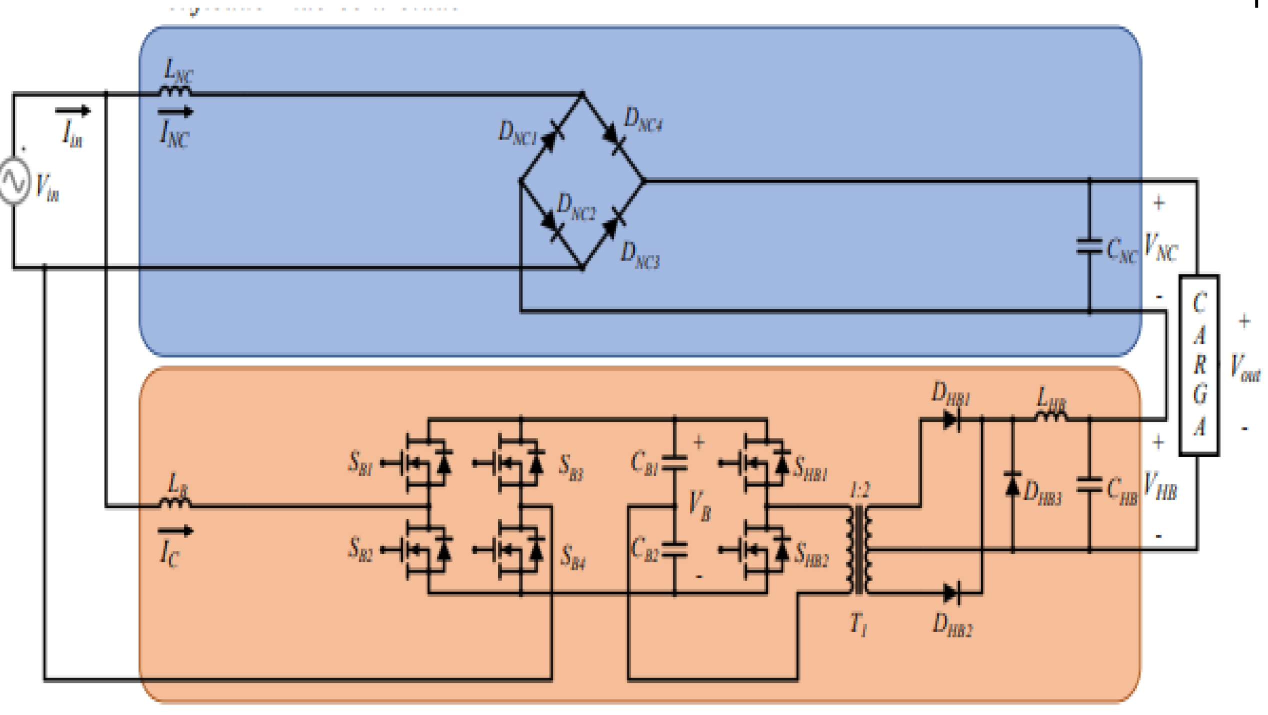

Fig. 1. Proposed structure of the hybrid converter, highlighting the blocks of uncontrolled (blue) and controlled (orange) rectifiers.

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For the sizing of photovoltaic panels, the demand value of each load was obtained through the active and reactive powers. The battery bank was sized considering two charging and unloading situations.Charge situations (Pin[t]) and discharge (Pout[t]) can be observed in Figure 2.

**3.** Operation Principle

The following subsections detail the principle of operation of the proposed single-phase hybrid rectifier.

A. Principles of operation of the imposition of current at the entrance

The parallel connection of the rectifiers causes the current resulting from the input is the sum of the parcels of current from the controlled rectifier and the uncontrolled rectifier. In this way, the input current of the converter can be imposed by controlling the rectifier current controlled, mitigating the effects of harmonic distortion present in the uncontrolled rectifier current of non-sinusoidal characteristic.

In Fig. 2 it is possible to observe the illustration of the currents of each of the rectifiers: uncontrolled (INC), controlled (IC) and input current (Iin). From the initial time until the beginning of the growth of the current drained by the uncontrolled rectifier (t1) it is possible to verify that the controlled rectifier current has shape following the sine wave characteristic.

