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THE SPREAD OF SMART CITY AND POWER QUALITY REQUIREMENTS

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In view of the structural changes that the electrical system is living in recent years, deriving for the most by the increasing penetration of non-programmable renewable distributed in the territory, it feels more and more to speak about Smart City and Smart Grid for greater flexibility, efficiency and reliability of networks.

In recent decades, major changes in production systems, electricity transmission, both from the technological point of view that regulatory and economic have been. Energy efficiency, energy conservation and use of renewable sources are elements, very important, that could determine this change, for example the improvement that can be done through the relationships between smart city, smart grid and power quality (PQ). The Smart City brings many new challenges on PQ; these should result in the introduction of new technology through intelligent use of them. The scope of this paper is to give an overview of the smart city development, observing a possible correlation with the power quality.

Keywords: Smart city, ICT, Power quality, IoT (Internet of things), Smart grid

1. Introduction

Nowadays, we can clearly view how incident upon the day-by-day life and economic balances is everything that concerns the quality of perceived life, environment, human and economic system developments, and the required infrastructure for producing and delivering electrical Energy [1].

In the last decades increased and became mature the proposal of alternative development model for realizing urban development with various qualitative characteristics, focusing on "smart" systems integrated between them and comprising key points for developing the smart cities [2, 3].

Technically, the goal of Smart Cities comprises many sources of development, one of them in particular being the core of this purpose: the distribution grid, intended in a large way. Regarding the "smart grid", within its definition must be included the production and distribution of electrical energy

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with the objective to exploit a smart grid characterized by an increased level of IT (Information technology) infrastructure and capable of "multi-directional" flows of energy and information [4]. Fig. 1 shows how the Smart City concept comprises a large part of the Smart grid.

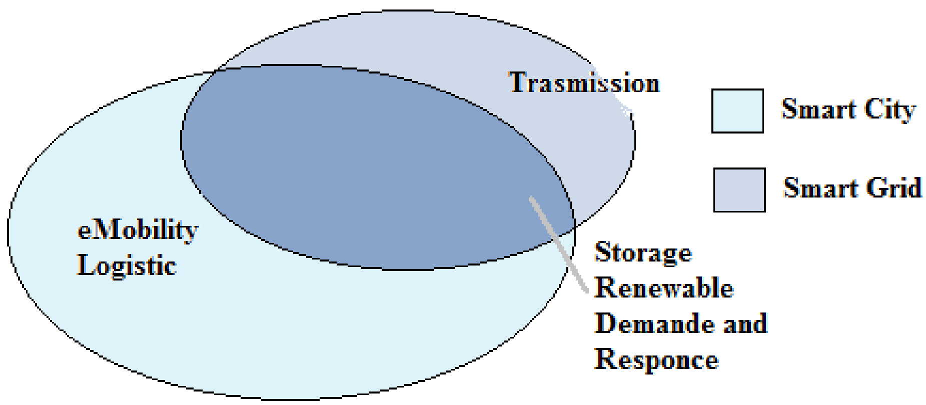


Fig. 1. Interaction between Smart City and Smart Grid

The power systems have a fundamental part in the energy framework of a country: an inadequate power infrastructure risks to defer the realization of new investments in generation plants or to constrain the operation of the power plants already in exploitation, due to the difficulty to transport the electrical energy from production location to the consumption centers [5-7].

The high diffusion of renewable sources non-dispatching has an important impact on the distribution grids; this phenomenon requires the development of the network with respect to the past model (where the power flow was from the production point to the consumption center), for facing the new case with an increasing diffusion of small capacity generators connected together with the loads. Making smart a distribution grid essentially requires to allow the utilities to control the generators (but considering also the loads) connected to its network. The control is achieved sending to the generators appropriate commands to vary their operation points (hence the active and reactive powers exchanged with the grid) to allow a safety operation of the distribution grid in presence of a high rate of interconnected distributed generators. Thus, a telecommunication network is required for the communication between the distribution network and the distributed generators. This telecommunication network must be high capillary to reach a large number of generators spread within the territory, reliable, for guaranteeing that the commands reach the destination in specified times. In addition, this telecommunication network must have low investment costs for not economically penalizing the small-capacity generators characterized by important costs [2].

