Sustainable Energy, Grids and Networks 1 (2015) A1–A3

Contents lists available at ScienceDirect

Sustainable Energy, Grids and Networks

journal homepage: www.elsevier.com/locate/segan

Editorial

1. The evolution of modern power systems as our starting point

Fundamental changes are currently taking place in modern energy systems and, particularly, in electrical ones. Infrastructures have to satisfy conflicting requirements: providing reliable and secure services to an increasing number of customers, taking into account a rational use of energy and the protection of the environment. This last requirement drives major changes in electrical and energy systems where increasingly renewable energy sources need to be connected to the grid. It is generally acknowledged that these sources need to be massive and distributed, in order to provide a non-negligible part of the consumed electrical energy [1]. It is also generally agreed that such integration of renewables into existing grids depends on the successful combination of specific processes (e.g. demand side/response management, real-time consumption management, real-time local energy balance, accurate forecasting of renewables at continental, country and regional scales) and new technologies (e.g. smart meters, agent-based distributed controls).

Currently, there is a major effort from different research communities, in particular those of applied mathematics, control theory, computer science and, of course, power systems, to propose, discuss and validate new methodologies for the planning, operation and control of future electrical and energy systems. It is within this context that *Sustainable Energy, Grids and Networks* (SEGAN) has been launched.

2. Need for rigorous methods

Computer scientists and applied mathematicians have historically achieved scientific developments by developing rigorous methodologies and defining performance-evaluation processes to solve generic problems (e.g. [2]). This has realized, for instance, the fast evolution of modern communication technologies and associated infrastructures. In the power system community, the approach has been different. Indeed, historically, dedicated methodologies have been developed to solve specific problems. This is exemplified in the so-called *Optimal Power Flow* (OPF) problem representing the key problems related to optimal operation of power systems. The first formulation of an OPF problem occurred in the early 1960s [3]. As known, it is used to determine the operating point of controllable resources in an electric network in order to satisfy a specific network objective subject to a wide range of constraints. The problem objective is usually the minimization of losses and/or generation costs, and typical constraints include power flow equations, capability curves of controllable resources, as well as operational limits on line power-flows and node voltages. The OPF problem is known to be non-convex and, thus, difficult to solve.

Since the problem was first formulated, several specific and dedicated techniques have been used for its solution [4]. Among others, non-linear and quadratic programming techniques, Newton-based methods, and interior point methods in earlier years, as well as heuristic approaches based on genetic algorithms, evolutionary programming, and particle swarm optimization in more recent years.

There is currently a substantial effort, far from completion, to frame these kind of problems in a larger category in order to address the issues related to optimality of solution and speed of convergence. The main outcome of this effort will be to develop solution methods that are as universal as possible considering the stochastic nature of resources supplying modern power systems.

An example demonstrating this concept is the tendency to couple advanced statistical methods, like machine learning, with multistage stochastic optimisation problems (e.g., [5]).

Generic and rigorous solution methods for these kinds of problems will find applications in several fields, ranging from planning to real-time operations of electrical and energy systems.

It is hoped that such developments will allow one to define grid codes and policies, and make possible a-priori evaluation, testing and validation, similar to what is done nowadays in communication systems.

3. The grand challenges of the integration of massive uncertain energy resources

3.1. *The future structure of the power system*

The main factors promoting the evolution of modern power systems are mainly the following: increased societal participation, policies aimed at encouraging lower carbon generation, large integration of renewables into electrical grids, ageing assets of the electrical infrastructure, and progress in technology, including information and communication.

These factors suggest two possible models for the future network development [6]: (i) the *supergrid* model composed of continental/intercontinental networks for bulk transmission, enabling networks to share centralized renewable power generation by interconnecting various countries (e.g., [7]); or (ii) the *microgrid*

http://dx.doi.org/10.1016/j.segan.2015.01.001
2352-4677/

model where small networks for electricity distribution, including decentralized local power generation, energy storage and active customer participation, are intelligently managed so that they are operated as independent cells capable of providing different services from each other and of being operated as islands (e.g., [6]). It is likely that both of these models will emerge, and as a consequence, electrical systems will need to become more dynamic and adaptive, and thus more complex.

The planning of the whole system needs to account for detailed models of the distributed generation, storage and demand response (e.g. [8]) going beyond the known concept of network equivalents and with a consequent change of the problem's size and complexity.

3.2. The challenge of bulk grid control in the presence of large stochastic resources

The equilibrium in any traditional AC power system is based on the link between the power imbalance and the network frequency. As is well known, it is generally composed of four main time frames:

1. *Primary-frequency controllers* are locally installed in generation units and act immediately after a power imbalance resulting in a frequency deviation (locally measured). Droop regulators usually compose these controllers. The primary-control reserve represents the maximum amount of power available in the interconnected network after a frequency imbalance. This concept can be applied to a single generation unit or to the whole system.
2. *Secondary-frequency controllers* are, in general, centralised for each area that makes up the interconnected power system, and are responsible for compensating the frequency deviation from the rated value after primary control intervention. The time-frame of secondary-frequency control ranges from a few tens of second to a few minutes. In an area of interconnected networks, the secondary-control reserve represents the power responsible for bringing the frequency back to its rated value.
3. There are different definitions of *tertiary-frequency* control, however, in general, the power that can be connected in order to provide an adequate secondary control reserve, belongs to this control layer. This reserve must be used in such a way that it contributes to restoring the secondary control reserve when required.
4. The fourth time frame is composed of the *generation-dispatch* schedule that takes place, in general, at a larger time scale partially superposed with the tertiary frequency control. This specific level of the power system operation has substantially changed in the recent decades. Indeed, the need for a more efficient operation of the system to achieve reduced prices and increased quality of service, has led to unbundling of the power system and liberalization of associated energy markets [6].

