

# An Overview on the Smart Grid Concept

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# The Smart Grids Concept

- A Smart Grid (SG) has been defined by the Smart Grids European Technology Platform as “an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers, in order to efficiently deliver sustainable, economic and secure electricity supply”.
- The primary goal of a SG is to deliver the optimal amount of information and load control for customers, distributors and grid operations in order to reduce system demands and costs while increasing energy efficiency.
- The SG concept is naturally associated with the production of energy through the use of Renewable Energy Sources (RES), promoting social benefits like reduced emissions, lower energy costs, greater flexibility to accommodate new renewable distributed energy sources.
- These results can be achieved by the integration of many different technologies including Information and Communication Technology (ICT) necessary for making the energy demand and production more predictable and controllable.

# Context

- An Introduction of Active Network Management and Smart Grids
- Some Research Activities on Smart Grids
- Application of Power Electronics on Smart Grids
- Control and Automation Methods of Smart Grids
- Application of Computational Intelligence Methods
- Electric Vehicles and Smart Grids
- Design and Planning Methods of Smart Grids
- Smart Metering and Demand Side Management
- Economic Aspects and Liberalized Market Related to Smart Grids

# Active Network Management (ANM)

- Active Network Management forms one area of work within the SG concept and is expected to emerge as the preferred solution for the connection and operation of distributed generation (DG).
- Active Network Management is concerned with the connection and operation of DG in real-time network constraints and can be efficient in network development for connecting increased levels of Renewable Energy Systems (RES) and DG.
- Active Network Management includes the management of distribution network constraints to support the extension of DG and RES. The most recent literature on the active distribution networks proposed methods for managing the system in order to make better use of available resources.
- The Active Power Management will be based on network management by using real-time communication and remote control.
- ICT based systems, state observation methodologies and identification techniques will be required in order to develop innovative strategies able to estimate both changes in system parameters and to carry out real time automation.

- In order to design a reliable, highly secure, and manageable SG, open communication infrastructures connecting the parts of the grid and distributed intelligence will be required.
- SGs are expected to provide self-corrective, reconfiguration and restoration to handle with load variability and market participants in real time.
- This result can be achieved using intelligent equipments and smart routing algorithms, thus dealing with very complex systems.
- The purposes of SGs design are, among others, to create controllable assets, to increase the power system performance, security and reliability and decrease operations costs and environmental pollution.

# Power Electronics Applications in SG

Distributed Energy Resources (DERs) that can be installed in a SG, usually, **are not suitable** for direct connection to the electrical network due to the fluctuating characteristics ( and the poor quality of the produced energy

- For such a reason, energy conversion systems, based on power electronic devices, are required.

- Advancements in the field of power electronics in combination with modern control strategies for inverters offer a variety of operation strategies for efficient system management.

- **Future inverters need to be flexible and intelligent** and must be able to support any local conditions. SGs claim integration as the basic needs for a secure future power supply.

- In the field of power electronics applications in a SG, Flexible AC Transmission System (FACTS) and High Voltage Direct Current (HVDC) will be helpful to provide fast dynamic voltage control, power flow and stability control of the power grid while increasing efficient utilization of transmission assets.

- The combination of FACTS and HVDC control with Wide Area Stability Control and Protection Systems will exploit control capabilities of both technologies to achieve fast stability control of the SG and to avoid the system blackouts.
- The voltage control devices consist of shunt reactors and shunt capacitors, tap-changing transformers, synchronous condensers, synchronous generators, Static Var Systems (SVS), Converter-based FACTS controllers such as Synchronous Static Compensator (STATCOM), Static Series Synchronous Compensator (SSSC), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC), Generalized Unified Power Flow Controller (GUPFC).
- The **Converter-based FACTS have excellent dynamic reactive power and voltage control capability**. If suitable damping controllers will be designed, FACTS devices can accomplish appropriate damping for small signal disturbance.
- Advanced components are used in the SG including next generation FACTS, power quality devices, advanced energy storage, fault current limiters, superconducting transmission cable and rotating machines, advanced power electronic switches and conductors.