The availability of a communication network superimposed on the distribution grid allows to manage the load, based on the signals provided by the power system. One of these signals is the price of electrical energy, variable on 1 hour basis through the day. The consumer can decide when he can use the electrical energy function of its price, shifting his load to the hours when the price is low. The consumer will also have the possibility to answer to the power system signals. for example, to overcome at a certain time instant the demand excess in the power system, the flexible loads can, function of a specific request of the utility, to reduce their demand and contributing in this way to the power system balance. For their availability to supply this kind of service for guaranteeing power system safety operation, the flexible loads will receive an incentive. In this way, the distribution network will go from the existing passive operation, to an active operation. Hence, the management of the distribution network will be more similar with the one of the transmission network, where the large power units are controlled in real time by the system operator [1]. The high number of small capacity generators interconnected to the distribution network that must be controlled, represents a task that the smart grids must overcome, for passing from prototype implementation to the large scale development.

2. Power Quality in a Smart City

The growth of intermittent, non-predictable and non-dispatching energy generation imposes constraints on power balance control, from primary control through optional planning, but through 'smart meters', the consumers become no (longer) passive consumers. In fact, they can monitor their own voltage and power, and manage their energy consumption based on the use of green electrical energy. The Smart City brings many new challenges, respectively managing the PQ, and the ICT must establish new ways for selective PQ management. PQ covers two groups of disturbances:

- Variations, which are continuously measured and evolved: slow voltage changes, harmonics, flicker and unbalance (EN50I60);
- Events, that occur unpredictable and require a trigger action to be measured: rapid voltage changes, dips, swells and interruptions [8].

Advanced distribution automation (ADA) is necessary for development for network operators and it is the next large step in evolution of the power systems for Smart Cities. The Smart City must be connected with different types of grids for energy, transport, lighting, consumer, intelligent equipment, etc. The Smart City may increase the use of a new types of consumption (battery charges electric vehicles, electric vehicles feed through charging station, compact fluorescent lamps, building automation 'Domotique', micro-generation), but these new types of equipment could determinate PQ disturbances, for example harmonic emissions. The modern devices could introduce new disturbances in the grid [9] which can interfere with power line communications, or could create a high disturbance level at the frequency chosen for power lines communication. With Smart City, the amount of consumption will have no provided limit; this continued growth in both production (and consumption) could lead to the harmonic voltage distortion becoming unacceptably high, and the number of switching actions will keep on increasing on might reach unacceptable values. In fact, production and consumption are in balance at the frequency of power system, but not at harmonic frequencies. This assumes however that it will know how many customers will connect in the future [10]. A Smart City could improve the performance of the power systems without the need for large investments. For the customer, the improvement can be in terms of green energy, price, voltage quality that it expected to be made by SC in the near future – undervoltages and overvoltages might be mitigated by keeping the correct local balance between production and consumption [10-12]. The ICT and the IoT could perform the control and the trade-off of all loads, taking into account also the values of the harmonic voltage disturbances when they become too high, or a harmonic filter could be turned on [13]. Micro-grids with loading capability [14] could play an important role, because of their deployment and could mitigate the voltage dips. The challenges related to the power-line could be solved by choosing the appropriate frequency [15]. The SC through the IoT will allow a continuous PQ monitoring that will not improve directly, the voltage quality but will detect quality problems helping to mitigate them [16]. PQ requires a grid wide ICT infrastructure that provides coordinated monitoring and control of the grid as the smart agents. The architecture serves as a concrete representation of a common vision that facilitates the design and development of various components of the ICT infrastructure and emergence of standards and protocols need for a Smart City. ICT infrastructure should be capable of providing for proof and nearly instantaneous bidirectional communications among the devices ranging from individual loads to the grid-wide control center including all levels. This requires high performance infrastructure capable of providing intelligent local and second responses coordinated with a higher global level analysis in order to prevent or contain rapidly evolving adverse variations and events. A distributed architectural of SC (Fig. 2) can enable the high performance infrastructure with local intelligence using new technology as:

