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TO DEVELOP FUTURE ENERGY SYSTEM BY THE RENEWABLE ENERGY BASED SMART-GRID IN DISTRIBUTION NETWORK

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ABASTRACT: *By optimizing the energy consumption to increase the efficiency in the distribution of electrical energy, reduction of greenhouse gases, in order to increase the proportion of energy from renewable energy sources, distribution network and more intelligent devices it should be connected. The development of the future of the energy system is based on the planning and management of the distribution system on the basis of the principles of smart grid (SG). This approach, the realization of smart logistics system, active participation of demand, not only the availability of energy storage, in order to enable the integration of renewable energy sources, innovative control and information and communication technology (ICT) It includes a wide range of use of the system (RES) and distributed generation (DG), as well as electric vehicles has increased. In the paper, to open the problem in the development of power distribution by smart grid, it has a review of the challenges and possible solutions main current is presented*

KEYWORD: Smart grid; Information and communication technology; Distribution management systems; Distributed energy sources

INTRODUCTION

The development of the future energy system will be based on planning and management of the distribution system in accordance with the philosophy of Smart grid (SG). This approach involves the extensive use of Information and Communication Technology (ICT) and innovative control systems in order to enable the realization of smart distribution systems, the active participation of demand, the availability of energy storage, as well as the integration of Renewable Energy Sources (RES) and Distributed Generation (DG), as well as the growing number of electric vehicles. The distribution industry is facing the problem of the connection and integration of renewable and other generation plants to networks which have traditionally carried electricity from transmission systems to final consumers in one direction only according to a passive network management scheme. New power flow patterns may require changes to control strategies, enhanced distribution automation, enforcement of distribution network infrastructure and/or greater degrees of information management and control according to the SG paradigm In

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this context, as depicted in Fig. 1, Distribution Net-work Operators (DNOs) will need to control electricity productions, consumptions and storage, as well as power flow by means of a Distribution/Energy Management System (DMS/EMS), also able to manage the evolution of the distribution network towards a more flexible structure. The possibility of having a large number of controllable Distributed Energy Resources (DER), DG units and loads under Demand Side Management (DSM) control, electrical vehicles (EV) and distributed storage (DS) requires the use of a hierarchical control scheme, which enables an effective and efficient control of this kind of system, where the DMS operates at the higher level and is able to exchange information with local control systems. The increasingly significant use of management systems based on automatic controls and advanced ICTs for the network management will lead to the realization of active networks and SGs. In particular, in the development of smart distribution grids, a multidisciplinary approach will be necessary and focused on the development of new communication systems and their interfacing with the power system elements and the development of DMS/EMS able to manage in a smart way the distributed system for energy production, consumption and storage. The paper is organizes as follows. In the first Section the review of the main currently available and more promising future wireless and wired communication systems for smart grid are presented In the second Section the main aspect related to the interfacing of ICT infrastructures with power system infrastructures are discussed. In the third section the importance of the energy management system in the coordination/optimization of the distributed resources is underlined, in particular considering the expected smart behavior of generation and loads discussed in Section four. The final section underlines the importance of the combined planning and simulation of the whole cyber-power system that will establish the future smart grid.

