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# Investigation of Power Quality in Presence of Fuel Cell Based Distributed Generation

F. Gharedaghi, M. Deysi, H. Jamali, A khalili

Department of Electrical Engineering, Genaveh Branch, Islamic Azad University, Genaveh, Iran.

**Abstract:** Fuel cell systems are advancing beyond conventional bulk power applications. New technological approaches are allowing dynamic response that can solve short-term power quality problems, specifically voltage sags and momentary interruptions. This paper presents a case study involving one of the main technologies of distributed generation – dg, commercially available, fuel cell, focusing the aspects related to the quality of the electric power supplied by such devices, especially harmonic and voltage imbalances. The measurements and evaluation were made in a fuel cell, PC25C™, 200 kW power plants, based on phosphoric acid fuel cells. Finally, the work will present the main obtained conclusions, indicating the main aspects of power quality, which must be considered in the application of this device to distribution networks.

**Key words:** Power Quality; Fuel Cell; Distributed Generation; Harmonics; Voltage Imbalance; Electrical Distribution Systems; Interconnection Requirements.

## INTRODUCTION

The distributed generation - DG - is constituted in a new focus for the electric power generation. Differently of the centralized generation, that is responsible for the great majority of the energy supplied in the world, DG is characterized by not being dispatched by transmission lines and being of small load when its power is compared to the other types of electric power generation. Some authors put DG as an electric source of energy connected directly to the distribution networks in the consumer's point of common coupling (Dondi, P. *et al*, 2002; Greene and Hammerschlag, 2000). Authors as Dondi *et al.*, (2002) Laurie, (2001) and Standard & Poor´s (2000) put DG, besides the production, as storage of energy. Combined Heat and Power Plants - CHP and others are also purposes mentioned by the authors (Laurie, 2001; Strachan and Dowlatabadi, 2002; DPCA,2002) and (Turkson and Wohlgemuth, 2001). The reference (DPCA, 2002), for his/her time, it defines DG as "any generation technology in small scale that supplies electric power direct to the consumer or to the transmission or distribution systems of the utility" (Turkson and Wohlgemuth, 2001). On the other hand, the technical progresses happened in the power electronics and microprocessors allowed the interconnection of such devices to the electric net, with quality and efficiency, through the application of inverters for this end.

In the context above, this presents the preliminary results of a case study dealing with the operation of a fuel cell, 200 kW power plant, based on phosphoric acid fuel cells, under the Power Quality point of the view - especially harmonic and voltage imbalance. The aim of this paper is to analyze the behavior of this device, as much as pollutant load for the system, as well as it is a sensitive load for the system power quality, in the point of common coupling between CASE STUDY and the local utility.

### *2 Fuel Cell – Case study:*

The CASE STUDY´s fuel cell was produced by International Fuel Cell. This cell is fed by natural gas, reformed in a first stage to supply hydrogen, which also produce 200 kW of AC electric power. This fuel cell has three operation modes: grid connected, grid independent and idle. In the first case, it operates in parallel with the utility, being able, for instance, to reduce the consumption of energy of a given installation. In the second case, it operates independently of the distribution net, feeding a group of defined loads, according to the consumer's criteria. In the last one, it is ready to generate energy.

It is worth to point out that, in spite of this technology to be available commercially, the fuel cells application is still area of intense study. Subjects as the durability of the cells, interconnection issues, influence of the type of fuel used (e.g., injection of hydrogen substituting the natural gas), reliability levels, configuration of the electric net, readiness of gas, disputes for reliable energy, impact in the environment and in the market of energy and quality of the energy (main of the present paper), among others, are points of study during the evaluation of the technology for applications in distributed generation of energy.

### *3 Case study's Fuel Cell:*

Figure 1, in the Appendix 1, presents the one-line diagram of the CASE STUDY´s FC facility. Measurements were done, by using ACE 2000 Power Quality Monitor, in order to verify the operation of the

**Corresponding Author:** F.Gharedaghi, Department of Electrical Engineering, Genaveh Branch, Islamic Azad University, Genaveh, Iran.

cell under the power quality point of view, especially, harmonics and voltage imbalance. The PQ monitor was installed at busbar 2.