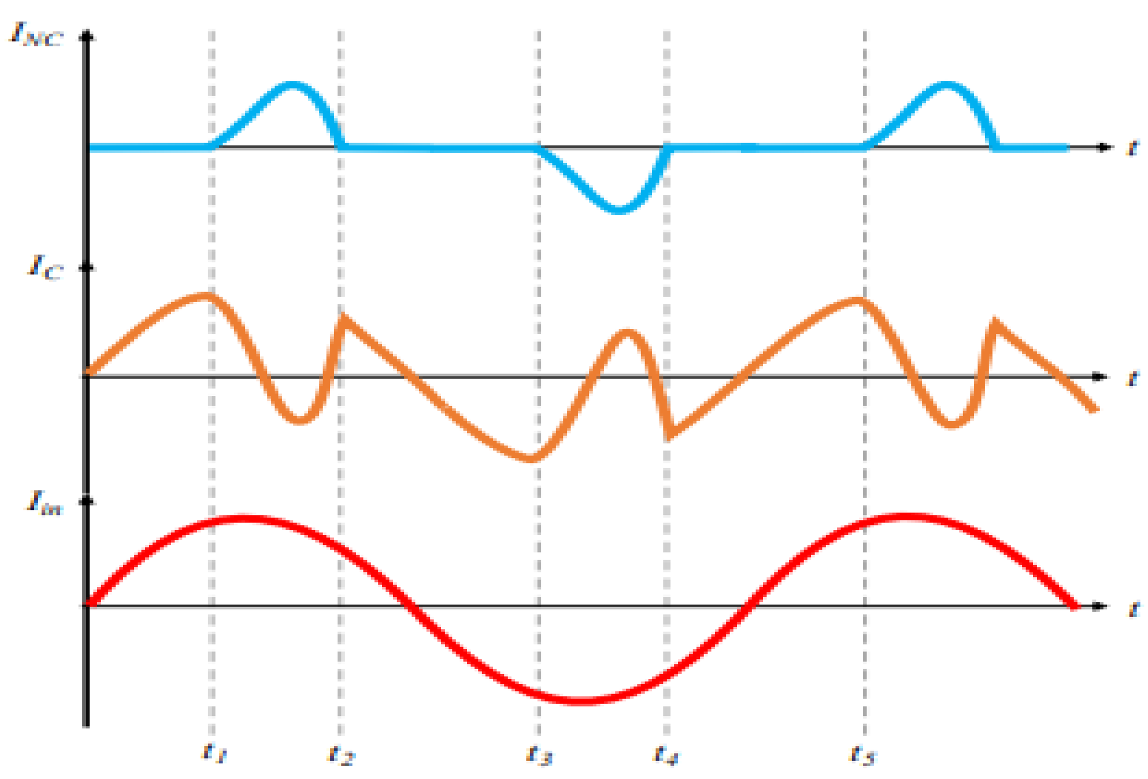


Fig. 2. Illustration of rectifier current waveforms uncontrolled (INC), controlled rectifier (IC) and current resultant input (Iin).

*B. Compensation operating principles voltage series*

In this way, the output voltage can be imposed controlling the voltage output of the controlled rectifier, mitigating the effects of load variation and intermittence of renewable energy sources that the DC bus is subject due to the characteristic of the GDs.The halfbridge converter will have as input the constant voltage output of the boost and regulate the output voltage so that it adds to the uncontrolled rectifier voltage hold voltage constant on the DC bus.In Fig. 3 it is possible to observe the illustration of the voltages of converter output (Vout), boost converter (VB), voltage mains AC input (Vin), rectifier not controlled (VNC), and the half-bridge converter (VHB).

