PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Pasquale De Falco

XXX Cycle

Training and Research Activities Report – Second Year

Tutor: Guido Carpinelli

1. Information

Pasquale De Falco obtained his Master's Degree in Electrical Engineering (110/110 cum laude) at University of Naples "Federico II". He is now a XXX cycle ITEE PhD student, with fellowship financed by Ministero dell'Istruzione, dell'Università e della Ricerca. His tutor is prof. Guido Carpinelli.

2. Study and Training activities

In the second year of PhD course, Pasquale De Falco attended the following modules, seminars and PhD schools:

Modules

- Game theory and analysis of competitive dynamics for industrial systems. Prof. Mallozzi.

Seminars

- Beyond the data: how to achieve actionable insights with machine learning. Lecturer: dr. Santoro (Camelot Biomedical Systems), organizer: prof. Corazza.
- Model based and pattern based GUI testing – Part I. Lecturer: prof. Paiva (University of Porto, Portugal), organizer: prof. Tramontana.
- Model based and pattern based GUI testing – Part II. Lecturer: prof. Paiva (University of Porto, Portugal), organizer: prof. Tramontana.
- The evolution of railway signaling systems. Lecturers: eng. Bargellini and eng. Trezza (Italferr S.p.A.), organizer: prof. Carpinelli.
- Radar Adaptivity: Antenna Based Signal Processing Techniques. Lecturer: eng. Alfonso Farina (VP Industry Relations of IEEE Aerospace and Electronic Systems Society), organizer: prof. Aubry.
- Medical Robots Research at IPR – KIT Karlsruhe. Lecturer: prof. Heinz Worn (Karlsruhe Institute of Technology, Germany), organizer: prof. Siciliano.
- The Development of a Fast Pick-and-Place Robot with an Innovative Cylindrical Drive. Lecturer: prof. Jorge Angeles (McGill University,Canada), organizer: prof. Siciliano.

PhD Schools

- 3rd Summer School on Smart Grid, Fisciano 2016.

In the following table, the CFUs acquired for the above-reported activities during each of the six two-months periods are reported.

	Credits year 2							
		1	2	3	4	5	6	
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary
Modules	10	0	3	0	5	0	0	**8**
Seminars	5	2.6	0.4	0	0.5	0	0	**3.5**
Research	45	9	9	9	9	4.5	8	**48.5**
	60	11.6	12.4	9	14.5	4.5	8	**60**

3. Research activity

Electrical distribution systems are evolving towards the new concepts of Smart Grids (SGs), that were made available thanks to the spread of Distributed Energy Resources. Among them, non-programmable renewable power plants, such as wind and photovoltaic systems, are characterized by a significant intrinsic randomness due the uncertainty affecting the corresponding main natural source. Also the power demand of non-controllable electrical loads cannot be determined univocally; this obviously complicates the optimal management and planning of smart distribution systems, as neither the generation powers nor the load demands can be considered known in advance [1].

In this context, reliable and accurate forecasting tools are mandatory to provide accurate and reliable estimations of power production and power demand, for different time horizons [2]. The research activity performed during the first year of PhD course was indeed aimed to provide advanced short-time forecasting tools of electrical variables that can be used for the optimal operation of SGs. The short-time horizon was preferred to longer horizons, since tools that allow the SG operators to make decisions are usually scheduled from some minutes to few days before [3-6]; this is the case of purchasing power, generating power, switching loads and shedding loads, also furnishing external services to the distribution grid (i.e., reactive power support, etc.) and simultaneously being competitive in liberalized energy markets.

The research activity continued during the second year of PhD course and involved both load demand and renewable generation power production forecasting.

A probabilistic Bayesian method was applied to load power forecasting, in order to provide accurate and reliable forecasts not only at different aggregated load levels, but also for single domestic loads. This is not a simple task, as the unpredictability of single loads is way more enhanced. In particular, load powers were prior modelled through two probability density functions (i.e., the Log-Normal and the three-parameters Weibull distributions); the load power differences were instead prior modelled through Normal distributions. Like many other probabilistic methods, the Bayesian method was based on an underlying deterministic model that provided an estimation of the mean value of the predictive distribution. An AutoRegressive Integrated Moving Average model was selected for this purpose, since the process is non-stationary. Then, the remaining parameters of the predictive distribution were estimated through a Bayesian inference approach. Due the lack of an analytic closed form for the solution, a Monte Carlo Markov Chain was used to provide samples of the parameters for the Log-Normal and three-parameters Weibull distributions, while the parameters of the distribution resulting from the prior Normal distribution assumption were found in closed analytic form.

With reference to non-programmable renewable power plants, the research activity was focused on the proposal of a new ensemble methods to optimally combine two or more probabilistic predictors of PV power. The resulting, combined predictive distribution is usually over-dispersed if base predictors are normally-calibrated [7,8]. The key result of the research activity was indeed to adapt a linear tool for the combination of predictive density functions to inhomogeneous base predictors, in order to provide sharp forecasts with an acceptable level of reliability. This was made through a Multi-objective optimization procedure, aimed to balancing both sharpness and reliability of the combined forecasts.

Finally, a research activity was also carried out to deal with the extreme events affecting power systems. In particular, extreme values of wind speeds (EWS) were considered, as they affect the wind power production and the mechanical reliability of electrical lines and wind generators [9]. First, a new Inverse Burr distribution was proposed and tested to model the randomness of EWS. The performances were evaluated for several real wind datasets, and compared to existing EWS distributions. The proposed Inverse Burr model was proved to be particularly suitable for such events. Then, a reliability stress-strength model based on the Inverse Burr distribution was proposed. The solutions of the reliability model were found in a Bayesian approach, and can be used as input for risk assessment tools.

