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Ahmet Yavuz Oral
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3rd International Congress on Energy Efficiency and Energy Related Materials (ENEFM2015)

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Editorial

The 3rd International Congress on Energy Efficiency and Energy Related Materials (ENEFM2015) provided all scientists the opportunity to meet, present their work, discuss and mutually interact in order to enhance and promote their research work.

This volume, published by Springer, includes selected papers presented at this Congress, held in Oludeniz, Turkey, October 19–23, 2015.

On behalf of organizing committee we would like to thank all the participants, plenary and invited speakers for their valuable contribution.

We would also like to thank AIGTUR for their support in the organization of the Congress as well as the publishers for the quality of this edition.

Gebze, Turkey

Ahmet Yavuz Oral
Zehra Banu Bahsi Oral

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Part I
General Issues

Urban DC Microgrids for Advanced Local Energy Management with Smart Grid Communication

Manuela Sechilariu

Abstract This paper presents an urban DC microgrid aiming an optimal energy management and taking into account messages from the smart grid. Concerning ancillary services, a microgrid controller is proposed to interact with the smart grid; it provides voltage control, power balancing, load shedding, and takes into account the system imposed constraints. Experimental results prove the technical feasibility of the urban DC microgrid. The study limits concern mainly the forecasting uncertainties and the real-time optimization.

Keywords Microgrid · Power optimization · Energy management · Smart grid

1 Introduction

The distributed energy generation shows a very rapid growth and reveals an increasing complexity for grid's managers due mainly to prosumer sites, i.e. producer and consumer sites.

The intermittent nature of renewable energy sources, e.g. photovoltaic (PV) generator, remains an issue for their integration into the public grid resulting in: fluctuations of voltage and/or frequency, harmonic pollution, difficulty for load management. This leads to new methods for power balancing between production and consumption [1].

Urban areas have great potential for intensive development of PV sources. To increase their integration level and obtain a robust power grid, the smart grid could solve problems of peak consumption, optimal energy management, and demand response. The smart grid is being designed primarily to exchange information on grid needs and availability, help balancing power, avoid undesirable injection, and

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perform peak shaving [2]. Concerning ancillary services (power grid technical regulations), for a better decentralization of the production, microgrids play an important role. A microgrid includes a multi-source system consisting of renewable and traditional energy sources, storage systems, and adjustable loads. A microgrid controller interacts with the smart grid; it provides voltage control, power balancing, load sharing or load shedding, and takes into account the constraints of the public grid provided by smart grid communication [1, 2].

In this context, at urban scale, the proposed system is a building-integrated DC microgrid, which provides a solution for the self-supply of buildings, electric vehicles, and grid-interaction control [3–5]. The microgrid controller is designed and developed like an intelligent energy management system that optimizes power transfer, adapts to conditions imposed by the public grid through the smart grid bus communication, and takes into account the various constraints in order to minimize the energy consumption from the public grid and to make full use of local production [6]. The interface between the smart grid and the proposed microgrid offers strategies which ensure, at the same time, local power balancing, local power flow optimization and response to grid issues such as peak shaving and avoiding undesired injections. The microgrid is proposed with DC bus link for an efficiently integration of other renewable sources and storage, for absence of phase synchronization, and because only the voltage must be stabilized. In addition, considering the DC bus and a DC load directly connected, the overall performance is improved by removing multiple energy conversions [5]. Indeed, a DC network building distribution may use the existing cables with the same power transfer as in AC distribution [7]. The DC bus can supply directly many building appliances (lighting, ventilation, electronic office equipment) as well as an electric vehicle.

The main scientific issue is the difficulty of global optimization due to the risk of mismatch between production/consumption predictions and real time operating conditions, on the one hand, and the need to take into account the constraints imposed by the public grid, on the other hand.

This paper presents the urban DC microgrid in Sect. 2 and the power management and optimization following the proposed microgrid controller in Sect. 3. A grid-connected DC microgrid, for which experimental results are given, is described in Sect. 4. Conclusions and furthers works are given in Sect. 5.

2 Urban DC Microgrid

The concept of smart grid appears and leads to microgrids for prosumer sites in order to reduce losses and peak energy demand, and also to play a role in local regulation, through the data communication. In urban areas, at the local level, the microgrid may be integrated to the building prosumer and connected to public grid by an adapted controller. At urban scale there are several building-integrated microgrids and parts of traditional public grid, all connected to the grid by a point of common coupling [2]. Intelligent switches are used to allow connection and islanding. Furthermore, a communication network is added, i.e. communication bus, whose routers are dedicated to direct messages following energy management priorities or special areas. Some dedicated controller interfaces generate and receive messages. The urban DC microgrid developed below is building-integrated and connected to the smart grid as described above.