The continual connection of additional non-dispatchable renewables, together with the planned penetration of demand-response mechanisms, is expected to have a large impact on the above-described operation philosophy. Reserve scheduling will need to be increased with appropriate schemes in order to maintain safe margins and ensure that grid vulnerability remains at acceptable levels (e.g. [9,10]).

In recent decades, several approaches have been proposed to keep the control structure constant, but with an increasing share of resources. One is the introduction of flexible AC transmission system (FACTS) devices that permit some level of direct power-flow control in electrical transmission networks (e.g. [11]) by enhancing the usable capacity of existing transmission lines and thus increasing the whole system loadability [12,13]. However, as discussed in [14], the installation of FACTS devices is restricted in view of the physical constraints of line loadability.

A similar approach dealing with direct power-flow control in transmission networks refers to the deployment of DC supergrids, composed of high-voltage DC (HVDC) networks, added as a top layer onto the existing AC transmission infrastructure (e.g. [7]). As discussed in [15], this approach also exhibits several technical limitations associated with centralised control philosophies of electrical grids.

Another approach was taken during the 1980s when manufacturers of supervisory control and data acquisition (SCADA) software for power systems started the progressive integration of functionalities of so-called energy management systems (EMSs). Typical examples refer to state estimation and contingency analysis in SCADA of power plants and transmission networks. Such functionality was also partially deployed in distribution networks towards the concept of so-called distribution management systems (DMSs) (e.g., [16]). DMSs essentially rely on a centralised approach inherited from SCADAs, and are used in large transmission networks, but the progressive introduction of distributed energy resources, particularly from renewables connected to power distribution grids, makes this approach inadequate and necessitates a complete redefinition of the control hierarchy of the entire infrastructure (e.g. [17,18]).

Other approaches have tried to apply distributed-control approaches using marginal virtual prices (also called "marginal prices") as a proxy for the state of internal resources [19,20], or using multi-agent-based control systems (e.g. [21]) as a step towards the distribution of control.

In evaluating current operation philosophies and deriving those for the future, we must ask important questions such as:

With a constant increasing dependency between the primary/secondary frequency-control reserves, and the errors associated with the forecasts of load absorption and production of renewables, how will we evolve methods to achieve safe and controllable bulk power systems?

The massive adoption of power electronic interfaces has a general influence on the reduction of grid inertia. Therefore, can we still rely on the above-described operation approaches when the system evolves its physical nature towards an inertia-less one?

Can we define unique, optimal and safe control frameworks that can be applied to systems of any size?

4. The role of information and communication technologies

It is generally accepted that the introduction of intelligence in electrical and energy systems requires the application of Information and Communication Technologies (ICT). The main challenges in doing so relate to the limited capabilities of utilities' communication infrastructure. Indeed, nowadays sensing is well integrated in high-voltage transmission networks (mainly for operation and security purposes) as well as in low voltage (LV) distribution systems (mainly for billing and open requirements). To address these challenges, the communication and information infrastructure must extend beyond utility control centers and substations and reach into consumer premises.

There is an enormous amount of data generated and available for interpretation both offline and in real-time, while associated methodologies for data sharing and processing require further development and deployment.

A typical example of data sharing and accessibility is the use of *information-centric networking* (ICN) versus traditional *point-to-point networks*. In the former, systems, devices and applications are enabled to expose their information; authorized known and unanticipated consumers *pull* or *subscribe to* what they need regardless of who produced the information. In the latter, predetermined *point-to-point* connections in systems on disparate networks are defined and producers *push* information to predefined consumers (e.g. [22]).

However, robust assessment, discussion, validation and performances assessment of these two approaches with respect to electrical and energy systems is required.

5. The journal rationale

The above sections have discussed the main scientific drivers, and boundary conditions, for this new journal. This section aims at providing further information concerning the rationale for launching this new journal.

Let us start with the title of the journal: *Sustainable Energy Grids, and Networks*. It combines three main concepts: *energy grids* as infrastructures to enable the transportation of energy (with particular reference to electrical energy); *networks* as infrastructures that exchange information and that are coupled with energy grids; and, finally, *sustainability* as a guiding principle—conserving an environmental balance by avoiding depletion of natural resources.