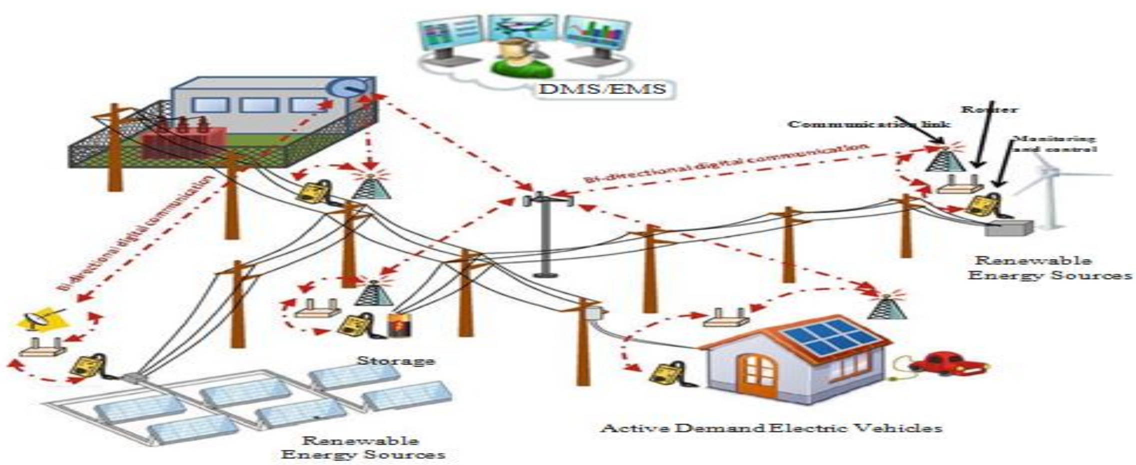

Fig. 1 The Smart grid scenario

Communication systems for the smart grid

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Communication technology is seen as an essential enabling component of future smart grids. In particular, the smart metering, protection and control communication is the major component of the overall smart grid communication architecture and consists of smart meters, protection and control systems which are two-way communicating devices with the central SG controller. The whole system could be organized according to hierarchical structure with a Home Area Network (HAN) formed by appliances and devices within a home to support different distributed applications, Neighborhood Area Network (NAN) that collects data from multiple HANs and deliver the data to data concentrator, Wide Area Network (WAN) which carries metering data to central control centers and, finally, a Gateway which is in charge of collecting or directly measuring energy usage information from the HAN members and that transmits this data to interested parties. All the above network scenarios have different communication requirements and several communication technologies could be employed to fulfill them. In Fan et al. (2013) a deep analysis of communication requirements and capabilities of the different type of net-work is presented. In the following we give an overview of the potential technologies suitable for smart metering by distinguishing between wired and wireless systems.

Wireless communication systems

Wireless architecture can be either an option for HANs, NANs and WANs, or mandatory in case of Vehicle-to-Grid (V2G) communications. Due to the heterogeneity of the smart grids composed by a 10–20 km geographically extended distribution networks with a large number of power generating sources and energy consumers, multiple communication technology and standards could coexists in different part of the system. For HANs and NANs where the coverage range vary from tens to hundreds of meters, IEEE 802.15.4 (ZigBee) and IEEE 802.11 (Wi-Fi) are suitable technologies for smart meter while for WANs where tens of kilometers are the coverage requirements impose the use of cellular wireless networks like GPRS, UMTS or future LTE, or broadband wireless access net-works like IEEE 802.16 m (WiMax) can be used to the interface between meters and central systems. Wireless Sensor Networks (WSN) is a new frontier for wireless communications for smart grids especially for metering purposes within the framework of Internet of Things (IoT) Pilloni and Atzori (2011) and Machine-to-Machine (M2M) communications Wu et al. (2011). Furthermore, another alternative could be a serious contender: low-cost frequency shift keying (FSK) radios in the white-space spectrum. White spaces are open TV channels in the VHF and UHF regions. TV white spaces are unused TV broad-cast channels made available by the recent transition from analog to digital TV. As part of the National Broadband Plan, the Federal Communications Commission (FCC) has declared that TV white spaces are well suited for wireless data networks and can be used to deliver cost-effective broadband connectivity for a wide variety of consumer, business, and government applications. Because of the lower frequencies involved, white-space radios inherently have a longer range and a greater link reliability, even without a line-of-sight (LOS) path, than Wi-Fi, ZigBee, and other radios operating in the microwave bands. This makes them attractive for robust control links in the utility industry as well as for providing a solid consumer-to-utility

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connection. White-space radio modems can deliver a data rate of 1–3 Mbits/s in a 6-MHz channel at a range up to 4 miles reliably in a non-LOS environment. Base stations can run up to 4 W. TV channels 2 through 51 include the VHF frequencies in the 54–216-MHz range and UHF frequencies in the 470–698-MHz range. For instance, in the U.S. market there are lots of white spaces across the US country, but the available channels vary widely from area to area. White spaces are easy to identify thanks to a unique geo-located database developed by Spectrum Bridge Inc. Now, Spectrum Bridge, Plumas-Sierra Rural Electric Cooperative & Telecommunications (PSREC), and Google have launched the nation's first wireless network trial using TV white spaces to test their viability in the Smart Grid. The test is underway in Plumas-Sierra County in California. Since white spaces provide outstanding propagation characteristics, the ability to penetrate foliage, and non-LOS connectivity, PSREC chose them to enable Smart Grid technologies and investigate more efficient ways to manage its supply of and demand for electricity, improve system control and data acquisition (SCADA) with PSREC sub-stations, and provide broadband Internet access to under-served areas. The PSREC application uses a channel in the 550-MHz range. The range is exceptional at these frequencies, with even more range possible with higher antennas. The only downside is that these low frequencies require longer antennas. PSREC currently employs a wide variety of wireless solutions across multiple frequency bands, but still faces challenges in some areas due to challenging terrain. To prevent the TV white-spaces net-work from interfering with licensed television broadcasts and other protected TV band users, the system operates under the control of Spectrum Bridge's intelligent TV White Spaces database. The base station radios link to the database via the Internet. The database dynamically assigns non-interfering frequencies to the white-spaces transceiver, which then adapts in real time to new TV broadcasts as well as other protected TV band users operating in the area. Spectrum Bridge's database technology underlies the TV White Spaces trial network and allows it to operate efficiently and without causing interference. TV white-spaces availability can be determined for any location in the USA further protection level can be introduced by enabling base station to locally perform spectrum sensing