# Control and Automation of SGs

- Advance integration of telecommunication, sensing, control, and optimization have been recognized to help achieving adaptive interaction, self-healing, efficiency and reliability of SG.
- Advanced control methods should provide real-time forecasting by using computational intelligence methods.
- The required real-time data required by wide area monitoring and control systems will be provided by smart sensors and sent to the system main controller that should be much faster and more accurate than traditional Supervisory Control and Data Acquisition (SCADA) control systems.
- The increasing complexity and nonlinear nature of future SG will require, in particular, fast and accurate online monitoring systems such as a wide area monitor (WAM) and effective control systems such as adaptive wide area controller (WAC).
- Next Figure shows a summary of the major functional elements to be considered in the SG design.

- The Wide Area Monitor is essential for SGs in order to carry out functions such as self-healing, fault-tolerance and dynamic optimization.
- An optimal WAM system, based on a Radial Basis Functions (RBF) neural network has been developed in to identify the input-output dynamics of the nonlinear power system.
- The Wide Area Controller acts as a global controller to coordinate the actions of local controllers including those on a wind farm.
- Each local controller connects with the WAC and receives remote control signals from it, thus improving system dynamic and transient performances.

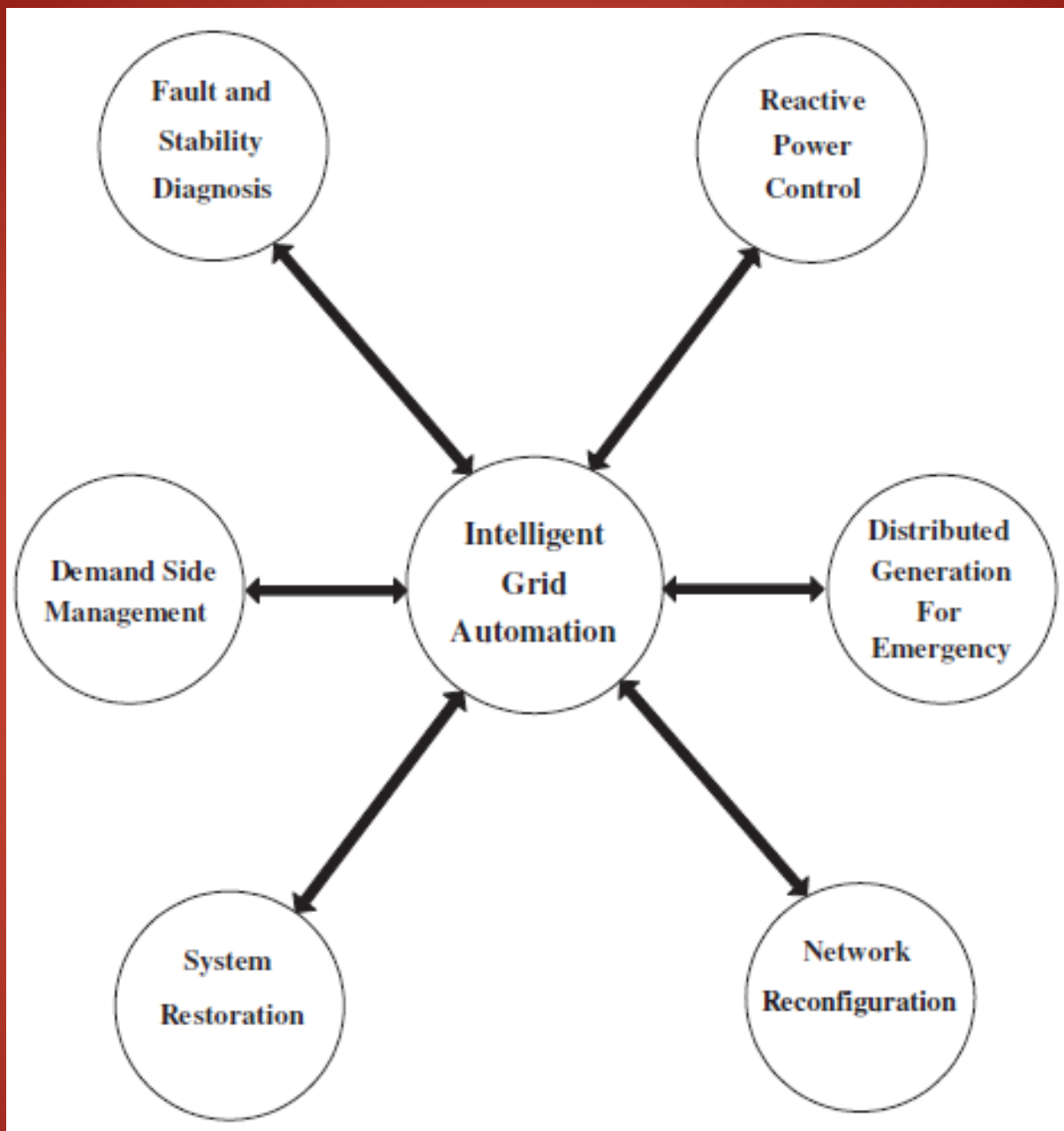


Fig.1. Smart Grid Intelligent automation functions

## Control of SG with DG and RES

- RES such as Wind Turbines (WT), Photo Voltaic (PV), and Combined Heat and Power (CHP) systems are set up at different levels in power systems.
- Output power from the RES can be controlled by the central supervisory controller for achieving various requirements in the grid.
- A supervisory controller should take care of the optimal power flow, Volt/VAR optimization in the grid.
- For efficient, secure and reliable operation of SG, voltage control and VAR management require various voltage control devices installed at different locations of the systems.
- WTs have various remote control options with regard to active power control such as maximum power control, power limiter control, delta control, balance control.

# Computational Intelligence Methods

- Computational Intelligence (CI) can endow smart grids with innovative, powerful and effective tools summarized in next Figure. CI adaptive methods can contribute to achieve intelligent behavior in complex and changing domains.
- These adaptive approaches include artificial intelligence paradigms able to learn from experience [34] that can be combined to form hybrid methods resulting in Neuro-Fuzzy systems, Neuro-Swarm systems, Fuzzy-Particle Swarm Optimization (FPSO) systems, Fuzzy-Genetic Algorithm (GA) systems, Neuro-Genetic systems, ant Colony Optimization and Immune Systems, etc.
- The challenges that are facing the CI include structure of neural network, learning method, training range, long convergence time, etc.
- There are several CI applications for the SG including energy and power flow management algorithms.
- Adaptive design tools and Particle Swarm Optimization-based fuzzy logic have been demonstrated to carry out optimal energy dispatch in a grid with a photovoltaic system.
- The typical paradigms of CI are illustrated in the next Figure 3.