The research activity has been performed in collaboration with the following Universities:

- Università di Napoli “Parthenope”

In the next year of PhD course, the research activity will be mainly focused on: (i) probabilistic combination of deterministic base predictors; (ii) estimation algorithms for parameter and confidence interval estimation of mixture probability density functions; (iii) forecasting of dynamic thermal rating of SG components.

References

[1] R. Johnson, “An era of many options: future energy planning must take into account unprecedented numbers of options,” IEEE Power and Energy Magazine, vol. 13, no. 4, pp. 18-28, 2015

[2] T. Hong, P. Pinson, S. Fan, H. Zareipour, A. Troccoli, R.J. Hyndman, “Probabilistic energy forecasting: global energy forecasting competition 2014 and beyond,” International Journal of Forecasting, vol. 32, no. 3, pp. 896–913, 2016.

[3] P. Basak, S. Chowdhury, S. H. Dey, S.P. Chowdhury: "A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid", Renewable and Sustainable Energy Reviews, Vol. 16, no. 8, October 2012, pp. 5545-5556

[4] E. Planas, A. Gil-de-Muro, J. Andreu, I. Kortabarria, I. M. de Alegría: "General aspects, hierarchical controls and droop methods in micro-retes: A review", Renewable and Sustainable Energy Reviews, Vol. 17, January 2013, Pages 147-159

[5] E. Unamuno, J. A. Barrena, “Hybrid ac/dc microgrids - Part II: review and classification of control strategies,” Renewable and Sustainable Energy Reviews, vol. 52, pp. 1123-1134, 2015.

[6] J. Momoh, S. Surender Reddy, “Review of optimization techniques for Renewable Energy Resources”, Power Electronics and Machines for Wind and Water Applications (PEMWA), 2014 IEEE Symposium. IEEE, 2014.

[7] R. Ranjan and T. Gneiting, “Combining probability forecasts,” J. Roy. Statistical Soc.: Ser. B (Statist. Methodol.), vol. 72, no. 1, pp. 71–91, 2010.

[8] T. Gneiting and A. E. Raftery, “Strictly proper scoring rules, prediction, and estimation,” J. Amer. Statist. Assoc., vol. 102, no. 477, pp. 359–378, 2007.

[9] R. Billinton, R.N. Allan, Reliability evaluation of power systems. Springer Science & Business Media, New York, USA, 2013.

4. Products

In the second year of PhD course, Pasquale De Falco was co-author of the following papers:

Journal papers

- A. Bracale, G. Carpinelli, P. De Falco, R. Rizzo, A. Russo, "New advanced method and cost-based indices applied to probabilistic forecasting of photovoltaic generation," Journal of Renewable and Sustainable Energy, vol. 8, no. 2, 023505, 2016.
- E. Chiodo, P. De Falco, "Inverse Burr Distribution for Extreme Wind Speed Prediction: Genesis, Identification and Estimation," Electric Power System Research, vol. 141, pp. 549-561, 2016.
- A. Bracale, G. Carpinelli, P. De Falco, "A probabilistic competitive ensemble method for short-term photovoltaic power forecasting," IEEE Transactions on Sustainable Energy, DOI: 10.1109/TSTE.2016.2610523, available on-line.
- A. Bracale, G. Carpinelli, P. De Falco, "A new ensemble probabilistic method for short-term photovoltaic power forecasting," chapter in Future Energy Systems, InTech (accepted for publication).

Conference papers

- A. Bracale, G. Carpinelli, P. De Falco, "A Bayesian-based approach for the short-term forecasting of electrical loads in smart grids. Part I: theoretical aspects," in Proc. of 23rd International Symposium on Power Electronics, Electrical Drives, Automation and Motion. SPEEDAM 2016. Capri, Italy, 22-24 June 2016.
- A. Bracale, G. Carpinelli, P. De Falco, "A Bayesian-based approach for the short-term forecasting of electrical loads in smart grids. Part II: numerical applications," in Proc. of 23rd International Symposium on Power Electronics, Electrical Drives, Automation and Motion. SPEEDAM 2016. Capri, Italy, 22-24 June 2016.
- E. Chiodo, P. De Falco, "Bayesian Estimation of Inverse Burr Stress-Strength Model for Power System Components Reliability Assessment," in Proc. of 23rd International Symposium on Power Electronics, Electrical Drives, Automation and Motion. SPEEDAM 2016. Capri, Italy, 22-24 June 2016.

Papers in preparation or waiting for approval

- A. Bracale, G. Carpinelli, P. De Falco, "A new mixture distribution and its expectation-maximization procedure for extreme wind speed characterization".

5. Conferences and Seminars

Pasquale De Falco attended the following conferences and seminars:

- 3rd Summer School on Smart Grid, Fisciano 2016.
- 23rd International Symposium on Power Electronics, Electrical Drives, Automation and Motion. SPEEDAM 2016. Capri, Italy, 22-24 June 2016.

6. Activity abroad

No activity abroad has been carried out during the first year of PhD course.

7. Tutorship

Pasquale De Falco was involved in tutorship activities for a duration of 30 hours for the preparation of a Ms. Sc. thesis.