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Single -Phase Hybrid Converter With Series Voltage Compensation On The DC Bar Applied to Micro grids

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Abstract – This work presents the development of computer simulation of a topological structure of single-phase hybrid converter that aims to impose sinusoidal input current and the supply of a DC bus with regulated voltage using the voltage series compensation. With the increase in distributed generation by the use of DC renewable energy sources by microgrids, the characteristics of the structure proposed to make it an excellent alternative for applications involving the compensation of voltage fluctuations due to to the intermittence of microgeneration systems.

Keywords: Direct Current, Microgrid, Hybrid Converter, Series Compensation, Voltage,.

1. 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].

The use of one form of current or another, and even systems that mix both forms are part of the evolution of concept of microgrids and their characterization, aiming reduce disadvantages in a specific way and increase the efficiency of these generation and distribution microsystems [4].

Among the motivating factors was the efficiency of generation and ease of voltage rise in CA. However, the technological advances of the last century, mainly in power electronics, allow the establishment of portions of the electrical network in DC [5]. In this way, the distribution of electrical energy in DC has been the target of interest due to the growth of the distributed generation (DG) with the use of renewable resources more close to the consumption center [6]. Among the main advantages of using DC over AC in systems modern systems, it is clear that the absence of reactive power and of the frequency eliminate the respective control steps and synchronism [7]. Furthermore, due to the presence of loads and DC sources, there is also an elimination of the stages of AC-DC or DC-AC conversion reducing complexity and losses of these subsystems [6].

The greatest simplicity in power flow to integration of generation, energy storage and vehicles electrical in DC in relation to AC, is mainly justified by renewable energy sources to generate energy electricity directly into DC (such as photovoltaic panels) or have their control facilitated by operating in DC (like the wind turbines). Furthermore, the growing presence of components that require a DC infrastructure for the its operation (such as battery banks and systems charging electric vehicles) contribute to the advantage of this use [5], [6].

Microgrids are now considered hybrid (CCCA) when they have a DC bus for distribution and interconnection between DGs and loads, but also has an interface with the traditional CA network, which may or may not have a bidirectional power flow, where the surplus generated by the renewable sources can be injected into the AC grid, and in the absence or intermittence of generation the loads can be supplied by the AC network [5], [8]. In this sense, microgrids are, conceptually, complementary to the electrical power system and are not intended to completely replace the way conventional generation, transmission and distribution [17].

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]

2. Proposed Structure

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]. The problems and context show that it is necessary to use AC-DC converters to DC link voltage regulation that is capable of mitigate the effects of load steps and network oscillations.

In the context of mitigating oscillations in a microgrid CC by the intrinsic behavior of the GDs present, this work proposes the use of the AC power grid for compensation, controlling the DC link voltage with greater resilience. The keys used in converters have their cost associated with the processing power capacity. In order to reduce this factor, a topology of hybrid conversion, with a processing power in a larger portion using a rectifier structure not controlled, with the other portion of power being processed by a controlled rectifier structure. The proposed structure can be seen in Fig. 1, highlighting the rectifier blocks.

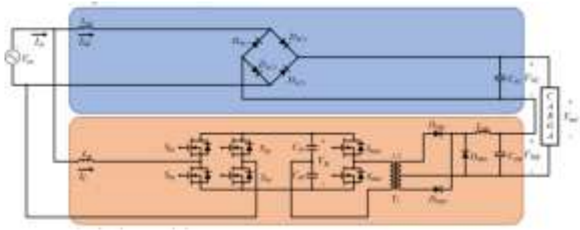

Fig. 1. Proposed structure of the hybrid converter, highlighting the blocks of uncontrolled (blue) and controlled (orange) rectifiers.

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.

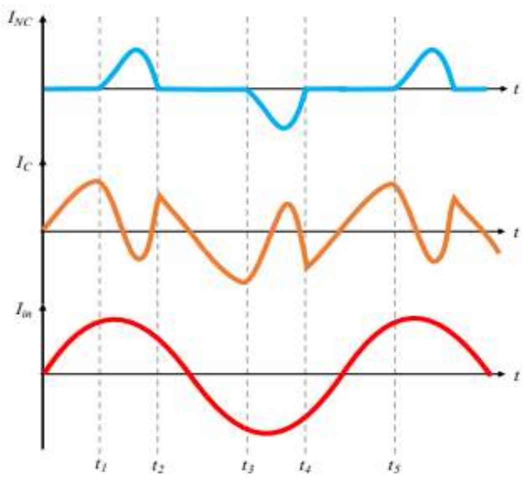

Fig. 2. Illustration of rectifier current waveforms uncontrolled (INC), controlled rectifier (IC) and current resultant input (Iin).