3 Power Management and Optimization

The microgrid controller must provide the interface between the public grid and the loads (e.g. buildings, electric vehicles), aiming an optimal power management.

Figure 1 illustrates the power management interface principle based on the main data which have to be exchanged between the microgrid and the public grid. Thus, the microgrid controller must take into account information about the public grid availability and dynamic pricing, inform the smart grid on injection intentions and power demand, meet the demand of the end-user with respect to all physical and technical constraints, and operate with the best energy cost for the public grid and for the end-user. To meet these objectives as well as other actions described in Fig. 1 (forecasting, smart metering, monitoring…) a specific interface associated with the urban microgrid was designed as proposed thereafter.

The developed microgrid controller presented in Fig. 2 is a multilayer and multiscale design able to provide flexibility with respect to the necessary algorithms [6]. There are four functional layers whose response times range from days to less than a second. Human-machine interface allows taking into account the end-user options as predefined operating mode, or building critical loads, or load shedding limit, or other specific criteria. Prediction layer takes into account the end-user option, several forecast data (building operating mode, grid time-of-use, and weather), and aims to calculate two powers related to: renewable energy production prediction and energy demand prediction. These two powers are given as inputs for the energy management layer which is the most important intelligent layer. The energy costs optimization is calculated in this layer and is mainly based on the previously calculated predictions and the system constraints such as dynamic pricing, peak consumption, public grid vulnerabilities, and storage capacity. The

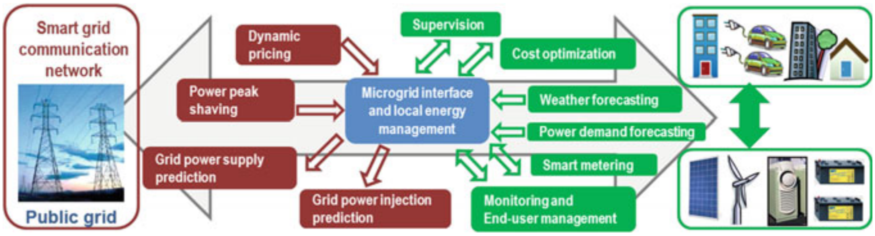

Fig. 1 Power management interface principle

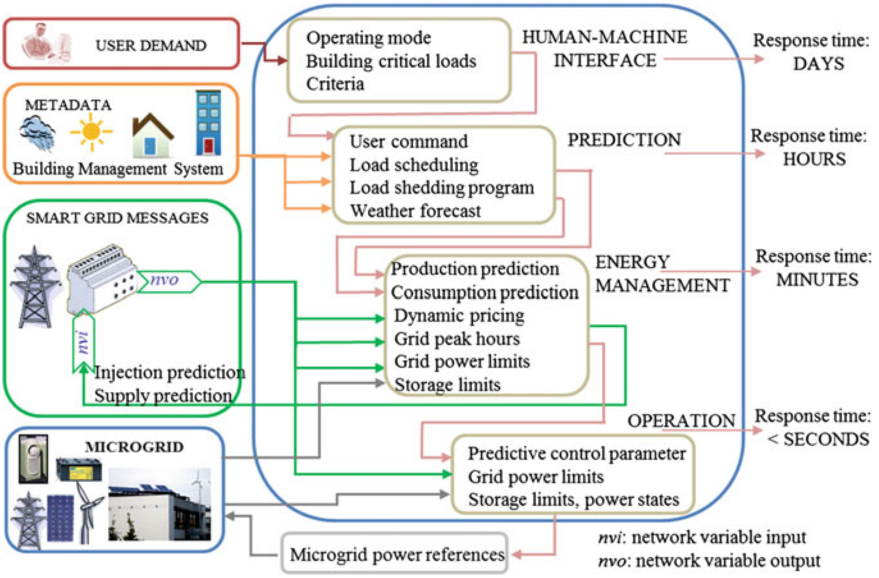

Fig. 2 Microgrid controller

optimization is solved by mixed integer linear programming and the solver could be CPLEX [8]. The obtained results are the optimal power evolution of each source for which the total cost is the minimum for the considered time duration. These powers cannot easily be implemented in real-time control. The solution is to translate the power flows into a single interface parameter for power balancing control, which is the predictive control parameter, one of the outputs of this layer. The second output concerns the predictions to be transmitted to smart grid (injection and supply). The predictive control parameter is applied in the operational layer, which algorithm controls the power balancing in the microgrid system.

The algorithm provides real-time references of the system powers and the coefficient of possible load shedding.