The bridge between the communication and the power system

Wireless or wired communication technology need to accomplish to IEC 61850 (IEC International Electro technical Commission 2008) standard to be used with distributed energy resources and power distribution networks. Intelligent Electronic Devices (IED) with security features and control are becoming standard equipment for power system components, new substations and are also used to improve the systems of protection and control of existing substations. Microprocessor based protection relays provide, in addition to the basic function of protection, different functions, such as measurement, data acquisition, recording events and disturbances, tools for failure analysis, and control. The combination of these functions with the substation LAN or WAN with utility, results in a system of protection and control of a hierarchical distributed intelligence. It is therefore necessary to identify new network architectures in order to be able to analyze, store, integrate and process the increasing quantity of information available in the various devices. Objective of defining such a structure, in IEC61850-level communication substation, is to implement an architecture characterized by

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high-speed, expandable, and ‘‘peer-to-peer’’. A further challenging aspect in the smart grid environment is the necessity to define a control architecture that can handle the complexity of future distribution networks and build a bus of information accessible to the various control functions that can exchange the information of the state of the system on the basis of a common format. The large number of proprietary formats used nowadays by DMS applications requires many translators to import and export the data between multiple systems. This exponential growth in complexity when integrating increasing numbers of applications and exchanging between multiple companies has driven the requirement for a common format that covers all the areas of data exchange in the electrical power domain (as reported in Fig. 2).

In this sense the development of the IEC 61968 for the exchange of information of the distribution networks based on CIM (Common Information Model) is trying to address such issue (IEC International Electro technical Commission 2008). As it is evident that the communication infrastructure and the power system domain are becoming more and more interdependent do to the massive use and necessity is active and advanced control into the distribution network.

Energy management systems in the smart grid

In order to support the complexity of the smart grid architecture, current and emerging smart devices should be integrated at different levels. Smart devices or Intelligent Electronic Devices (IEDs) are, indeed, responsible for real time monitoring and control at all levels of the smart grids, ranging from the transmission level to the building/home level and the highest the number of installed smart devices is, more flexibility is given to the smart grid

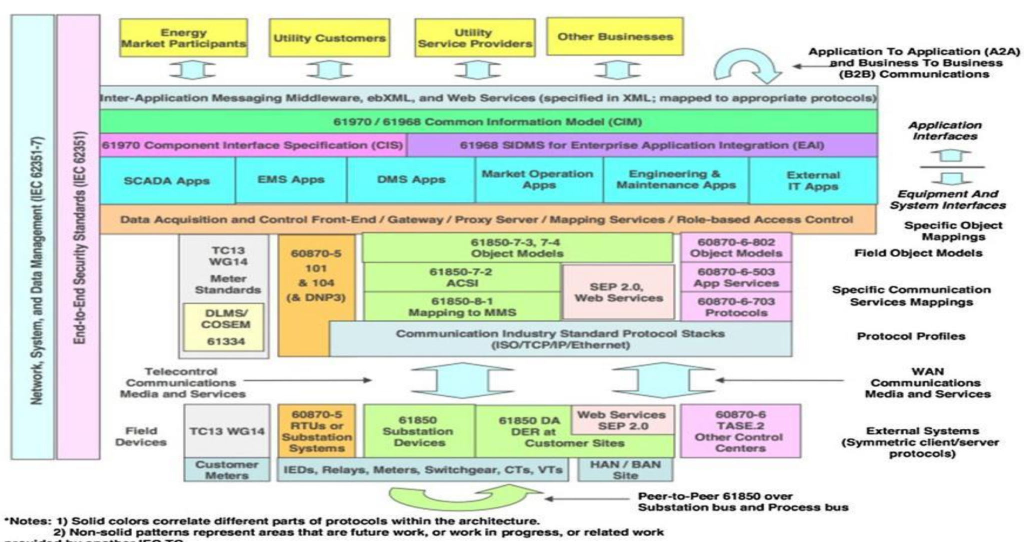

Fig. 2 TC57 reference architecture

At transmission and distribution levels, centralized generation based on automated generation

