PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Andrea Scalfati

XXX Cycle

Training and Research Activities Report – Third Year

Tutor: Diego Iannuzzi – co-Tutor: Maurizio Fantauzzi

1. **Information**

   a. Andrea Scalfati, M.Sc. Degree in Electrical Engineering (cum laude) - University of Naples Federico II, 1997
   b. PhD Student, XXX Cycle - ITEE – University of Naples Federico II
   c. No fellowship (full time worker for the Italian Ministry for Education, University and Research, High School teacher in electrical engineering)
   d. Tutor: prof. Diego Iannuzzi – Co-Tutor: prof. Maurizio Fantauzzi

2. **Study and Training activities**

   a. Courses
      - Cambridge Advanced English (50h course – CLA Federico II), final exam held on June UA1 (AM1) 2017 session, Certificate in Advanced English, CEFR level C1.
      - Global Optimization and Uncertainty Quantification, held on 19-22 June, 2017, at University di Napoli Federico II, DISTAR, by Prof. MRINAL K. SEN, Institute for Geophysics, The University of Texas at Austin (USA).

   b. Seminars
      - Security Operations in una Telco (ing. F. Zamparelli), 11/11/2016
      - L'innovazione nel mercato IT (dott. G. Pirollo, ing. A. F. Fucito), 01/12/2016
      - SmartPowerSystem (G. Graditi, F. Lionello, O. Caputi, L. Nicolais), 14/12/2016
      - The impact of modern technologies in power system design (prof. P. Varilone), 20/12/2016
      - From Mathematical formalization to Artificial Visual-Attention: Toward a Human-Like Robot Vision (prof. Kurosh Madani), 04/04/2017
      - Living bots and alter ego (M. Gori), 04/04/2017
      - Power system stability and synchronization: application to the lossy power grid system (prof. Navdeep M. Singh), 30/06/2017

   c. External courses

      None

3. **Research activity**

   a. Title

Optimal Sizing of Distributed Energy Resources in DC Microgrids

   b. Study

The research activity has been focused on the development and application of new methodologies to solve the problem of optimal planning of DC Microgrids, investigating the economic viability of the microgrid deployment and determining the optimal mix of Distributed Energy Resources for installation.

In recent years Microgrids are one of the most relevant research topics in electrical power systems, as they are electricity distribution systems containing loads and distributed energy resources that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded, and they are considered a key component of the smart grid scenario, aimed at obtaining better integration of distributed energy resources, increasing energy efficiency and reliability of the whole system, and providing the possibility to improve power quality and to achieve grid-independence to individual end-user sites.

Despite the strong consensus existing among researchers and stakeholders on the variety and importance of the advantages deriving from the implementation of the Microgrid paradigm in modern electrical distribution systems, their widespread diffusion is hindered from cost considerations and from the difficulties in conducting a comprehensive cost-benefit analysis and in identifying qualified modalities for system design and management.

Although the accurate evaluation of the economic results originating from the deployment of a µG is a demanding task, the identification of efficient methodologies for the optimal system design is important to allow appropriate analyses and informed choices on the opportunity and feasibility of µG realizations. A fundamental aspect involved in the Microgrid design process is the choice and sizing of Distributed Energy Resources to be installed, including both Distributed Generators (DGs) and Electrical Energy Storage Systems (ESSs).

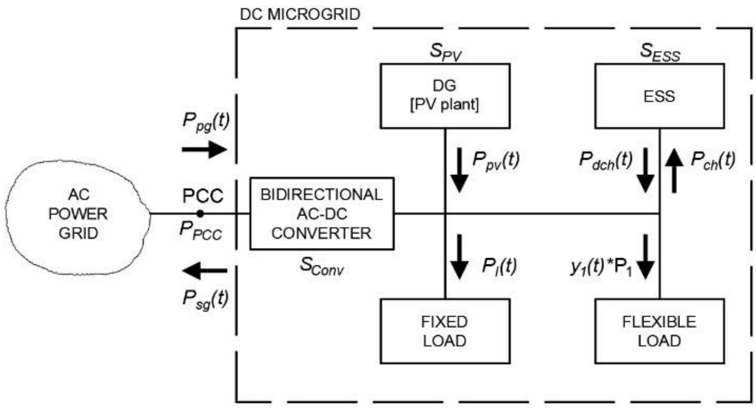
Microgrids (µGs) can be classified into AC µGs, DC µGs or hybrid µGs, depending on whether they transmit electricity in the form of alternate current or direct current, or with a combination of the two technologies. The research activity has been focused particularly on DC µGs and distribution systems, which are gaining interest both in academic and industrial world, because of potential benefits in terms of energy efficiency and capital savings and in terms of lower control system complexity (with positive consequences on system reliability and controllability). In fact, the DC paradigm avoids phase imbalances, reduces power losses and improves the efficiency of DC appliances due to the absence of reactive power.
Housing, commercial and industrial buildings are one of the more interesting field of application for these technologies, because in presence of endues loads natively DC (e.g., computers, solid-state lighting or variable speed drives for electric motors and HVAC systems), and of onsite renewable generation and distributed energy resources also mostly based on DC technology (e.g. PV or micro-wind generators, storage systems and electric vehicles), DC-based building microgrids can bring additional benefits, allowing direct coupling of DC loads and DC energy resources. DC microgrids can thus give a significative contribution to increase the energy efficiency of buildings (which are responsible for approximately 40% of total energy consumption and roughly 40% of greenhouse gas emissions in USA and in Europe) and to achieve the goal of Net Zero Energy Buildings (i.e. buildings that produce as much energy as they consume).