For urban microgrids several operating strategies are developed based on sources that make up the microgrid (PV sources and wind turbine, storage, public grid connection, micro-turbine or bio-diesel generator) and loads (buildings electric loads and electric vehicles charging stations). Figure 3 presents the main possible strategies. Renewable energies supply the building and charge the electric vehicles. The renewable excess energy could be stored and/or injected into the grid. The grid, if available, is used only as back-up for the building and the electric vehicles. The micro-turbine operates only if the grid is not available. The electric vehicles, if required for stringent situations, can supply the building and/or provide energy to the grid. The messages received from the smart grid command the microgrid operating mode aiming compliance the actual availability of the grid.

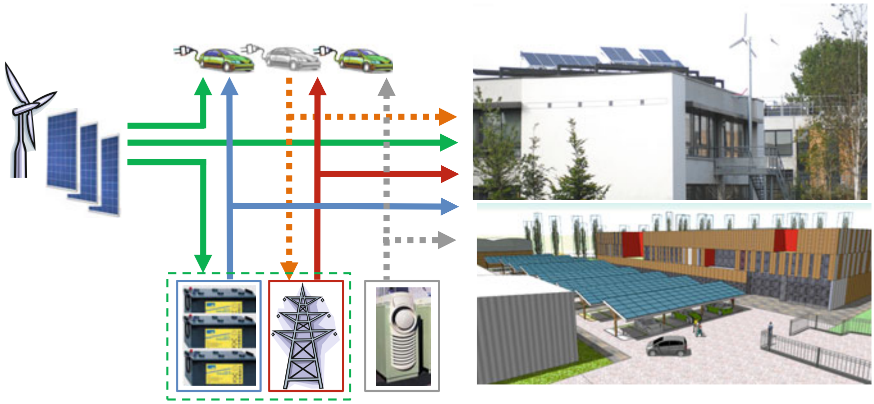

Fig. 3 Energy management strategies for urban DC microgrid

4 Building-Integrated DC Microgrid for Grid-Connected Mode

The DC microgrid given in Fig. 4 consists of physical power system and its controller as presented above. The power system includes a DC load and sources which are connected on the DC bus through their dedicated converters, while the DC load demands power directly from the DC bus.

The power balancing control principle and constraints are presented following the power flow schema shown in Fig. 5 [6]. The proposed strategy is to operate with the minimum energy cost for the considered period. Within the given limits, the public grid can supply or absorb energy to or from the microgrid. The same applies to the storage, charge or discharge operating mode. The DC load can demand power up to its maximum power, but limited power can be a load shedding result. For the PV array (PVA), two controls are implemented: a maximum power

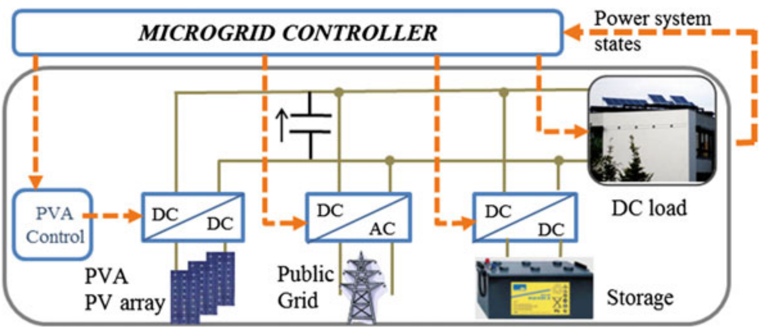

Fig. 4 DC microgrid building-integrated for grid-connected mode

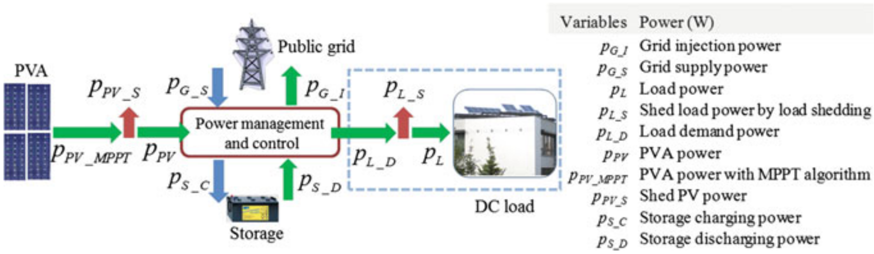

Fig. 5 Control principle and constraints following the power flow schema

point tracking (MPPT) control to extract the maximum power and a limited control to extract a limited power to meet power balancing for some stringent situations. The power balancing shows that the adjustment variables are the public grid and storage, within their physical and functional limitations. The predictive control parameter decides the contribution of these two sources, grid and storage. This control parameter must be the image of the power flow optimized in energy costs. The energy cost optimization take into account the day-ahead forecasting of the PVA production as well as the load power demand. Combined with this robust power balance strategy, the energy cost optimization is formulated as minimization of the total energy cost with respect to system physical constraints and imposed limits. To minimize the energy cost, energy tariffs are imposed as follow. The storage can be used as often as possible; an arbitrary but lowest tariff is given. In order to avoid the two operations, very penalizing energy tariff is proposed for PVA power limiting and load shedding. Public grid tariff is suggested to be lower than the PVA or load shedding tariff. There are two grid tariffs: peak hours and normal hours. The end-user can accept certain amount of load shedding.