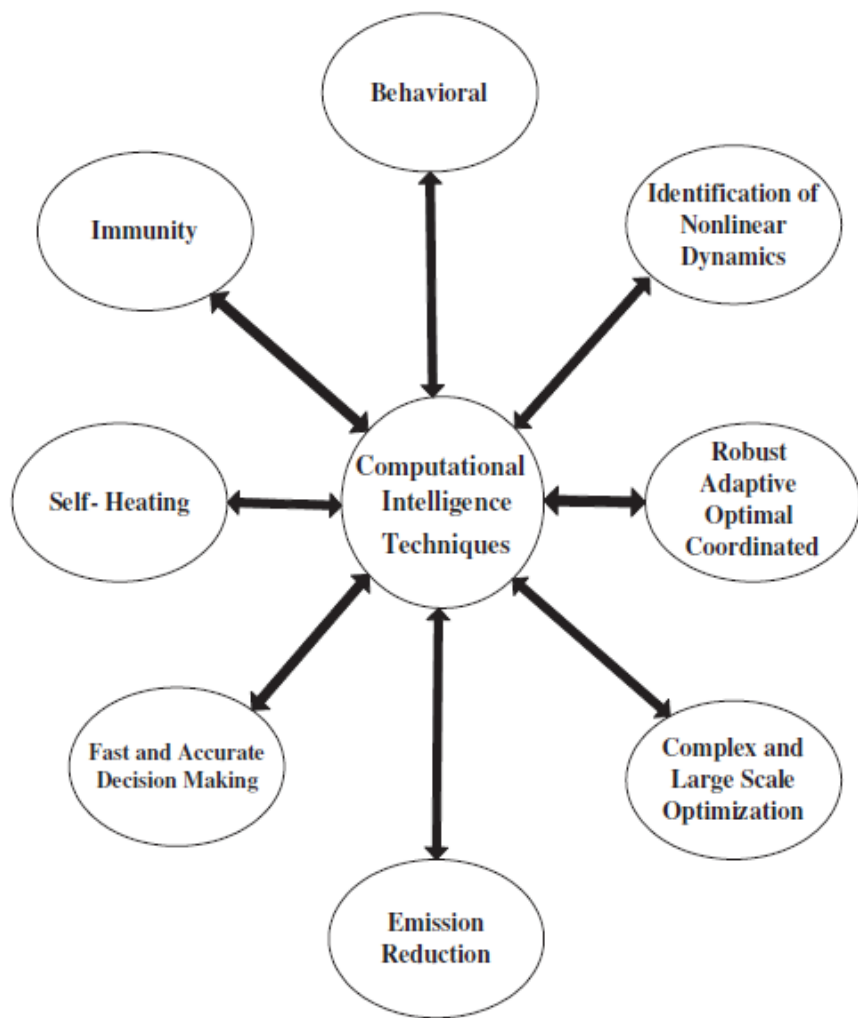


Fig.2. Capabilities of Computational Intelligence Methods for Smart Grids.