c. Research description

During the third year of PhD course, the mathematical programming approach developed during the second year has been further developed and expanded, to cope also with the uncertainties affecting the design process.

Specifically, a Mixed Integer Linear Programming model has been developed and applied to the microgrid planning problem, considering a DC µG with a given base load and some flexible loads, with assigned power, number and duration of respective working cycles to be held in prefixed time windows. The formulation is aimed at minimizing the Total Cost of Ownership of the microgrid, via optimal sizing and control of DERs, like Distributed Generators (DGs) and Energy Storage Systems (ESSs), and optimal control of flexible loads, respecting a set of technical and financial constraints.

With reference to a DC µG including an ESS and a PV generation system, the optimal sizing has been firstly performed through a deterministic approach, claiming a perfect knowledge of all the relevant parameters and particularly of hourly loads demand and solar irradiation.
While the main outputs of the planning problem are the sizes of the PV system, of the ESS and of the bidirectional converter installed on the Point of Common Coupling (PCC) between the DC µG and the AC main grid, the optimal sizing procedure produces also references for the optimal control of the µG, essentially in terms of energy exchanged with the grid and with the storage system.



Sensitivity analyses has been subsequently implemented to highlight the parameters whose uncertainty mostly affect the results of the deterministic procedure.

The Monte Carlo method has been therefore applied to verify the results of the deterministic sizing procedure against the uncertainties affecting the input data of the optimization problem. The Monte Carlo method has been applied considering Gaussian probability distribution functions (PDFs) both for the non-controllable load and for the solar radiation. For each instance, values extracted from the above-mentioned PDFs have been used to alter the profiles of non-controllable load and of PV system productivity, then the optimization model has been solved using these altered profiles and maintaining the already found sizes of the bidirectional converter, the PV system and the ESS, thus allowing only the optimal management of the µG equipped with deterministically sized DERs. Results of Monte Carlo tests show that the deterministic sizing based on solar irradiation and load profiles of typical days performs quite well, even considering increasing uncertainty levels, with resulting TCOs not far from that of the reference case, and seems to be sufficiently resilient also against unpredicted increases of the total demand.

Finally, Robust Optimization (RO) has been used to guarantee the optimal sizing results against the variability of the load demand in a predefined set of possible values: specifically, a scenario based RO approach has been applied, based on 10 years of registration of hourly load demands and allowing the study of the effect of different uncertainty levels considered in the sizing procedure.

4. **Products**
    a. Publications:
        a.i. Published works

- *Journal paper*: M. Fantauzzi, D. Lauria, F. Mottola, A. Scalfati. Sizing energy storage systems in DC networks: A general methodology based upon power losses minimization. Applied Energy, Volume 187, 2017, https://doi.org/10.1016/j.apenergy.2016.11.044

- *Conference paper*: A. Scalfati, D. Iannuzzi, M. Fantauzzi, M. Roscia. Optimal Sizing of Distributed Energy Resources in Smart Microgrids: a Mixed Integer Linear Programming Formulation. Accepted for presentation at IEEE International Conference on Renewable Energy Research and Applications, 5-8/11/2017, San Diego

        a.ii. Works in preparation

A. Scalfati, D. Iannuzzi, M. Fantauzzi. Optimal Sizing of Distributed Energy Resources in Smart Microgrids: Deterministic and Robust Optimization Approaches based on a Mixed Integer Linear Programming Formulation

b. Patents:
None

5. **Conferences**
None

6. **Activity abroad**
None

7. **Tutorship**
None

8. **CS summary**

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	24		3	3	3	12		21	15		3	6			8	17	3				6			6	44	30-70
Seminars	6		0,4	0,8			1,8	3	8	2,2	1,1	0,7	0,7		0,4	5,1	3	2,4		0,8	0,3			3,5	11,6	10-30
Research	30	10	4	4	4	4	6	32	40	8	6	6	8	6	8	42	60	10	8	8	8	10	10	54	128	80-140
	60	10	7,4	7,8	7	16	7,8	56	63	10,2	10,1	12,7	8,7	6	16,4	64,1	66	12,4	8	8,8	14,3	10	10	63,5	183,6	180