Following the experimental platform given in [5, 6], three tests were done in 2013 for three different meteorological profiles. For each profile, Table 1 presents the obtained total energy costs for ten hours: C1 as optimum cost following power predictions, C2 as actual cost (experiment), and C3 as optimum cost for real conditions calculated after operation. One notes that C2 is close to C3.

Table 1 Energy total cost

Case	Total energy cost (€)		
	August 21	August 9	July 30
C1	−0.777	−0.149	0.386
C2	0.225	0.929	3.219
C3	−0.247	0.357	2.165

5 Conclusions

The DC microgrid optimizes energy cost and offers good predictive management. It is a reconfigurable control, easy to implement, and uncertainties do not affect the control; however the energy cost becomes suboptimal.

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Proper Orthogonal Decomposition Applied to a Turbine Stage with In-Situ Combustion

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Abstract The paper presents a POD analysis of the numerical simulation results obtained from the numerical simulation of transport phenomena in a one-stage turbine-combustor (i.e. a turbine stage with in situ combustion). The motivation of this research is to investigate the new fuel injection concept that consists of a perforated pipe placed at mid-pitch in the stator row passage and different axial positions. The main goal of this simulation is to assess the stability of the in situ combustion with respect to the unsteadiness induced by the rotor-stator interaction. To identify the sources of instability for this complex flow, the proper orthogonal decomposition technique is used to analyze the natural patterns and couplings between various modes of pressure, temperature, velocity and chemical production rate distributions.

Keywords Turbine combustor · POD · Natural patterns

1 Introduction

This in situ reheat takes place in a turbine-combustor, that is, a turbine where fuel is injected and combusted, in addition to the combustion that takes place in the main combustor. For the same power produced, in situ reheat allows the decrease of the thermal load in the main combustor, therefore reducing the maximum temperature of the cycle and the temperature variation throughout the combustion process. Decreasing the combustor temperature reduces the NOx and unburned hydrocarbon emissions and also diminishes the need for costly combustor materials and thermal barrier coatings on the combustor liner, enabling a more resource efficient

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manufacturing. A performance cycle analysis for this type of GTE included in [1] showed that for high speed transportation (above Mach 2.2) the turbine burner has the best fuel economy. To our best knowledge, besides pioneering works referenced in [2–4], one of the most interesting publicly released research in this domain dates back in 2009 and belongs to a group of researchers at University of California at Irving [5].

2 Proper Orthogonal Decomposition

The Proper Orthogonal Decomposition (POD) is a method that reconstructs a set of data from its projection on an optimal basis. Besides using an optimal basis for reconstructing data, POD does not use any prior knowledge of the data set. Because it is dependent only on the basis of data, POD is also used in natural patterns analysis of the flow field.

To rebuild the dynamic behavior of a system, POD breaks down data into two parts: a time dependent part, that generates the amplitude coefficients $a_k(t)$ and a spatial coordinates dependent part that yields an orthonormal functional basis $\psi_k(\mathbf{x})$. The reconstructed model reads:

$$u(\mathbf{x},t) = \sum_{k=1}^{M} a_k(t) \cdot \psi_k(\mathbf{x}) \tag{1}$$

where M is the number of data snapshots. The reconstruction dataset error is:

$$\varepsilon(\mathbf{x},t) = u(\mathbf{x},t) - \sum_{k=1}^{M} a_k(t) \cdot \psi_k(\mathbf{x}) \tag{2}$$

The functional basis on which this set is reconstructed is optimal as the average of the squared error is minimized for any number $m \leq M$ of base functions from all possible sets of orthogonal functions.

In the field of fluid mechanics, two main approaches have been used: the first one, the classical, continuous POD was promoted by Lumley [6]; the second one, is based on the so called snapshot approach and originates in the works of Sirovitch [7].

Herein, the discrete POD-snapshot approach is used. We start form a set of M snapshots obtained from the numerical simulation of the given model. The simulation can be performed either with a commercial or in-house code. The sampling rate must comply with Nyquist-Shannon [8] criterion used for signal reconstruction. The construction of the correlation matrix is done as follows, either for a vector valued or scalar valued function. Assuming that the quantity of interest is denoted by u, first we have to arrange all its values for a certain snapshot in a vector with dimension N (N could be very large depending on the discretized