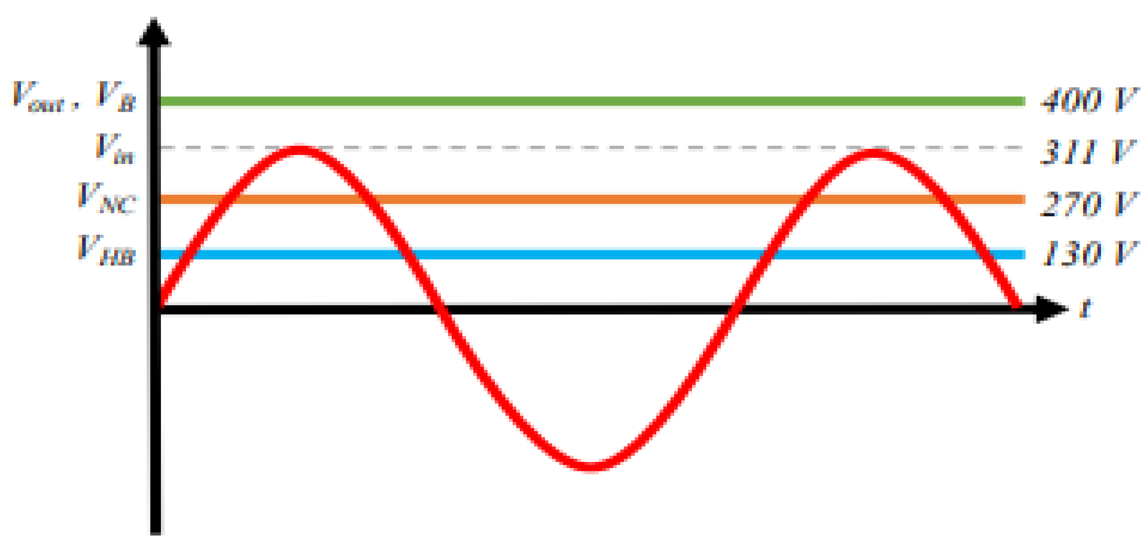



Fig. 3. Illustration of the waveforms of the output voltages of the hybrid converter (Vout), boost converter (VB), AC input (Vin), the uncontrolled rectifier (VNC) and the halfbridge converter (VHB).

## III – Results

The schematic simulation of the converter circuit proposed hybrid was developed in simulation software computational PSIM®. In Fig. 4 it is possible to observe a screenshot of the software with the complete circuit containing the scaled and adjusted values for simulation. The ideal component was used in the case of transformer to neglect the possible effects of saturation.

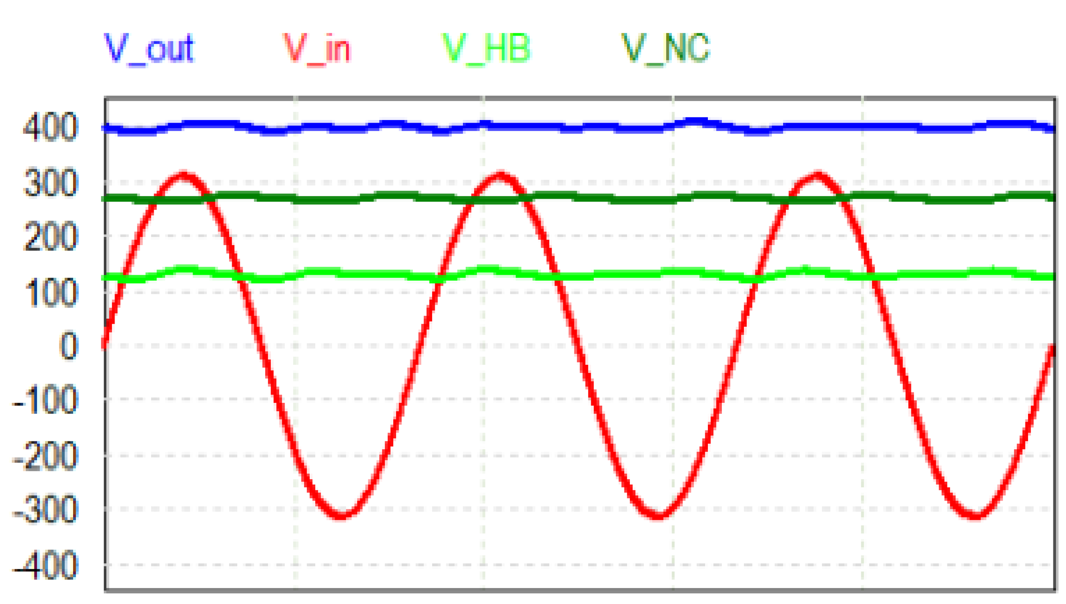
The power circuit presents the uncontrolled rectifier with parallel input connection with the boost converter. This, in turn, is connected in cascade as a half-bridge converter, forming the controlled rectifier. Below the power circuit are the control circuits.