- Proactive and adaptive control (algorithms based for example on Smart Agents);
- Embedded intelligent devices and their control;
- Integrated and secure communications;

- Internet of Things to facilitate data exchange.

SC offers the opportunity to improve the PQ, in fact despite the exponential growth of new technologies, the controlled management of all elements of energy, allows you to allocate more and more the optimal power flow.

Fig. 2. Smart City: distributed architectural

3. Renewable Energy and Power Quality in Italy

A large-scale wind, water, and solar energy system can reliably supply all of the world's energy needs, with significant benefit to climate, air quality, water quality, ecological systems, and energy security, at reasonable cost. Infact, in this paragraph they are analyzed this concepts that characterized a Smart City and possible disturbances on the electric grid. The data are collected in different periods; in particular, it has been considered a range of 6 years, in particular from 2008 to 2013 in Italy.

3.1. Distribution of Renewable Energy in Italy

Different factors contributed at the realization of SC, in particular the use of renewable energy (photovoltaic, wind, geothermal, bio-energy and hydraulic systems) are very important to do a city of type smart and green. Fig. 3 shows the typical renewable energy that they are diffusion in Italy.

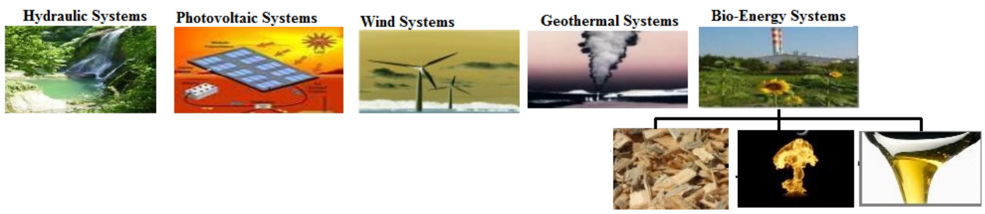
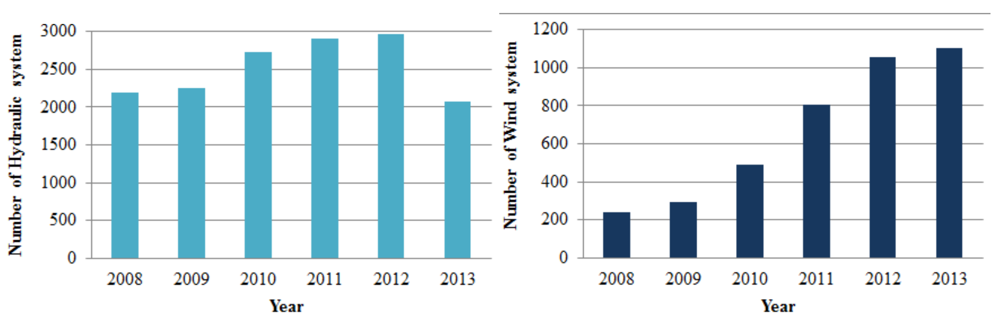


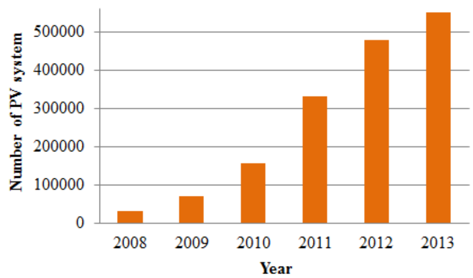
Fig. 3. Different classification for renewable energies