Several condition were defined - 10, 20, 50, 100, 150 and 200 kW -, considering monitoring periods of 24 hours each. This is presented in Figure 6 which shows the different load steps during the monitored days. This procedure had been implemented to analyze harmonic injections of the FC, as well as its impact in the facility as well as utility network. Two measurement types were implemented:

- Measurements of Harmonic and Energy with the FC disconnected from the substation busbar;
- Measurement of Harmonic and Energy with the FC connected to the substation busbar.
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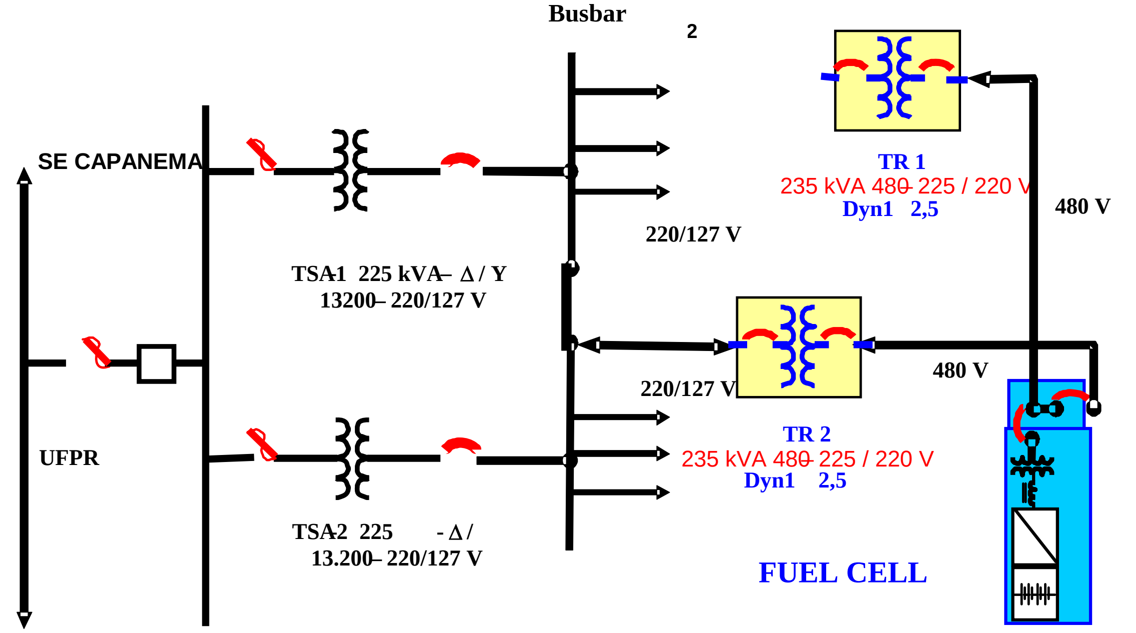


**Fig. 1:** One-line Diagram of case stud

***Results of the Harmonic Measurements and Energy Accomplished in Field:***

The results obtained from FC monitoring under operation conditions previously mentioned are presented in the next figures.

