# Smart Grid: What's news?

M. Caciotta, M. D'addazio, S. Giarnetti, M. Grossoni and F. Leccese

Department of Electronic Engineering
Roma Tre University
Via della Vasca Navale n.84, 00146, Rome (Italy)
Phone/Fax number:+39 06 57337342, e-mail: **caciotta@uniroma3.it**, **matteodaddazio@gmail.com**, **s.giarnetti@uniroma3.it**, **mauriziogrossoni@alice.it**, **leccese@uniroma3.it**, **daniele.trinca@tin.it**

**Abstract.** As a direct consequence of the increasing demand of energy and the need to decrease pollution in order to cope with global warming, political, industrial and scientific interests have combined to understand the way ICT technologies can help to review all phases of energetic cycle, from generation (through renewable sources), to accumulation and transportation, until distribution. The union between ICT and energy is usually identified as "*Smart Grid*", to emphasize an expectation change in what will be the Power Grid of the incoming future. The aim of this study is to give some ideas about the experimentation of new techniques of energy acquisition through renewable sources (solar, chp, wind, etc.). These techniques would guarantee more accessible prices for production, improving performances, the overcome of those constraints that did not allow the exploitation of potential energy capacity of renewable sources. This grid will be made of devices forming a control cycle that will check the station of energy generation as much as the behaviour of single consumers.

## Key words

Distributed Generation (DG), Renewable Energy, Smart Grid, Microgrids.

## 1. Introduction

Energetic sustainability has a straight link with renewable energies, which consist in inexhaustible sources, due to their capacity of regeneration within a period comparable to the consumption time. The main goal of energetic sustainability is "to reach a democratic solution for the global energetic crisis, decreasing the impact of $CO_2$ on global warming". Since Distributed Generation (DG) often involves renewable energy, it is important to facilitate integration of DG into existing networks.
They are based on the Active Network Management (ANM) concept, where automation, ICT and power electronics are used to integrate more DG by exploiting active resources instead of just reinforcing the network.
The concept of energetic sustainability linked with renewable energies is addressed in this presentation in section 2, which analyzes a method for the production of energy from combined heat and power, with particular application in residential (chp), in sections 3 and 4, which raises the problem of overcoming the obstacles that still prevent the sun to play a primary role in the production of clean energy on a large scale, through innovative techniques tested at two American universities: Stanford e MIT. In sections 5 and 6 will be evalueted in terms of benefits the contribution of ICT to facilitate the integration of DG into existing networks. Section 6 presents activities that are performed at the Departement of Electronic Engineering of Roma Tre University where, through measurements of electric parameters to check the network, is optimized the use of the network. The idea is combining the needs of production with those of the consumers so improving the quality of service.

## Combined production of heat and electricity (CHP)

The "Oak Ridge National Laboratory" is among those laboratories which has already started a combined production of heat and electricity (CHP), reducing $CO_2$ emissions. The separated production mechanism of heat and electricity is named "*Cogeneration*" [1]. Cogeneration systems are usually made of a prime mover, converting fuel in mechanic energy, a generator, transforming mechanic energy in electric energy, and a heat recovery system, collecting rejected energy and converting in usable heat energy. Further improvements would allow to use cogeneration systems to produce heat and cold for residential usages. This system works with vegetable oil combustion through a power generator, which supplies home electricity. The rejected heat of this process is used to supply heating and hot water and furthermore to cool refrigerators. In addition the system that burns fuel absorbs $CO_2$ and consequently produces zero greenhouse gas emissions. This system is named "Micro-three-generation" [2]. This system will release energy only when needed due to an energy storage system. A potential use of Micro-three-generation is the "*Croton-Megalocarpus*" a bio-energetic crop that grows in east Africa [3].