***A. Simulation results under normal conditions***

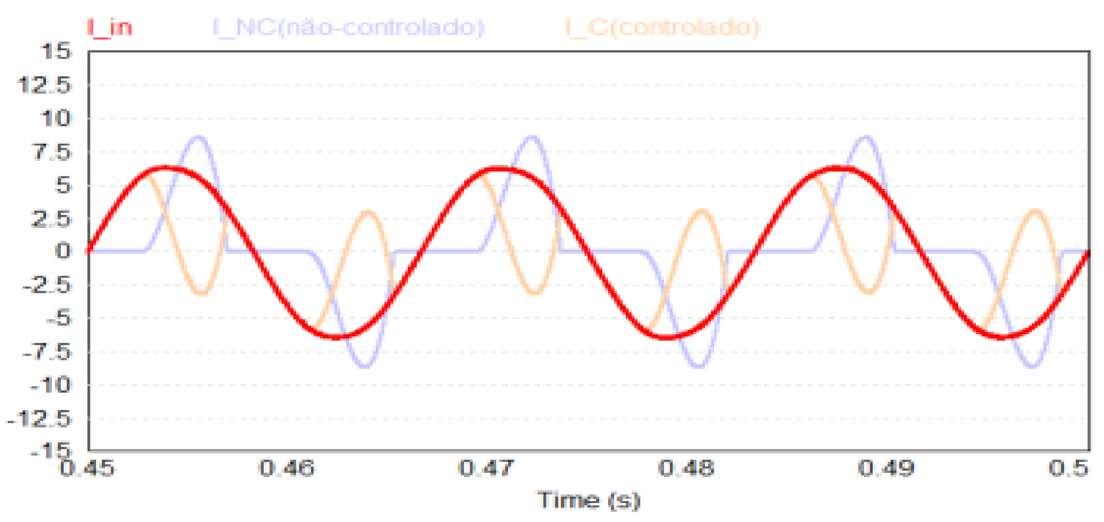
***AC mains supply*** Under normal operating conditions, the supply, the alternating voltage value of 220 Vrms and simulated full load operation scenarios and with a load step. Then, we obtained the graphs of voltage, current and power waveforms of each step of the circuit.

1) Operation at full load

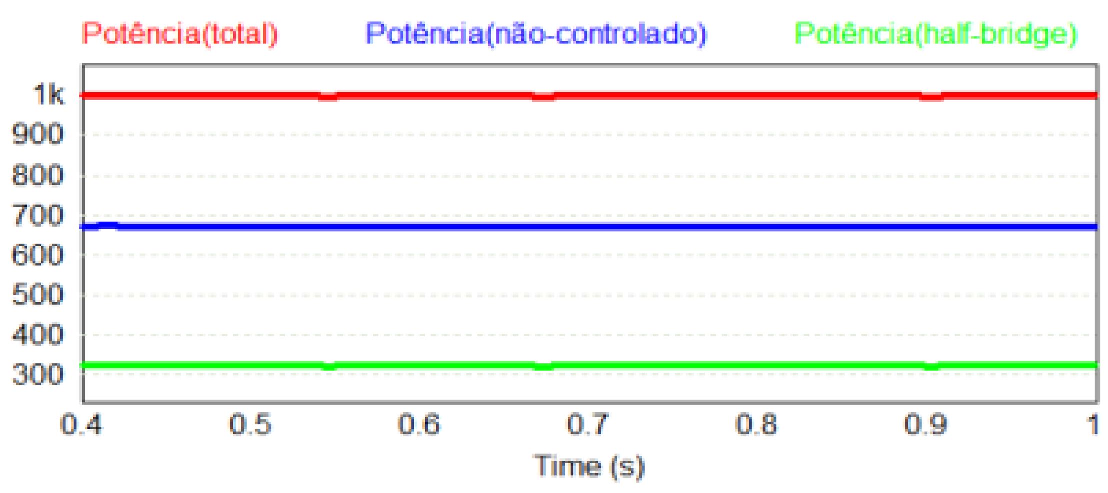
2) Fig.4. Results of voltage waveforms for operation at full load under normal power grid conditions.




