Fuel Cell Connection Inverters used for Unbalance Compensation in Low Voltage Distribution Systems

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1. Introduction

The aim of this paper is to evaluate the benefits that can be achieved by operating the connection inverters of the distributed energy resources as active power filters in LV distribution networks. The use of the future fuel cell inverters to compensate zero sequence currents, arising from unbalances among phases, can improve the efficiency of the distribution networks by means of reducing the total amount of losses. A common unbalanced load connected to a LV feeder where a FC inverter is present has been simulated. The reductions in the distribution power losses and compensation of zero sequence currents have been analyzed.

Key words: Active power filters, fuel cells, power quality, unbalances compensation, distributed generation.

2. Main elements implemented.

A. Description of a Fuel Cell

The type of FC used in our research is a high temperature proton-exchange membrane (HTPEM) fuel cell. This kind of FC is quite developed and seems to be the first hydrogen technology to be used for massive integration into the EPS. Apart from that, the range of power they produce is from several watts to some tens of kilowatts. This range fits perfectly with the LV distribution network and that is way according to future trends they will be probably used locally in many places by individual consumers.

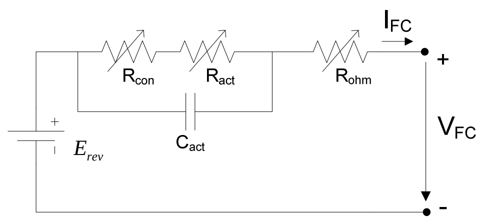

Fig.1. FC equivalent electric circuit.

The behaviour of these FCs is described and an electrical model developed and implemented in Matlab/Simulink.

B. DC/AC inverter topologies

Traditionally, based on Akagi's Instantaneous Power Theory published in 1984, Three-Leg Full Bridge (TLFB) inverters have been used as APF in various applications. Nevertheless, this configuration does not allow the inverter to inject zero sequence currents into the EPS, being not useful for three phase unbalanced loads with neutral compensation. For LV distribution networks with presence of the neutral wire, other inverter configurations should be employed to allow zero sequence current injections and the corresponding unbalance compensation. Three main topologies are:

- The first one, known as capacitor midpoint type or Three-Leg Split Capacitor. Used for small rating applications. Since the entire neutral current flows through dc-bus capacitors it must have large values.
- The second topology, known as the four-pole switch type or Four-Leg Full Bridge, in which the fourth pole is used to stabilize the neutral of the APF.
- Finally, the Three-Bridge Four-Wire configuration. It is quite common and allows the proper voltage matching for solid-state devices and enhances the reliability of the APF system. It is currently used for high power systems.

3. FC integrated simulated system

Two different studies have been performed and are presented for comparison: the first one analyzes the LV network distribution losses without any compensation, and then a second analysis studies the reduction of losses in the same network when the compensation offered by the FC connection inverters is introduced. A standard example of a MV/LV real transformer with one LV feeder supplying energy to groups of unbalanced loads in an apartments building has been modelled. The scheme of the system can be observed in Fig.2.

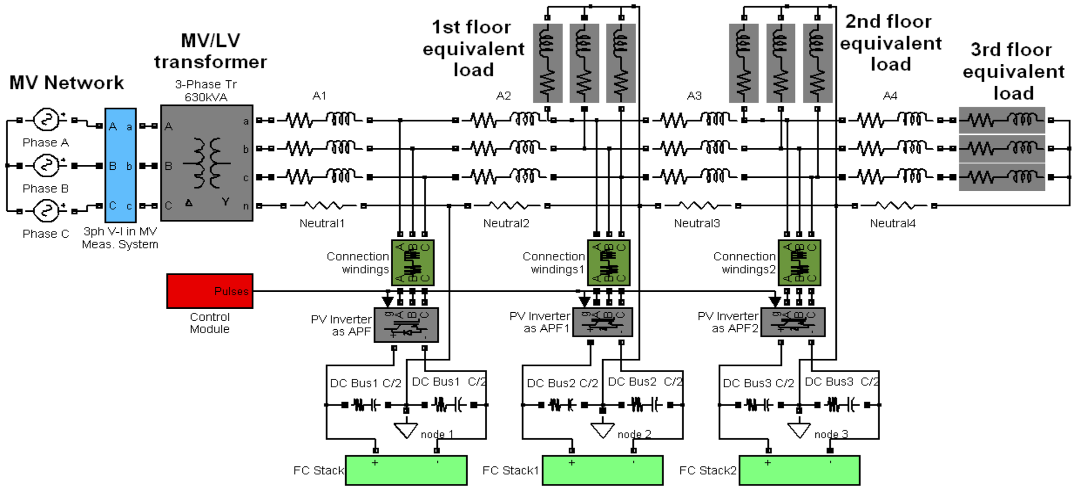

Fig. 2. FC system integrated to the distribution network.

4. Simulation results

Currents along the different neutrals wires and the voltages at the DC buses of the inverters have been considered in both cases. For the dc voltage, both capacitors forming the bus have been monitored to study the unbalance in this bus. The connection of the inverters is produced at 0.05ms when they start injecting active power. At 0.1s the first floor inverter is turned on to compensate unbalances. And finally, at 0.15s the other two inverters launch their compensation algorithm. The effects introduced over the neutral currents by them, for the case 1 of the study, can be observed in Fig. 3.

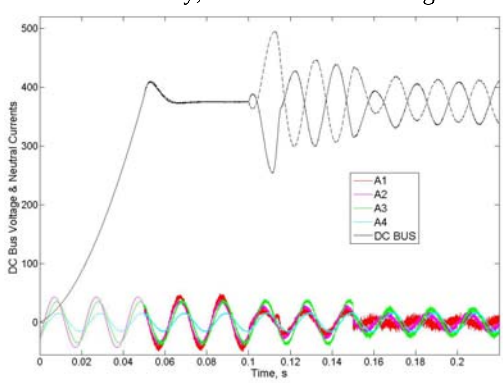

Fig. 3. Currents in different neutral sections, case 1.

The neutral current at section A1 is reduced to a value close to zero when all the converters are compensating unbalances (from 0.15s on). Previously and from t=0.1s, neutral currents at A1 and A2 sections where reduced due to the compensation introduced by the inverter at the first floor. Its dc bus voltages can be appreciated in the same figure showing the great unbalance appearing among capacitors.

5. Conclusion

A Simulink model of FC system and its connection inverter is simulated. The unbalance compensation is analyzed and the improvement in the power quality of the EPS clearly highlighted. The model has been introduced in a LV network composed of a feeder where unbalanced loads are connected.

Results obtained in simulations confirm the possibility of using the FC connection inverters in order not only to inject active currents into the LV distribution system, but also produce zero sequence currents to inject on the different phases improving the efficiency. A more balanced situation is obtained in the system and neutral currents get cancelled. That comprehends a reduction in the overall distribution losses.

Distributed FC systems could implement the proposed function with just a few modifications in the hardware topology of their connection inverters (referred to the first models appearing in the market which are too close to PV ones) and by adding some control algorithms taking into account zero sequence currents consumed by the different loads. A brief analysis of the main converter topologies used for zero sequence currents cancellation has been introduced.

Acknowledgement

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