Fig. 1. Micro Tri-generation system to produce heat and cold in a residential

This biofuel grows on lands not addressed to traditional food crops or farming. Since the available areas for biofuel are 4,7 millions (estimate of Stanford University), they would guarantee 8% of the overall demand of energy in the world, and they would be a good alternative to oil. Despite the advantages, an uncontrolled production of biofuel may be dangerous for food safety and for environmental impacts hence for a sustainable development.

## 2. Sun + Water = Hydrogen

The overcome of the main obstacle, which is the creation of a storage system to use solar energy in absence of sun, would contribute to make solar energy the dominant source for the production of clean energy. [4] The chemist Daniel Nocera of MIT would be able to use sunlight to split water molecules, in order to use as hydrogen fuel that could later be burned in a generator or recombined with oxygen in a fuel cell producing energy electricity both day and night without $CO_2$ emission. The key component of the new process is the use of catalysts, one that produces oxygen from water, and another that extracts hydrogen. This technique of splitting very closely mimics the photosynthesis process, with which the professor of Chemistry at the Technical University of Lausanne, Michael Gratzel, has made its solar cell that combines with the catalyst of Nocera.

[5] Gratzel's cell uses a dye Reuten, which acts in a similar way to chlorophyll absorbing light and releasing electrons. In this type of process catalysts would be placed side by side and with the help of special dye molecules designed to absorb sunlight, the energy captured by the solar dyes would be directly used for the reaction of water molecules splitting.

## 3. Solar Energy

Discovered by researchers at Stanford University, a new process of solar energy conversion promises to bring solar to compete with oil. The system simultaneously combines light and heat of solar energy to generate electricity, reaching twice the efficiency compared to solar panels produced with current technology. The process is known as "PETE" (Photon Enhanced Thermoionic Emission). Unlikely photovoltaic technologies currently in use become less efficient with increasing temperature while the new process performs its best at higher temperatures. The majority of the cells use a portion of the spectrum of light while the rest of the radiations only generates heat. The waste of this thermal energy and the inherent inefficiency of the cells, lead to 50% loss of usable energy. The team showed that by covering the semiconductor with a layer of caesium results in a component able to take advantage of the double effect, heat and light, to produce energy, furthermore benefits from high temperatures since its peak of efficiency is not affected up to and beyond 200 degrees. For this reason this system is applied in the new concentrated photovoltaic systems that reach up to 800 degrees, with which the new technology PETE could reach 50% more efficiency. Concentrating solar systems, or thermodynamic, are a type of electrical systems that use thermal energy to generate electricity. Compared to traditional solar thermal systems, they derive their name from the presence of a thermodynamic cycle for converting heat into electricity through steam turbine. The great revolution is the energy production even in the absence of the primary energy source, or solar energy, thanks to the possibility to store heat in special tanks.

## 4. Active Distribution Network

The traditional passive network management or "fit and forget" principle for connection of Distributed Generation (DG) has little future compared to Active Network Management (ANM). With proper management of DG and other active resources the overall system performance may be improved from presently used practices. DG provides a good potential as a controllable resource for the active network. Other existing controllable resources are directed toward load control, reactive power compensation and demand side management. ANM adds value by increasing the potential for renewable energy, by improving efficient utilization of distribution network assets and by supporting distribution network by ancillary services from customer-owned resources. The aim of ANM is to add more flexibility for network management in order to utilize existing network assets more efficiently. The addition of flexibility comes from the utilization of active resources through grid code requirements or ancillary services. Active resources are needed for integration as a part of the distribution system instead of just connection to it. Active resources are typically utilized in extreme network conditions e.g. when the network is not capable of transferring produced wind power.

## 5. Using microgrids to integrate distributed renewable to the grid

[6,7] Electric utilities face a daunting challenge when they address local and regional mandates to increase use of renewables. Large wind farms and solar generators may be remotely located, with limited transmission corridors available to move power from production facility to distribution grid. Even when those corridors are available, moving power long distances incurs substantial loss and high costs.