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control systems (AGC) should be integrated with modern energy/distribution management systems (EMS/DMS) and supervisory control and data acquisition (SCADA). EMS/DMS and SCADA systems are used to manage data from distributed elements of the transmission and distribution system. The SCADA system transmits the measurement data, provided by an advanced meter infrastructure (AMI) and by a set of remote collecting data devices (RTUs) placed in strategic positions along the smart grid, to the EMS/DMS. The latter determines the actions required for the optimum state of the SG by using state estimation algorithms (SEAs) and Generation and load forecast system (GLFS) (Siano et al. 2010; Chen et al. 2010). Another smart girds related critical domain requiring smart devices is metering and AMI is actually the most widespread technology (Pilo et al. 2011).It consists of a smart meter end device, a wireless communication network, data backhaul network, and a meter data management system (MDMS) back office function. Distribution Automation (DA) includes geographic information systems (GIS), asset management systems (AMS), outage management systems (OMS), which will ultimately be entrusted in DMS. These smart devices are required for power flow congestion, voltage regulation, distributed generation (DG), load control, and fast reconfiguration Appropriate control and communication architectures are also required to complement and enhance these structures and to operate the smart grids in both connected and islanded mode (Siano et al. 2010; Mohsenian Rad and Leon-Garcia 2010). On the control side, different control techniques can be exploited for the control of the smart grid: local and centralized. In the local strategy (Pilo et al.2011), the control law is based on local measurements and local a priori knowledge of the smart grid, while there is no explicit use of any communication channel. As such, this approach largely disregards the theoretical and practical issues of distributed control and communication. The centralized approach, instead, consists in defining a rigorous optimization problem, where the decision variables are the control variables of each power converter connected to the smart grid, and the cost function to be minimized includes global performance metrics as power losses, voltage drop across the distribution links, and grid stability (Siano et al. 2010; Chen et al. 2010; Gungor et al. 2011). This approach yields large-scale, non-convex optimization problems, the solution of which requires the presence of a central controller capable of collecting data from all the devices and controlling. The main limit of the centralized control strategies is that they are infeasible in practical settings, mainly for scalability problems. Moreover a centralized control strategy results in a ‘‘single point of failure’’, thus requiring redundancy in control and communication hardware. Although the centralized option will be the preferred solution in the short/medium period, a long term perspective will prefer a distributed strategy Some recent researches confirm that most advantages that the smart grid will bring, if compared to actual power system, are due to its capability of improving reliability performance and customers’ responsiveness and encour-aging greater efficiency decisions by the costumers and the utility provider. These improvements will be favored by communication systems and sensors, automated metering, intelligent devices and specialized processors. For instance, smart metering and advanced ICT solutions for energy management in buildings emerge as a tangible

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opportunity to improve energy savings, to exploit renewable resources and to support participation of customers to the energy market (Chen et al. 2010). The smart building will, thus, represent the main element of the smart grid where the monitoring of real time energy and environmental data will allow energy control and electricity price forecasting at transmission and distribution levels.The development of the private energy management industry will, therefore, favor building energy management systems (BEMS) and home energy management systems (HEMS). These systems are based on some combination of metering and sub-metering, customer portals, in-home devices (IHD), including load control switches, smart thermostats and lighting, HVAC. The HEMS is the primary service interface to the customer, it may communicate with DMS via the AMI or via another means. The HEMS manages remote load control, monitoring and control of distributed generation, integration with building management systems and the enterprise.

Smart behavior of distributed energy resources

The key factor for smart grid break-through is the flexibility of the behavior of a large number of controllable distributed energy resources, including DG units, storage systems and loads, including electric and hybrid vehicles. DERs are typically small sized and dispersed in the electric distribution systems. Moreover, different types of DERs can be installed in a single site, for instance photo-voltaic generation, controllable loads, electric vehicle, cogeneration facility can be present in a single house. DG units at distribution level typically use renewable energy sources, such as solar radiation and wind. It is evident that DG units are consequently not dispatch able. Another type of generation facility at users' premises is represented by Combined Heat and Power (CHP) systems. The flexibility of CHP systems is restricted by the technical constraints of the adopted conversion process and by the limits on the thermal load variation. Such flexibility can be increased by introducing thermal energy storage systems.