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).

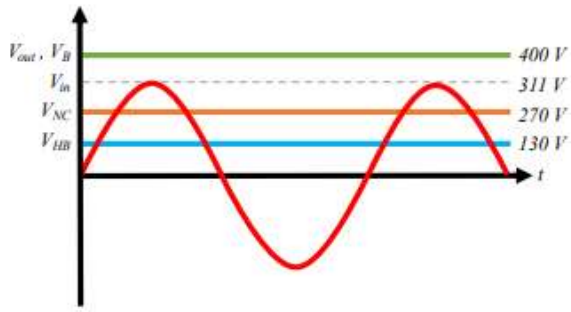

Fig. 3. Illustration of the waveforms of the output voltages of the hybrid converter (Vout), boost converter (VB), AC input (Vin), the uncontrolled rectifier (VNC) and the halfbridge converter (VHB).

4. Control Strategy

Based on the proposed structure for the rectifier controlled, a control strategy will be necessary, individually for each of the converters: boost and halfbridge. Considering the input current imposition and the voltage series compensation at the output, the total current of input, the boost converter voltage and the total output voltage must be monitored [15].

A. Boost Converter

With the determination of the reference value for boost converter output, a controller of the type proportional and integral (PI) will be responsible for converter closed-loop error compensation. Beyond addition, to guarantee the imposition of the sinusoidal current in the total input using a sine waveform moored with AC mains supply voltage, the control by hysteresis will carry out the compensation of the input current of the converter.

A. Half-Bridge Converter

The control of the half-bridge converter uses as reference the desired value of the total output voltage of the converter, and the PI controller for error compensation with respect to the voltage monitored at the output. due to intrinsic characteristics of this converter topology, it will be necessary the use of saturators to guarantee a ratio 50% maximum cycle, a signal generator configured for a triangular waveform and a set of comparators for key actuation semiconductors.

5. Project Specifications

The proposed hybrid converter design will take into account taking into account the usual values of the supply voltage of the AC grid, and those commonly found in a microgrid CC. In addition, the power parcels processed by each of the rectifiers has a ratio of 70% to the uncontrolled rectifier and 30% for the rectifier controlled. For the design of the hybrid converter were considered the parameters of Tab 1.

Table 1: Project Parameters

Project Parameter	Value
Input voltage (AC)	220 Vrms
Average output voltage (DC)	400 V
total output power	1000 W
Uncontrolled rectifier power	700W
Controlled rectifier power	300W
Average output voltage (boost)	400 V
Average output voltage (half-bridge)	150 V
Output voltage ripple (half-bridge)	0.5 V
Switching frequency (half-bridge)	50 kHz

6. Computational Simulation 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.

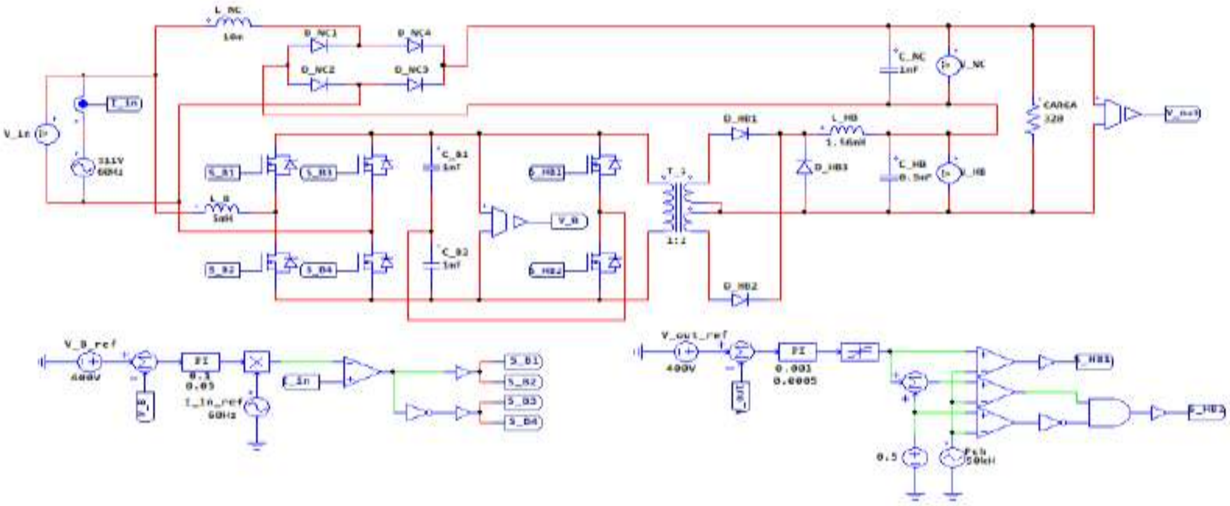

Fig. 4 Schematic of the computational simulation developed in the PSIM® software .