Remote sources are not, of course, the only options for power with which to meet renewables mandates. Local, distributed power generation from solar roofs and small wind turbines may already be available; utilities may already be paid for that power under regulator-imposed net metering requirements or voluntary local programs for encouraging cleaner energy.

Unfortunately, putting these small sources of renewable power to work within the distribution grid is very difficult. The production itself, dependent in many cases on weather conditions and used by the residential or business owner, constantly varies throughout the day. Power unexpectedly arrives in very small quantities. Quality may vary and utilities frequently have only limitation to ensure that generating equipment is maintained in good order. In most cases, economies of scale dictate that, while utilities count net-metered

distributed production toward mandated percentages of a portfolio, these odd kilowatts do not contribute to reductions in generation from fossil fuels.
One possible solution to this dilemma is the insertion of a new system that can operate on a specific geographical area of the utility's distribution grid, in concert with other systems similarly active in other parts of the larger utility operation. These smaller localized operational areas are called "microgrids," and the new localized systems are "microgrid controllers."
Microgrids are autonomous electricity environments that operate within a larger electric utility grid. The concept is not new. For years, chemical plants, refineries, military installations and other large facilities have had the ability to generate and manage their own electricity needs while, in addition, remaining connected to centrally located generation for supplemental needs.
Today, the promise of clean, locally produced, distributed energy resources from renewables is encouraging expansion of the microgrid concept. Such "micro" operation within an electric utility has the potential to revolutionize electricity distribution, permitting local renewables to substitute for higher-emitting fuels while also increasing efficiency and environmental sustainability.

### *A. The Potential Benefits of Microgrids*

Microgrids have the potential to better accommodate new demands for electricity by shifting the electricity paradigm away from an exclusive model of centralized, remote generation to one in which distributed generation from local, clean resources supplements centralized generation.
Microgrids are typically small electrical areas embedded inside of a single electrical utility's service territory. Examples of these smaller areas could be neighborhood(s), retail shopping areas, or commercial parks. The necessary elements of a microgrid are:
• Embedded distributed energy resources.
• Advanced energy storage.
• Flexible demand.
Each of these will be discussed in some detailed later in this paper. One of the primary aims of introducing microgrids into a typical utility's service territory today is to promote the use of new technologies that are becoming available for both electrical based transportation (electric cars) and advanced electrical energy storage. Without a more localized focus, electric utilities will need to attempt to upgrade their transmission and distribution facilities (a very difficult and costly regulatory and legal proposition) in order to accommodate these new items.
As anyone in the utility business today knows, building new major transmission lines is next to impossible. Getting the necessary approvals for such things as land sitting / right away and environmental impacts involves a lengthy hearing process and numerous public meetings. An extensive amount of time is required and there is no guarantee of success. Due to that risk, utilities have increasingly shied away from new transmission line construction. Only a handful of new major construction projects have occurred in the past almost 40 years. The same is true for new major new generation projects. The trend in the past 20 years has been to build smaller steam generation plants fueled by natural gas.
However, if the "intelligence" is provided in a local "micro grid" to manage the available local energy resources and serve the local demand, then utilities should be able to meet the growing demand without building major new infrastructure. They will be able to provide the improved electrical energy quality needed for the new technologies as they emerge. And these new technologies will become a reality. This requires utilities to plan today so that they can meet tomorrow's challenges.