In Fig. 5, the results of the waveforms were superimposed, being possible to observe that the controlled converter drains a negative current to reduce in the input current the peak current required by the non-controlled rectifier.



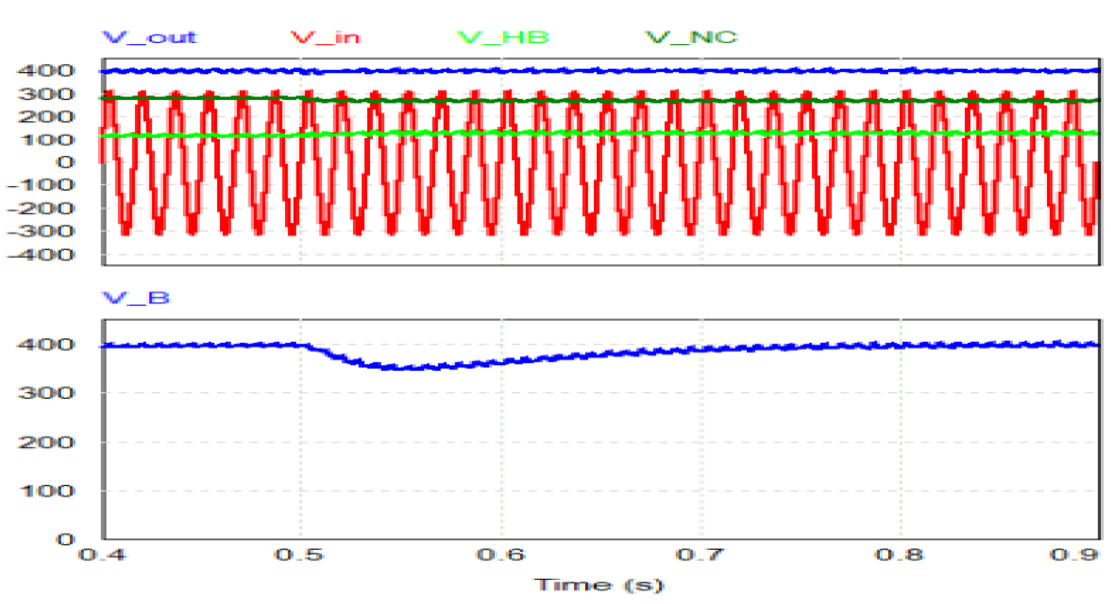

The power of each of the rectifiers and total power of the circuit can be seen in Fig. 6. Is it possible check that the controlled rectifier is processing about 30% of total power and the uncontrolled rectifier is processing the remaining 70% of the total power.




2) Operation under the effect of a load step

Still considering the normal conditions of the electrical network, a test of the converter operation was carried out under the effect of a load step of 50% for its total load.

Thus, using a load corresponding to 500W, calculated as an equivalent resistance of 320 ohms, at 0.5s, a load equivalent to 1000W was applied. The voltage waveforms, verified in Fig. 7, allow observing that the output voltage of the converter, Vout, remained with an average value of 400V and ripple as established and similar to the previous test.




## IV - Conclusions

The development of the single-phase hybrid converter using a topology with input connection in parallel and series-compensated output demonstrated that the proposed structure was able to mitigate the problems reported, as demonstrated by the results of the essay. The parallel connection on the input and the series connection on the output allowed the input current to always be imposed as sinusoidal and that the output voltage was always controlled at 400V, independent of load oscillations at the output or even voltage sags in the electrical network here.

The results of this work showed the feasibility of future work regarding the development of a prototype, with a validation of the topology and strategies of control employed. Furthermore, the topology presented has relevant potential for adaptation to a bidirectional power flow, allowing the injection of generation of excess energy from DGs on the AC power grid.

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