The annual distribution for renewable energy are shown in Fig. 4 and it is possible to observe that they have grown rapidly in recent years. One aspect to consider is the difficulty of managing the energy produced from renewable sources with regard to the unpredictability of the same, particularly with regard to the photovoltaic and wind power. Although the environmental benefits of reducing dependence on fossil fuels are obvious, the storage of large quantities of energy from renewable sources and the small-scale production still represent a major challenge to the stability and availability of electricity. The large diffusion is focused on photovoltaic and wind systems. The large diffusion is focused on photovoltaic and wind systems.

It is very important to observe the main difficulty that it derives from the intermittent nature of renewable energy.



(a) (b)



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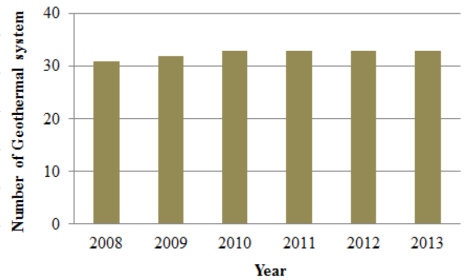

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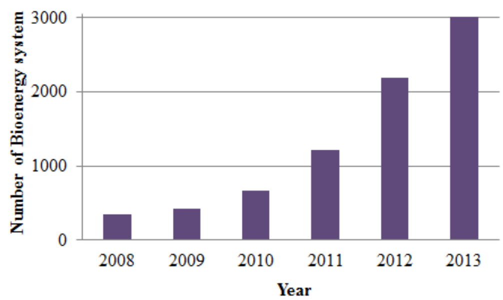
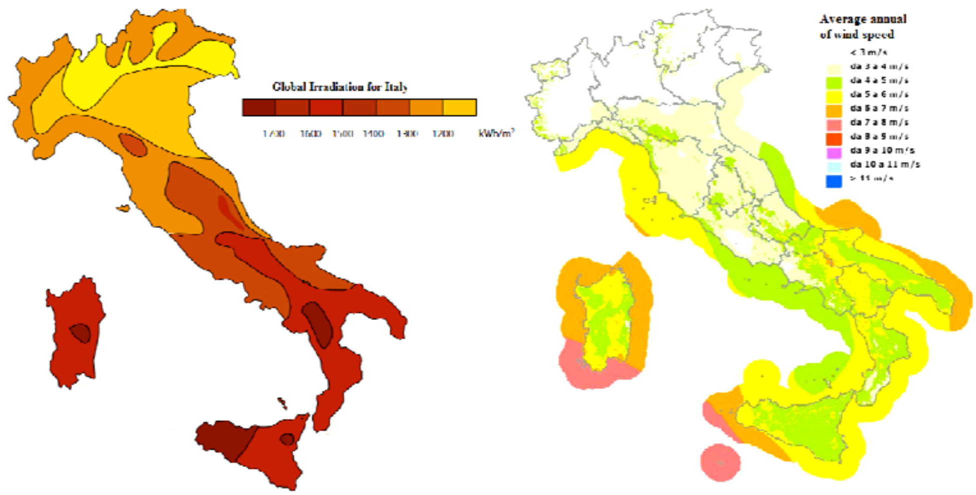


(e)

Fig. 4. Distribution of renewable systems (a) Hydraulic, (b) Wind, (c) Photovoltaic, (d) Geothermal and (e) Bio-energy systems.

While, the hydroelectric sources offer a highly predictable supply of electricity, the availability of most of the renewable resources can literally change with the wind. The energy production of the wind farms is characterized by periods of high productivity, followed by moments of not production, while the performance of PV systems are less if the weather is cloudy at night. Another challenge related to renewable energy sources is location.