### *B. Results*

The introduction of microgrids promises:
• Additional reliability.
• New services.
• Lower costs to the utility customer.
These benefits arise from the ability to localize the evaluation and application of proven optimization techniques to a prescribed area of a utility's distribution system. Additionally, the installation and operation of new energy sources and battery technologies permits microgrids to be largely self-sufficient. Without the introduction of microgrids, utilities will face the impossible challenge of managing effectively all of the new advances and providing the inherent benefits without the full utilization of labor- and money-saving technology.
There are additional benefits when the industry implements multiple microgrids through a region and beyond. These include:
• More complete use of generation. Today's 500 KV transmission line more than 100 miles in length operating at maximum capacity may see losses as high as 5 to 8 percent. In other words, 1000 MW electricity flow over 50 MWs — power that could supply 50,000 homes with electricity — is lost due solely to transmission. Microgrids, which can supply energy closer to the demand, avoid this loss.
• The postponement (or at least considerable delay) in the construction of new major transmission facilities. If microgrids can supply most residential and commercial needs with distributed energy resources located in close proximity to the demand, no (or little) additional high voltage transmission capacity will be necessary.
• Enhanced transmission grid reliability. Coordination among microgrids means that, whenever a disturbance occurs (manmade or natural), the Microgrid Master Controllers can accordingly answer. By reducing demand, adding more generation, and undertaking intelligent switching, the controllers can prevent an escalation that results in large-scale system blackouts. If enough demand can be quickly removed from the overall grid, cascading events do not occur or diminish to a ripple.

## 6. Roma Tre Objectives

In different countries, the introduction of the Smart Grid in electric systems is emerging in a discontinuous manner and with different characteristics depending on the context in which the various nations move. This article aims to analyze what has been achieved to date on the subject in order to highlight the current state of the art and to outline the development of intelligent networks at the international level and in our country.

A process, more cultural than industrial, that looks to the future urban and citizens, entering the heart of any sustainable development project. The concept of Smart Grid means connected to the mains power management in a flexible and dynamic, and takes into account respect for the environment and the contribution of renewable energy.

With local energy production (Distributed Generation), the Smart Grid needs to be integrated with ICT infrastructure. ICT acts at the level of distribution, monitoring and security, introducing the concept of the Internet into the power grid, which is having to manage a large amount of information that travels over TCP / IP, it needs elements such as sensors, chips, software and Smart meters that allow two-way flow of information.

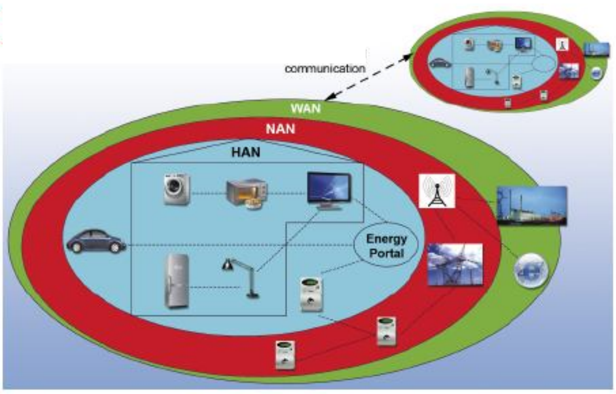



Fig. 2. [8] Segments of a communication network for Smart Grid.

Technically speaking, first of all, there is the necessity to get measurements of the electrical entities in each part of the electrical network. The Electric and Electronic Measurements Laboratory (MeaLab) of Roma Tre University is addressing its research to develop a series of instrumentation able to satisfy this exigency. A new instrument is developing for this aim (Fig. 3) [9,10,11].

The hardware is based on a personal computer that uses a new multi-platform Data Acquisition Card for Power Quality metrological certification[12] with eight channels, four connected to voltage sensors and four connected to current sensors. The firsts are voltage dividers able to partition the input voltage to preserve the analog input stage of the acquisition card channel. The maximum input voltage will be 6,000 V as required by the normative. The current sensors are Rogowski coils that give an output signals proportional to the derivative of the measured current. This implies that it is necessary to integrate their output before to pass them to the acquisition card. The choice of this type of sensor, compared with others, as amperometric clamp or current transformer, assures that the harmonic content would be unaltered. This aspect is fundamental to satisfy the harmonic analysis as required by normative[13]. The accuracy of these sensors is ± 1%. By these eight sensors, the probe is able to pick up voltage and currents of the four phases (R,S,T,N) of an electric net.