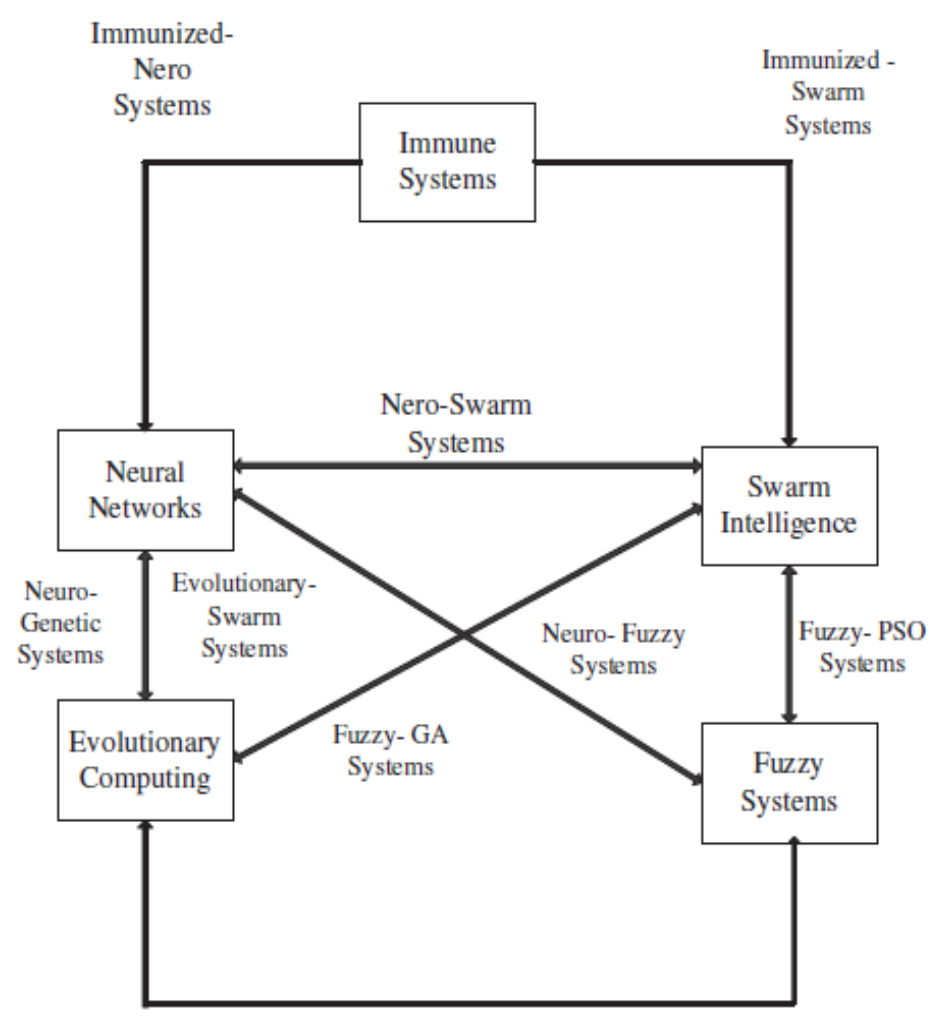


Fig.3. Typical Paradigms of Computational Intelligence Methods

# Electric Vehicles and SG

- As in the next years there will be millions of decentralized renewable power sources, the role of the grids is becoming very significant in order to balance the energy demand variations with the variable power generation from RES.
- Moreover, the grid operators will employ advanced energy management approaches to supply a huge number of public and private remotely metered recharging stations where plugin vehicles can charge/discharge.
- For organizing optimal usage of stored energy in these vehicles, innovative intelligent methods will be required.
- These vehicles, when parked, can inject power to the grid, known as vehicle-to-grid (V2G), or absorb power from the grid to charge the batteries, known as grid-to-vehicle (G2V).

# Design and Planning Methods for SGs

- Distribution network expansion planning is concerned with determining an optimal network configuration which can meet electricity demand, within safety and operational constraints, at a minimum cost.
- Investments on the network are made to develop the network due to the growth in demand or the renewal of ageing assets.
- Many approaches to find an optimal network expansion planning have been reported such as mathematical optimization methods and heuristic planning methods multiple objective methods, evolutionary optimization techniques.
- In stochastic programming has been introduced as a potential decision support tool to aid network planners in the long-term expansion planning process.
- Recent progresses in Artificial Intelligence have developed Adaptive Dynamic Programming (ADP) as an approach to manage complex power system problems with prediction under uncertainty conditions.
- Development of Stochastic Optimal Power Flow (DSOPF) as a computational tool in design of SG has been extended in.

# Smart Metering and Demand Side Management

- A SG generally involves the application of smart meters, sometimes called Advanced Metering Infrastructure (AMI), which usually includes control and monitoring of devices and appliances. Smart metering technology will be the foundation of any SG design.
- The most viable communications technologies for the Advanced Metering Infrastructure are wireless and Power Line Communication (PLC).