***4.1 FC Disconnected (Figures 2 to 5):***

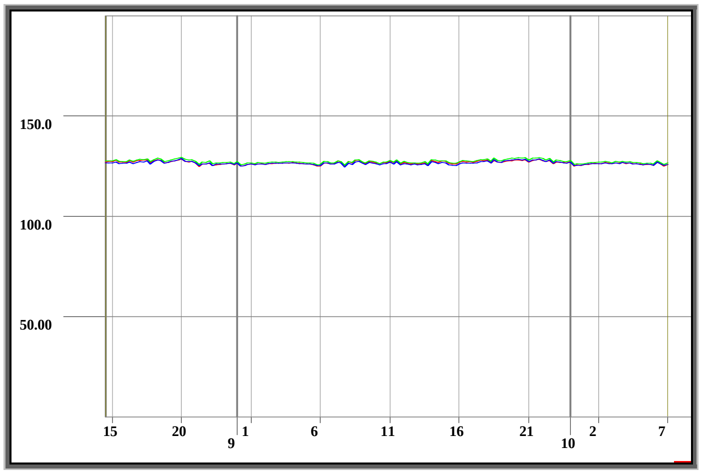


**Fig. 2:** Voltages in the substation busbar 2.

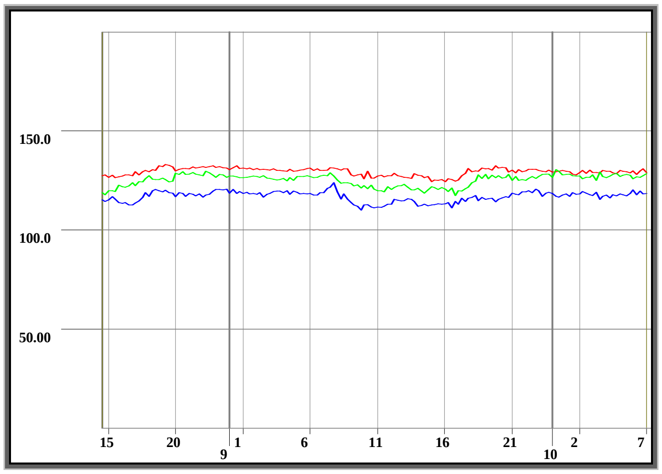


**Fig. 3:** Currents in the secondary of the transformer TSA 2 at busbar 2.

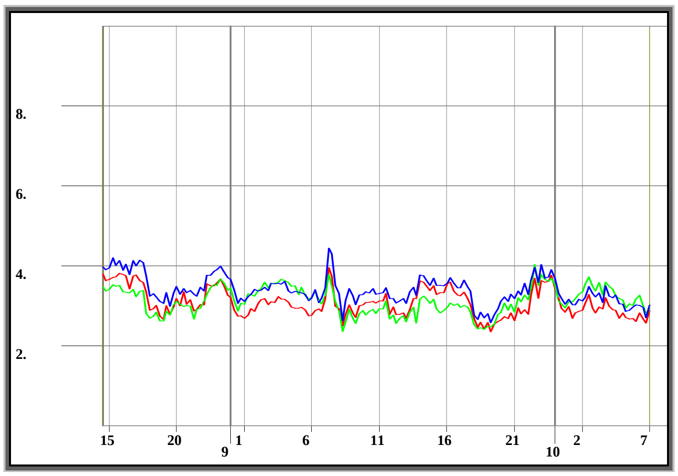


**Fig. 4:** Voltage Total Harmonic Distortion – VTHD.

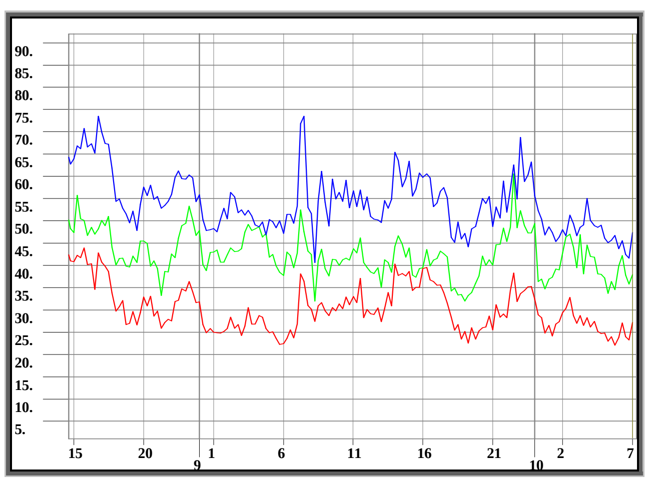


**Fig. 5:** Current Total Harmonic Distortion – ITHD.

### *4.2 FC Connected (Figures 6 to 9):*

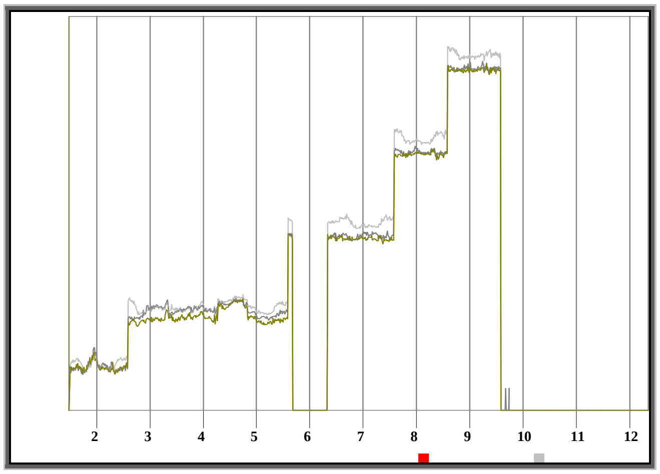


**Fig. 6:** Currents in the secondary of the transformer TR2 at busbar 2 during the monitored period – 8 days.

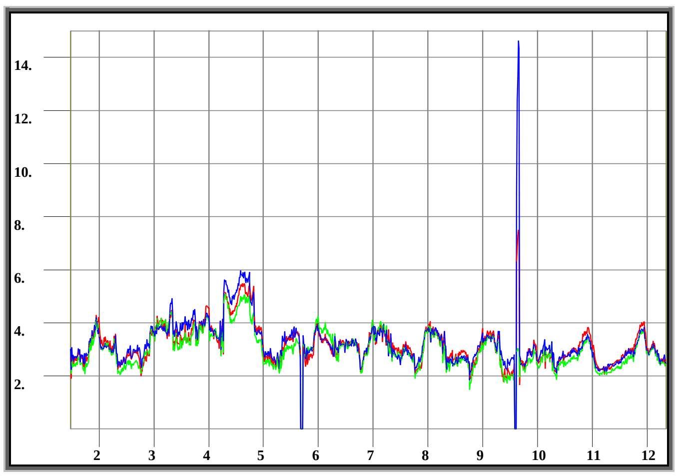


**Fig. 7:** Voltage Total Harmonic Distortion – VTHD.

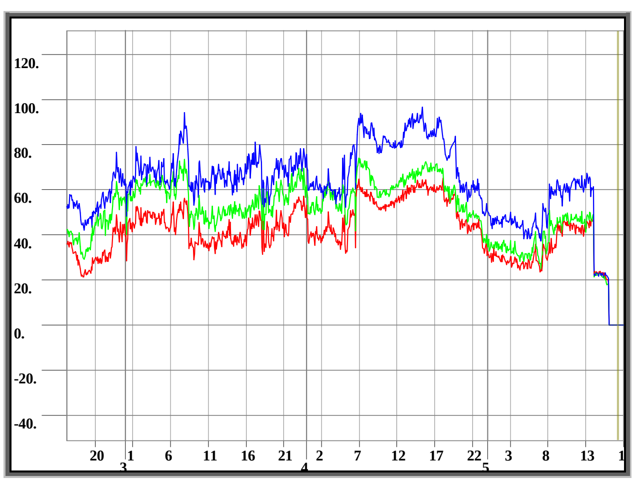


**Fig. 8:** FC under 50 % of the full load - ITHD.

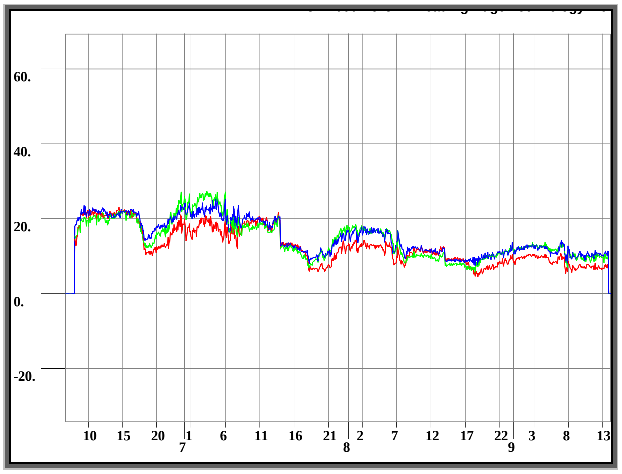


**Fig. 9:** FC under full load - ITHD.

### *5 Analysis of the Measurements:*

### *5.1 FC Disconnected:*

The results obtained considering the FC disconnected of the distribution network indicates:

- RMS Voltages – stable and balanced;
- Currents and Active Power - slightly unbalanced;
- Voltage Total Harmonic Distortion (VTHD) - it varied between 1,9 and 4,2%, for the three phases;
- Current Total Harmonic distortion (ITHD) - it varied among the phases – 23 % for the less distorted phase and 74 % for the more distorted phase;
- Power Factor - it varied between 0,8 and 0,95.

### *5.2 FC Connected:*

The monitoring results when the FC was connected with the distribution network at CASE STUDY facilities have indicated the following results:

- RMS Voltages - stable and balanced;
- Currents and Active Powers - they were shown more balanced for all of the generation conditions analyzed (10, 50 and 100 %);