One of the most important problem in case of civil suit, it is to determine more accurately possible the time of the fault. So it will be desirable that the synchronisms of the instrument, and particularly, of the sampling, were linked to the National Time Standard. At the present, the four active probes gets the synchronism directly by I.N.RI.M., the Italian Metrological National Institute. The instruments are inserted in particular structures, the Medium/Low voltage transformer room of Telecom, the most important Italian telecommunication company, that receives the time directly from the I.N.RI.M.

To make independent the probes by the Telecom synchronism, we are studying the possibility to connect them with the GPS system. We are investigating the possibility to realize a new time reference constantly locked to the Caesium-derived GPS satellites carriers by means of a new GPS receiver architecture able to lock the two GPS carriers and mix them to obtain a reference frequency with an accuracy close to the GPS one[14,15,16].

Figure 3 shows a bloch scheme of the new instrument realized to acquire electrical energy data.

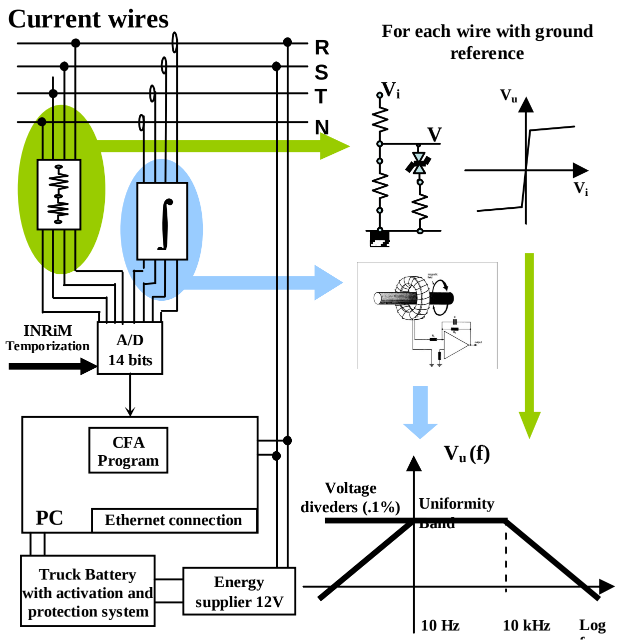
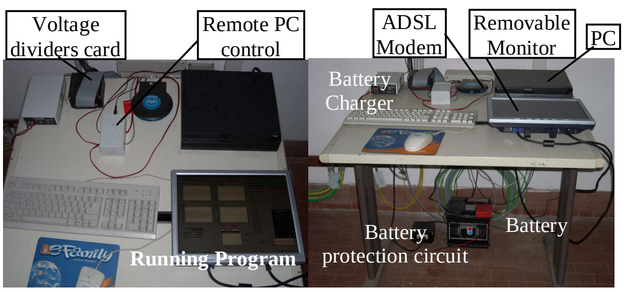



Fig. 3. bloch scheme of the new instrument realized to acquire electrical energy data.

Figure 4 shows a the new new instrument inserted in a medium-low voltage transformer room.




(a) (b)

Fig. 4. Top view (a) and front view (b) of the new instrument.

The software must be thought to satisfy the exigency to have the system under control in real time; this both for legal reasons and to reduce as soon as possible the intervention time in case of malfunctions. To respect as much as possible this constraint the FFT algorithm is not suitable [9,10,11,12], while the Curve-Fitting Algorithm, if appropriately modified, offers high accuracy performances producing results in real time[9,17]. At the present the program, that run in the probes, is able to determine the frequency of the fundamental with only three periods with an accuracy of 2‰. The program is then able to give all the Power Quality parameters required by the norms, quantifying, e.g., amplitude and frequency of the fundamental and its harmonics up to the $24^{th}$, short and long interruptions, voltage dips, supply voltage unbalance etc..

Another software problem is the accumulation of the enormous data quantity. Also this is an opened problem because the probe transforms the acquired samples in synthesized parameters every 5 seconds and store them in the hard-disk: every day is represented by about 5 Mbytes of data.