- Narrow-band PLC systems appear to be well suited to implement the SG due to their inherent low cost.
- Bannister et al. have shown that the Orthogonal Frequency Division Multiple Access (OFDMA) protocol, which combines frequency diversity and “orthogonality” with a multiple access scheme, offers a robust solution to the problems of narrow-band communications systems.
- Customers will have the chance to decrease their electricity bills by changing consumption from higher-priced hours to lower priced hours and smart metering will produce a market for new SG customer products.

# Economic Aspects and Liberalized Market Related to SGs

- A SG can decrease the amount of electricity consumed by houses and accelerate the connection of RES to improve the reliability, security and healthy living of electrical infrastructure.
- Advanced communication equipment, the enhanced knowledge of customers and local electricity supply management systems, enabled by smart metering and electronic technologies, will play an important role in employing new services.
- Deregulated markets will let consumers to utilize information to move between competing energy suppliers based on energy cost, greenhouse gas emissions and social goals.
- A SG vision for the market has been developed in recent years through the work of a consortium of utilities.
- One option is an “eBay for electricity”, where continual electronic sales match energy consumers with energy producers. One of the tasks of a regulator in the electricity market is to endorse the tariffs that a system operator charges to its clients on the basis of a satisfactory level of service.
- The major complexity in this task is the irregularity of information that exists between the regulator and the system operator even if numerous remuneration schemes exist for system operators. ---

# Conclusion

- This paper makes a first and very partial attempt to review SGs principal issues.
- It's worth pointing out that the SG implementation will require a huge amount of economic investments and further researches.
- Moreover, additional commercial arrangements and financial evaluations have to be set up.
- New market rules are required for providing new revenue mechanisms to share the benefits as well as the costs due to the SG realization between DG developers and system operators.

**Thank you  
for your attention**