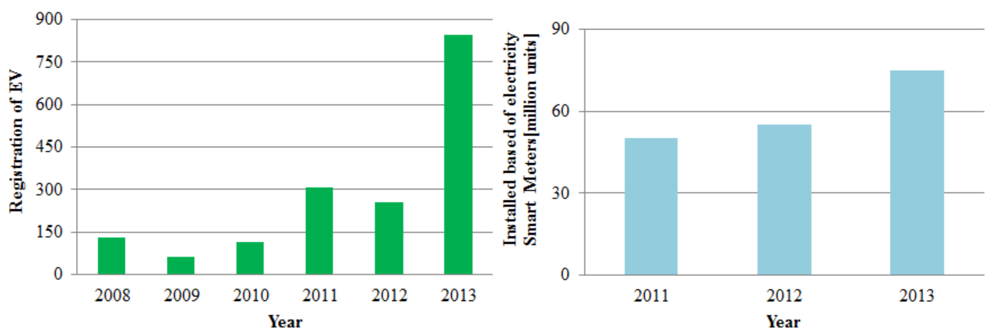
Fig. 5 shows a different distribution for the global irradiation and the wind speed. Obviously, it is possible to observe different zones where it is convenient to aim on renewable resources. In particular, the major production of energy with the PV systems is on South regions, while for the wind systems is not convenient to install them in the North regions where the wind is absent, but it will be strategic to install wind systems in centre and south Italy.



(a) (b)

Fig. 5. Different aspects, in particular (a) Global Irradiation (b) Wind speed distributed in Italy

The aspect, where the community has a particular attention is on Electric vehicle. This could drastically reduce greenhouse gas emissions in the transport sector, consistent with the type of fuel used. The idea of using electric vehicles for the storage of excess energy as a source of reserve is particularly interesting. The utility could potentially use the batteries of electric vehicles parked and connected to the electricity grid for energy storage in excess. On the contrary, in case of shortage of energy, electric vehicles could constitute a reserve rapid able to meet the peak demand, releasing pressure on utility linked to the availability of energy reserves and offering at the same time to vehicle owners a form of monetary compensation. Fig. 6a shows the registration of electric vehicles for different years (from 2009 to 2013).



(a) (b)

Fig. 6. Number of electric vehicles registration

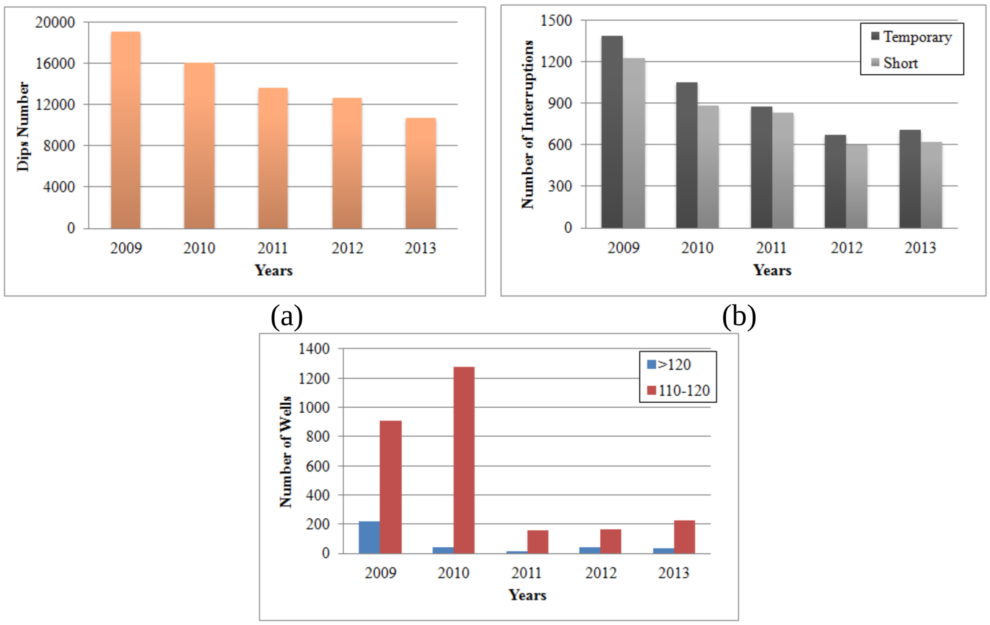
The direct consequence of the evolution of the electricity grid current in an intelligent network is to make the users able to manage their own consumption of electric energy saving on the bill. The infrastructure necessary for this transformation consists of devices capable of monitoring (metering) energy and communication of information. In last year's, different buildings have been integrated with new technology, in particular with "Smart Meter" (Fig. 6b). The integration of these components has permitted to able to communicate via a wireless protocol with management software. In this mode, if for example, these devices are configured as "smart devices" (i.e. refrigerator, washing machine, lights, etc.), they could be managed for the charging of electric vehicle. Before of 2011, the electric grid did not have intelligent instruments for monitoring the flow of energy, but now (from 2011 to today), the electric grid for 90% is under smart meter control right.