It is clear that to accumulate, to transfer and to analyze this data quantity multiplied for *n*-possible sites during a large time could be extremely hard. A possibility to solve this problem could be to send the data to a central server with a very large memory capacity and able to further synthesize the parameters, e.g., recording only the the signal trace that overcome the normative limits.

Another problem for this kind of instrument is the cost that could be unsustainable for Low Voltage Cconsumers. To overcome this problem other research on the electrical energy real expectations for this kind of consumer is fundamental to understand which aspects of the electrical energy must be pricipally analyzed. This approach is useful to plan a cheaper instrument, which can equally provide the measurements really interesting for the customers[18].

A series of these devices will be designed in the next future.

## 7. Conclusion

Since we cannot satisfy an increasing demand of energy in a limited system, as the earth is, where fossil fuel availability is running dry, the change to a Smart Grid with an energy production through renewable sources is the natural consequence. The ICT technology, which makes the Smart Grid a sort of "Internet Energy", will be the main driving force for the evolution; but the evolution does not require only technological approaches but mainly regulatory aspects. To this aim a political and regulatory contribution from Institutions is needed. The institutions will have to set up the standards (regulatory framework) to rule the operability among systems, and to organize the way in which telecommunications companies will provide the service and manage the data.

The evolution of the Smart Grid will be long but is important to be immediately involved in order to drive instead of undergo the evolution. It is important to invest now on tomorrow's ideas. Since current energy sources are not enough efficient and are very expensive, in order to reach the goal in the medium term period an evolution in the production techniques of power energy through renewable sources is expected.

## References

[1] Oak Ridge National Laboratory, Tennessee (USA) Cogeneration, "Combined Heat and Power ", Online Report, 2009 http://www.genitronsviluppo.com/2009/01/13/cogenerazione-combinare-calore-ed-elettricit-la-nuova-frontiera-oltreoceano-ottimizzare-rendere-pi-efficienti-le-risorse-energetiche-la-parola-dordine/.

[2] Joseph Swan Institute (Newcastle University) Micro-Three-Generation, "The dawn of the new energy for the home", Online Report, 2008. http://www.genitronsviluppo.com/2008/12/04/la-micro-trigenerazione-lalba-della-nuova-energia-per-la-casa-produrre-elettricita-calore-e-raffreddamento-ed-infine-recuperare-co2-grazie-un-innovativo-sistema-che-utilizza-biocarburante-sosten/

[3] David Lobell (Stanford University) "Biofuels sustainable land abandoned", Online Report, 2008. http://www.genitronsviluppo.com/2008/06/27/biocarburanti-sostenibili-dalle-terre-abbandonate-esistono-47-milioni-di-kmq-di-terre-e-pascoli-abbandonati-ecco-come-e-possibile-ripristinarli/

[4] Daniel Nocera (Massachusetts Institute Of Technology), "The Solar Energy Revolution", Online Report, 2008. http://www.genitronsviluppo.com/2008/08/01/energia-solare-anche-di-notte-una-grande-scoperta-del-mit-che-ha-innescato-la-prossima-rivoluzione-solare-la-scienza-che-copia-la-natura-la-fotosintesi-come-%E2%80%9Csistema-di-deposito-di-energia/

[5] Michael Gratzel (University of Lausanne) Without Silicon Photovoltaic: "Solar cells is copying the nature", Online Report, 2008.http://www.genitronsviluppo.com/2008/03/25/fotovoltaico-senza-silicio-le-celle-solari-che-copiano-dalla-natura-tinture-sensibili-celle-di-gratzel-e-mattoncini-lego-per-la-ricerca-di-annemarie-huijser-nuova-linfa-per-il-fotovoltaico-che-ci/

[6] Bradley Williams (Vice President of Oracle Utilities Global Business), Presented to IEEE PES Conference on "Innovative Smart Grid Technologies Europe", October 11-13, 2010,Gothnburg, Sweden.