- Voltage Total Harmonic Distortion (VTHD) - it varied between 1,9 and 6,0 % for the three phases;
- Current Total Harmonic distortion (ITHD) - it varied for each one of the FC operation conditions: for 10 %, it varied from 100 to 750 %; for 50 %, varied from 20 to 100 %; for 100 %, varied from 10 to 25 % of the nominal current;
- Power Factor – it also varied for each one of the FC conditions: for 10 %, FP varied from 0,2 to 0,7; for 50 %, varied from 0,7 to 0,95; for 100 % FP, was very close to 1,0.

### *Conclusions:*

For all of the operation conditions analyzed, the entrance in operation of the FC affects the levels of voltage total harmonic distortion, according the levels recommended in the most standards. In spite of the high harmonic content in current injected in facility, it was not capable to significantly distort the busbar voltages. It is worth to emphasize that this analysis is valid just for this case, and for another systems, especially that ones with smaller short circuit level, such condition becomes strongly relevant. Finally, we must ot remark that the results presented in this paper are preliminaries and this investigation is just in its beginning. In this case, faced to the unavailability of only one monitoring device, the results are not totally conclusive. In this way, the authors recommend that, for better results, the procedure be repeated, being used, at least and simultaneously, 2 monitoring devices: one connected in the FC output and the other in the secondary of the transformer feeder. It can be interesting also to install a third equipment close to the other loads, in order to evaluate the harmonic contribution of the same ones in the system in study.

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