3.2. Power Quality in Italy

QUEEN is the web portal of the "Ricerca di Sistema" to get access and examine the results database of the ongoing monitoring campaign of power quality on MV distribution networks in Italy [17].
Fig. 7 shows different disturbances, in particular: voltage dips, interruptions (classified for temporary and short) and wells. In general, it can be seen that the strong integration of renewable energy and other aspects that characterize a smart city certainly did not create criticality on quality of the network.

Rapid changes, if they exceed certain limits of magnitude and duration, have negative effects against many devices that use it, especially if they are operated and / or controlled by electronic systems, which are spreading more and more in production processes. They are of particular importance transient abrupt decreases the voltage to below 90% of its nominal value, which are called "voltage dips" (Fig. 7a). In this case, it is possible to observe the high decrease of the number of this disturbance.

The interruption is characterized by the duration as the magnitude is more or less constant and it might follow voltage sag if the sag is caused by a fault on the source system. Following circuit breaker operation, the system gets isolated and interruption occurs. In Fig. 7(b), it possible to observe as this disturbance is increased and for years from 2009 to 2013, it is decreased. This situation is possible because the entry of new technologies have led to an increase in the disorder as it does not have been accompanied by a smart grid. Over the years, the situation has improved due to the possibility of intelligent control of the network and of the 'coming of the smart city.



(c)

Fig. 7. Distribution of different disturbances, in particular (a) voltage dips, (b) interruptions and (c) wells

In Fig. 7c, the overvoltage is an increase of Root Mean Square (RMS) voltage magnitude for longer than one minute. Typically, the voltage magnitude is 1-1.2 p.u. and is caused by switching off a large load from the system, energizing a capacitor bank, poor tap settings on the transformer and inadequate voltage regulation. It can cause equipment damage and failure. Overvoltages with duration of 0.5 cycle to 1 min are called voltage swells. A swell is typically of a magnitude between 1.1 and 1.8 p.u. and is usually associated with single line to ground faults where voltages of non-faulted phases rise.

4. Conclusions

In this paper, the aim of study is to present the analysis of the possible correlation between Smart City and Power Quality.

In particular, it has been analyzed Italy on a period of five years (2009-2013), where it is possible to observe the integration of renewable energy, smart meter, electric vehicles and different factors to improve the environment and quality of life.

The recorded measurements have been analyzed to find a possible correlation with power quality and new factors generated of Smart City. The first consideration is that this new Smart scenario did not generate criticality into the grid, but rather it would seem that they have improved. The combination of the power quality and Smart City is optimal for the stability of the network as their capabilities enable the rapid and automated detection of anomalies while reducing the problems and downtime and improving quality. More attention is on the interaction between grid, citizen and city. The scope of this interaction has the aim of making sure that, the city becomes more suitable to the needs of the citizen and the citizen becomes increasingly active in the creation of a sustainable city.

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