[7] Michael Gahagan (Oracle Utilities Global Business), Presented to IEEE PES Conference on "Innovative Smart Grid Technologies Europe," October 11-13, 2010, Gothnburg, Sweden.

[8] Fabio L. Bellifemine, Claudio Borean, Roberto De Bonis, "Smart Grids: Energia e ICT" Internal Tecnichal Report of Telecom Italia, 2009.

[9] M. Caciotta, F. Leccese, A. Trifirò, "The Perceived Power Quality of Electrical Energy: an Assessment in Italy", *Proceedings of the XVII IMEKO WORLD CONGRESS, Metrology for a Sustainable Progress*, Rio de Janeiro, Brazil, 17-22 September 2006.

[10] F. Leccese, "Rome: A First Example Of Perceived Power Quality Of Electrical Energy", *Proc. of The Seventh IASTED International Conference on Power and Energy Systems ~EuroPES 2007~*, Palma de Mallorca, Spain, 29-31, August, 2007, CD-proceedings 582-084.

[11] F. Leccese, "Analysis Of Power Quality Data On Some Telecommunication Sites In Rome", will be presented on *The Eighth IASTED International Conference on Power and Energy Systems ~EuroPES 2008~*, Corfù, Greece, 23-25, June, 2008 CD-proceedings 608-086.

[12] M. Caciotta, S. Giarnetti, F. Leccese, D. Trinca: "A Multi-Platform Data Acquisition Device for Power Quality Metrological Certification," presented to 9$^{th}$ International Conference on Environment and Electrical Engineering (IEEE sponsored), May 16-19, 2010, Prague, Czech Republic, Proceedings, IEEE Catalog Number: CFP1051I-ART, ISBN: 978-1-4244-5371-9, Library of Congress: 2009909493.
[13] CEI EN 50160 (CEI 110-22) Voltages Characteristics of electricity supplied by public distribution systems edited by IEC Comitato Elettrotecnico Italiano.
[14] M. Caciotta, F. Leccese, E. Piuzzi: "Study of a New GPS-Carriers Based Time Reference with High Instantaneous Accuracy" presented to International Conference on Electronic Measurement & Instruments ICEMI'2007, August, 16 – 18, 2007, Xi'An, China, Proceedings Vol.I, pp. 1-4, ISBN: 1-4244-1136-X, IEEE Catalog Number: 07EX1748C, Library of Congress: 2007922758.
[15] M. Caciotta, F. Leccese, S. Pisa, E. Piuzzi: "A voltage controlled oscillator for obtaining a frequency reference constantly locked to L1 GPS carrier for Power Quality assessment applications" presented to 16$^{th}$ IMEKO TC4 Symposium Exploring New Frontiers of Instrumentation and Methods for Electrical and Electronic Measurements, September 22-24, 2008, Florence, Italy, ISBN CD: 978-88-903149-3-3.
[16] M. Caciotta, A. Di Liberto, F. Leccese, S Pisa, E. Piuzzi: "A System for Obtaining a Frequency Reference Constantly Locked to L1 GPS Carrier for Distributed Power Quality Assessment" presented to International Conference on Electronic Measurement & Instruments ICEMI'2009, August, 16 – 18, 2009, Beijing, China, ISBN: 978-1-4244-3864-8/09.
[17] M. Caciotta, F. Leccese, T. Trifirò: "Curve-Fitting-Algorithm (CFA) as Power Quality Basic Algorithm" , *Proceedings Of The XVII IMEKO WORLD CONGRESS, Metrology For A Sustainable Progress*, Rio De Janeiro, Brazil, 17-22 September 2006.
[18] F. Leccese: "A first analysis of Perceived Power Quality for domestic customers" presented to 12th IMEKO TC1 & TC7 Joint Symposium on Man Science & Measurement September, 3 – 5, 2008, Annecy, France, ISBN: 2-9516453-8-4.