Electric energy storage has a key role in smart grids because it enhances flexibility of renewable DGs and of loads. Most of the problems in power quality, distribution reliability and power flow management can be solved with energy storage devices. Concerning the technologies, the storage can use capacitors or super-capacitors, mechanical power of flywheels, electrochemical processes of batteries. Indeed, all these technologies are in constant evolution and the research mainly aims at reducing their costs, which presently do not allow a wide spread of storage systems. For this reason, the main contribution to increasing distributed storage capacity is expected to be given by hybrid/electric vehicles which will spread for sustainable mobility. These vehicles are plugged into the network for recharging but at the same time represent a distributed energy storage system which can contribute to optimal smart grid management. The burden of electric The flexibility of the various DERs can be aggregated to realize the ''active demand'', that is the active participation of DERs, owned by users, to the optimal management and operation of the smart grid. To this aim, DERs are used to provide services to the smart grid, such as voltage regula-tion and power flow control, tertiary active

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power reserve, load management, active power balancing. 0. Since DERs are small sized, dispersed in the grid and affected by uncertainties, it is necessary to ‘‘collect’’ their flexibility to obtain significant and reliable services. Such a task can be assigned to new management and control devices as well as to new players which occupy intermediate levels, in between the users and the Distribution System Operator. An example is the ‘‘Aggregator’’ in the ADDRESS project (Belhomme et al. 2009), who is the key mediator between the consumer one side and the other players in the electric energy distribution sector: on one side, he collects the ser-vices coming from the markets and, on the other side, he gathers the flexibility provided by consumers to form products that can be offered on the markets.

Combined planning and operation of the power and the communication system

The complexity of the several aspects underlined in the previous sections requires to rethink the planning of the power distribution networks. In fact, up to now the planning of distribution networks has had the objective of defining the best expansion plan of the system for ensuring adequate capacity (e.g., substation transformers, MV/LV stations, feeders) to meet the load forecasts within the planning horizon, but, in the transition towards the SG a key challenge of the distribution planning is the integration of all distributed energy resources (i.e., generators, energy storage, electric vehicles, controllable loads) that are going to be connected to the system Pilo et al. (2013). In this technology that is going to be implemented in distribution networks. This requires applying at distribution level techniques that have been used for decades in the trans-mission system. The future availability at the distribution level of an operation system is changing the objectives of system planning that will be mostly oriented to the maxi-mum exploitation of existing assets and infrastructures, by operating them much closer to their physical limits than in the past. The hosting capacity for RES can then be increased with less network investments since operational issues can be fixed with the so-called ‘‘no-network’’ solu-tions. The novel planning methodologies are intrinsically capable to select the integration of RES by incorporating ‘‘no-network’’ solutions as valid planning alternatives. Table 2 shows the most common issues in the distribution system arising from the current high integration of renewable generation. Communication capabilities are required at load level. interval. Typical examples are washing machines as shift able loads and lights as curtail able loads. In both the cases, smart control and context, new models and methodologies for planning have been proposed in the scientific literature and are still under improvement in order to take into account all the possibilities offered by the automation and communication Novel planning techniques should integrate operation models within planning as well as the models of the communication system. The simulation planning tools have to be capable of reproduce fluctuating renewable generation caused by the moving of cloud patterns and/or to simulate local meteorological conditions that can degrade

Table 1 Network and no-network solutions in modern distribution planning

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Challenge	Current solution	Future alternatives
Voltage rise	Reinforcement Operational p.f. 0.95 lag. Generation tripping	Volt/VAR control Storage Generation curtailment On-line reconfiguration
Voltage drop	Reinforcement Fixed capacitor banks	Volt/VAR control Storage Demand side response On-line reconfiguration
Network capacity	Reinforcement	Storage Generation curtailment Demand side response On-line reconfiguration

CONCLUSION

In order to increase efficiency in the distribution of electrical energy, optimize energy consumption and increase the percentage of energy from renewable sources, thereby reducing emissions of greenhouse gases, the distribution networks and the equipment connected to them should be made more intelligent. The development of the future energy system will be based on planning and management of the distribution system in accordance with the philosophy of Smart grid (SG). This approach involves the extensive use of Information and Communication Technology (ICT) and innovative control systems in order to enable the realization of smart distribution systems, the active participation of demand, the availability of energy storage, as well as the integration of renewable energy sources (RES) and Distributed Generation (DG), as well as the growing number of electric vehicles.

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