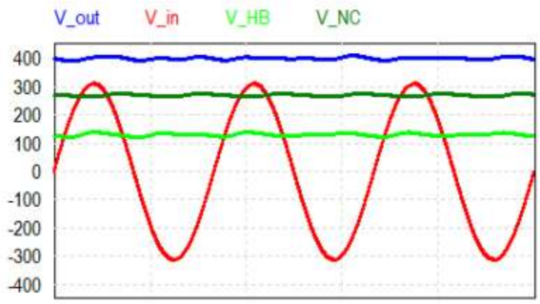

Fig. 5. Results of voltage waveforms for operation at full load under normal power grid conditions.

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

Considering the converter at full load, 1000W, it was calculated an equivalent resistance of 160 ohms for 400V on the DC bus. In Fig. 5 it is possible to observe the waveforms for steady-state voltage for each step of the circuit, in addition to the input and output voltages.
The output voltage of the converter, Vout, can be viewed with average value of 400V and maximum ripple 0.32V. The voltage waveform approaches the expected constant and the ripple can be considered low by the magnitudes associated with the converter. The VNC uncontrolled rectifier voltage can be viewed with an average value of 270V, with greater output ripple being observed.

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.

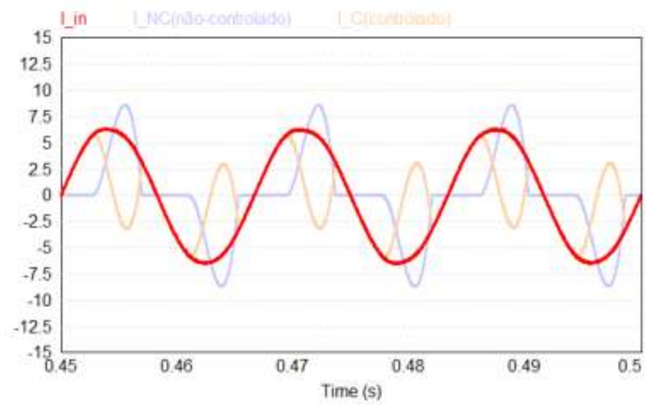

Fig. 6. Results of superimposed current waveforms for full load operation under normal grid conditions electric. (from the author).

The power of each of the rectifiers and total power of the circuit can be seen in Fig. 7. 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.

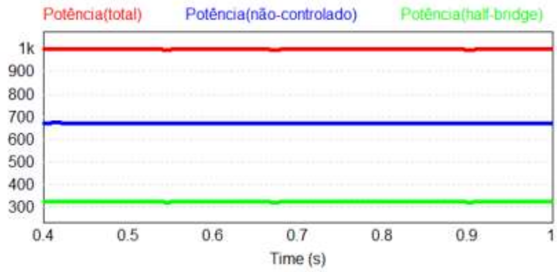

Fig. 7. Power results for full operation load under normal conditions of the electrical network.

The duty cycle of the half-bridge converter illustrated in Fig.8 lets you see that the control is set between 0.15 and 0.20 the value of the duty cycle for maintaining the voltage of output at 130V and series compensation imposes 400V on the output of the DC bus.

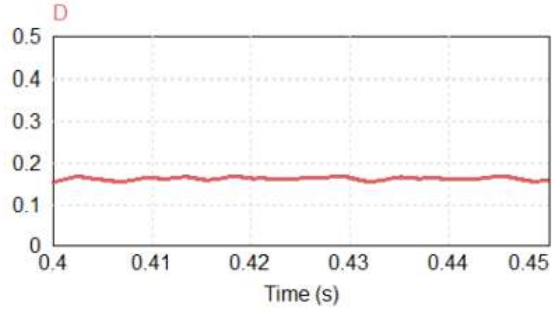

Fig. 8. Result of the duty cycle of the half-bridge converter for full load operation under normal grid conditions electric.

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. 9, 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.