Prior to the launch of SEGAN, publications in the areas of sustainable energy and information grids have been scattered across numerous journals focusing on individual topics. Meanwhile, there is considerable agreement across all levels of academia and industry that a united and integrated approach is required. SEGAN will fulfill this need by: providing a single go-to place for researchers and readers across academia and industry; promoting international editorship, authorship and readership; and endorsing an interdisciplinary approach spanning power, energy, computer science, engineering, applied mathematics, control and policy/regulation, to bridge the existing gaps between these research communities.

6. Concluding remarks

To conclude this editorial, on behalf of the entire Editorial Team, I would like to convey my sincere gratitude to the Authors who have submitted papers to SEGAN so far, and to our Editorial Board and Reviewers who have spent countless hours reviewing these manuscripts. We greatly value the contributions of all these individuals who are so pivotal in upholding the integrity of the individual articles and the overall integrity of the journal. We hope that you will consider contributing to SEGAN as an Author, Reviewer or Reader and, together with the SEGAN Editorial Board, lead the evolution of future energy systems.

References

[1] D. MacKay, Sustainable Energy-without the Hot Air, UIT Cambridge, 2008.
[2] J.-Y. Le Boudec, Performance Evaluation of Computer and Communication Systems, CRC Press and EPFL Press, 2010.
[3] J. Carpentier, Contribution to the economic dispatch problem, Bull. Soc. Fr. Electr. 3 (8) (1962) 431–447.
[4] P. Panciatici, M.C. Campi, S. Garatti, S.H. Low, D.K. Molzahn, A.X. Sun, L. Wehenkel, Advanced Optimization Methods for Power Systems, in: Proc. of the 18th Power Systems Computation Conference, PSCC, Wroclaw, Poland, August 18–22, 2014.
[5] B. Defourny, D. Ernst, L. Wehenkel, Scenario trees and policy selection for multistage stochastic programming using machine learning, INFORMS J. Comput. 25 (3) (2013) 488–501.
[6] N. Hatziargyriou, et al., CIGRE WG network of the future, electricity supply systems of the future, Electra 256 (2011) 42–49.
[7] S. Gordon S., Supergrid to the rescue, Power Eng. 20 (5) (2006) 30–33.
[8] G. Celli, E. Ghiani, S. Mocci, F. Pilo, A multiobjective evolutionary algorithm for the sizing and siting of distributed generation, IEEE Trans. Power Syst. 20 (2) (2005) 750–757.
[9] K.A. Papadogiannis, N. Hatziargyriou, Optimal allocation of primary reserve services in energy markets, IEEE Trans. Power Syst. IEEE Trans. 19 (1) (2004) 652–659.
[10] European Network of Transmission System Operators for Electricity (ENTSO-E), Draft Network Code on Demand Connection, Dec., 2012.
[11] D.J. Gotham, G.T. Heydt, Power flow control and power flow studies for systems with FACTS devices, IEEE Trans. Power Syst. 13 (1) (1998) 60–65.
[12] J. Griffin, D. Atanackovic, F.D. Galiana, A study of the impact of FACTS on the secure-economic operation of power systems, in: Proc. of the 12th Power Systems Computation Conference, PSCC, Dresden, Aug. 1996, pp. 537–544.
[13] F.D. Galiana, K. Almeida, M. Toussaint, J. Griffin, D. Atanackovic, Assessment and control of the impact of FACTS devices on power system performance, IEEE Trans. Power Syst. 11 (4) (1996) 1931–1936.
[14] S. Gerbex, R. Cherkaoui R., A.J. Germond, Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms, IEEE Trans. Power Syst. 16 (3) (2001) 537–544.
[15] D. Van Hertem, M. Ghandhari, Multi-terminal VSC HVDC for the European supergrid: Obstacles, Renew. Sustain. Energy Rev. 14 (9) (2010) 3156–3163.
[16] N. Singh, E. Kliokys, H. Feldmann, R. Kiissel, R. Chrustowski, C. Jaborowicz, Power system modelling and analysis in a mixed energy management and distribution management system, IEEE Trans. Power Syst. 13 (3) (1998) 1143–1149.
[17] N. Jenkins, R. Allan, P. Crossley, D. Kirschen, G. Strbac, Embedded Generation, IEE, London, UK, 2000.
[18] J. Northcote-Green J., R. Wilson, Control and Automation of Electric Power Distribution Systems, Taylor & Francis, Boca Raton, FL, 2007.
[19] D.P. Palomar, Mung Chiang, A tutorial on decomposition methods for network utility maximization, IEEE J. Sel. Areas Commun. 24 (8) (2006) 1439–1451.
[20] C. Zhao, U. Topcu, S.H. Low, Fast Load Control with Stochastic Frequency Measurement, California Institute of Technology, Pasadena, USA, 2011.
[21] C. Rehtanz, Autonomous Systems and Intelligent Agents in Power System Control and Operation, Springer, 2003.
[22] K.V. Katsaros, W.K. Chai, N. Wang, G. Pavlou, H. Bontius, M. Paolone, Information-centric networking for machine-to-machine data delivery: a case study in smart grid applications, IEEE Netw. Mag. 28 (3) (2014) 58–64.

Editor-in-Chief
Prof. Mario Paolone, Ph.D.
E-mail address: segan-editor@epfl.ch.

Available online 22 January 2015