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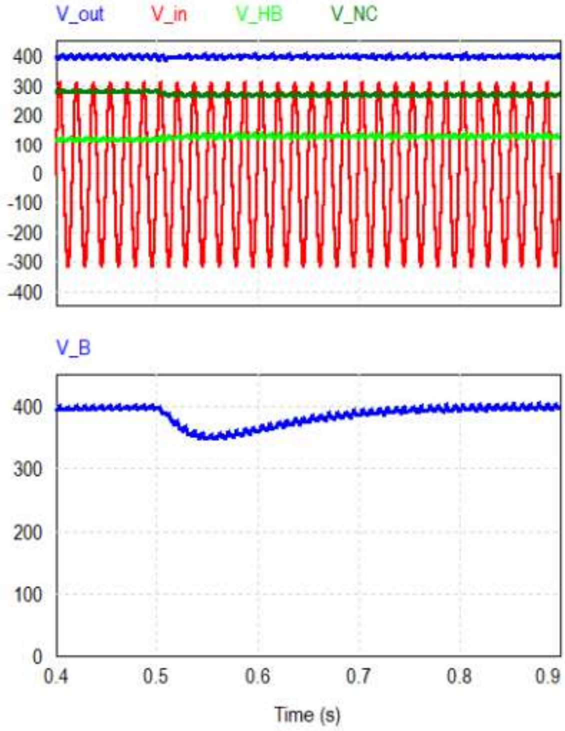

Fig. 9. Voltage waveform results for operation under the effect of a step load under normal conditions of the electrical network.

The rectifier current uncontrolled (INC), controlled rectifier (IC) and entry (Iin) maintained the test behavior above, but with the corresponding increase in amplitude to supply the new load from the instant 0.5s. In Fig. 10 it is possible to observe the results of the forms current waveforms superimposed over a wider range close to the transient of the load step, being checked what waveform of the input current remains controlled during the transitory period and rapidly accommodates to the new value.

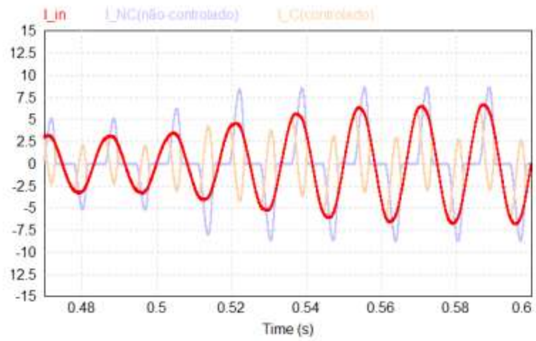

Fig. 10. Results of superimposed current waveforms for operation under the effect of a step load in conditions normal power lines

The power of each of the rectifiers and the total power of the circuit can be seen in Fig. 11. Is it possible verify that the processing power ratio is similar to the previous test. After the instant of the load in 0.5s, there is an increase in power to the full load value.

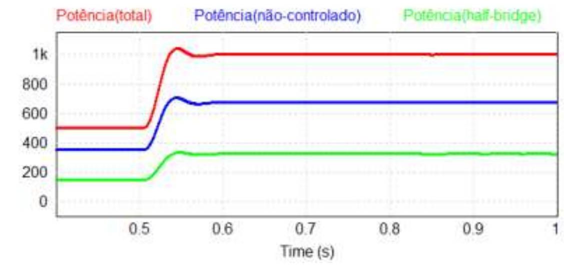

Fig. 11. Power results for operation under the effect of a load step under normal conditions of the electrical network.

The duty cycle of the half-bridge converter, illustrated in Fig.12, allows you to observe that the control is adjusted between 0.15 and 0.20 the value of the duty cycle for maintaining the voltage in the DC bus.

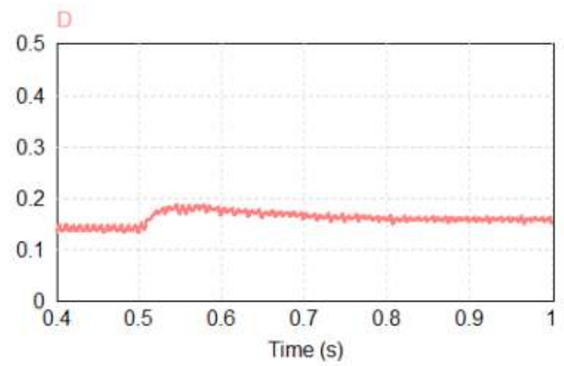

Fig. 12. Result of the duty cycle of the half-bridge converter for operation under the effect of a step load in conditions normal power grid.

7. 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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