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 – Third Year

Tutor: Guido Carpinelli – co-Tutor: Antonio Bracale

1. Information

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

2. Study and Training activities

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

Modules

- Machine learning. Proff. Sansone, Corazza, Isgrò, Prevete.
- Measurement systems based on microcontrollers. Prof. Schiano Lo Moriello.

Seminars

- The impact of modern technologies in power system design. Lecturer: prof. Varilone (University of Cassino and Southern Lazio, Italy), organizer: prof. Carpinelli.
- Nanostructured materials based biosensors: engineering next generation of biomedical devices. Lecturer: eng. De Stefano (Istituto per la Microelettronica e Microsistemi, CNR, Italy), organizer: prof. Fabricatore
- Plasma stability and dynamic events in tokamaks with a resistive wall. Lecturer: prof. Pustovitov (National Research Centre "Kurchatov Institute", Russia), organizer: prof. Rubinacci
- IEEE Student Branch: Constitution. Lecturer and organizer: prof. Maresca
- Reactive Power Control in AC Networks from the State of the Art to the Chopper Controlled Impedance Concept. Lecturer: prof. Ladoux (Institut National Polytechnique of Toulouse, France), organizer: prof. Del Pizzo
- Power circuits with high-bandgap devices. Lecturer: prof. Castellazzi (University of Nottingham, UK), organizer: prof. Irace.

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

	Credits year 3							
		1	2	3	4	5	6	
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary
Modules	0	0	0	0	4	3	0	**7**
Seminars	0	0.6	1.5	0	0	0	0.4	**2.5**
Research	60	9	9	9	8	7.5	8	**50.5**
	60	9.6	10.5	9	12	10.5	8.4	**60**

3. Research activity

The planning and operation of power systems are strongly affected by random weather, social, and economic factors, that must be accurately assessed in order to exploit energy resources and electrical components at their best [1]. In this context, reliable and accurate forecasting tools are mandatory to provide estimations of power system variables affected by randomness for different time horizons [2]. The research activity performed during the first and second year of PhD course aimed to provide:

i. advanced tools for short-time forecasting loads and renewable generation, 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;
ii. advanced probability density functions (PDFs) for characterizing extreme values of wind speed (EWS). This topic recently gained the attention of power system researchers, since EWS affect the wind power production and the mechanical reliability of electrical lines and wind generators [7]. Probabilistic forecasting tools based on the parametric characterization of EWS gain indeed benefits from exploiting PDFs that are well-suited for extreme values, to avoid severe underestimations or overestimations.

In continuation of this research activity, three key topics were developed during the third year of PhD course.

Industrial load forecasting

The research activity on load forecasting was particularly focused on industrial loads, the modelling of which is typically more challenging than aggregate loads at national regional or sub-station levels. Indeed, many variables that are usually considered as informative inputs in the traditional load forecasting appear to be uninformative for industrial loads. As a significant example, the dependence of national or regional aggregate loads on ambient temperature is widely acknowledged, but many aggregated or single industrial load are not weather-sensitive [8]. Moreover, work shifts and production schedules of the particular industrial facility could be used as informative inputs, thus increasing the accuracy of industrial load forecasts. Therefore, it is worth to perform a sensitivity analysis case-by-case, even for different loads in the same factory.

The research activity aimed to build models specifically addressed for industrial load forecasting; deterministic multiple linear regression and support vector regression models were developed by considering special treatments to reflect the nature of the considered factory and of single loads, in order to improve the forecast accuracy. Specifically, several qualitative variables were analysed to characterize the production schedule, in order to add interaction effects between loads, calendar variables, and work shifts. Model selection was performed through k-fold cross-validation and through the lasso regression analysis. Results were compared in terms of mean absolute errors in the test step, outperforming acknowledged benchmarks.

Forecasting the dynamic rating of electrical components

Load forecasts find different practical applications in modern power systems. As an example of the real-world use of load forecasts, a research activity was carried out to develop procedures to forecast the dynamic rating of electrical components of a micro-grid. Nameplate ratings of electrical components, indeed, are quite restrictive values, but fortunately these ratings can be exceeded in favorable thermal conditions to increase the exploitation of existing grids, still avoiding loss of rated life and breakdown [10-12]. However, a great attention must be paid in this kind of applications, since aging effects [11] rapidly occur as consequence of the raise of the temperature of sensitive components (such as insulating materials).

Forecasting the dynamic rating of electrical components is therefore a complex task, that cannot neglect the unavoidable uncertainties introduced by the estimation of initial and external conditions.
In particular, the thermal state of an electrical component strongly depends on the past and current electrical history of the component itself, and forecasts of the transformer load (or of the line load) are needed as inputs of models that aim to forecast the dynamic rating of the transformer (or of the line).
With reference to transformer dynamic ratings, the output of the research activity was a probabilistic procedure to forecast the allowable current (i.e., the operating current of the transformer) of an oil-immersed distribution transformer. The procedure relies on probabilistic forecasts of ambient temperature and of loads, that are used as main inputs; the IEEE thermal model of the transformer is then applied in order to build probabilistic forecasts of the dynamic rating, taking into account the uncertainties involved in load and weather forecasting, and in the estimation of transformer parameters. Then, a risk-based index is used to forecast the allowable current of the transformer at the desired time interval [13]. The quality of load forecasts obviously affects the overall quality of the allowable current forecasts; therefore, the results of the research activity on industrial load forecasting were applied to specifically develop a probabilistic load forecasting model based on quantile regression for the aggregate load of an Italian industrial facility. The so-obtained probabilistic forecasts were used as inputs of the probabilistic procedure to forecast the dynamic rating of the MV/LV transformer that feeds the considered industrial facility.

Modelling the extreme values of wind speed
The research activity on the probabilistic characterization of EWS produced as main result a new finite Inverse Burr - Inverse Weibull distribution. The choice of a mixture distribution aimed to increase the versatility of the model for different wind scenarios. Obviously, this resulted in an increased complexity of the model; an expectation-maximization algorithm was specifically developed to deal with the well-known difficulties in estimating the parameters of mixture distributions [9]. The goodness of fitting (GOF) of the mixture Inverse Burr - Inverse Weibull distribution was assessed on several real EWS dataset, and it was compared to the GOF of several extreme value distributions acknowledged in EWS relevant literature. The increased complexity in terms of number of parameters was assessed by applying an appropriate GOF index, that negatively weights distributions with more parameters and positively weights distributions with fewer parameters. The results confirmed that the increased number of parameters was reasonable, compared to increased GOF, on the majority of the considered EWS datasets.

The research activities have been performed during the third year of the PhD course in collaboration with the following Universities:

- University of North Carolina at Charlotte (Charlotte, USA)
- MINES ParisTech (Paris, France)
- University of Napoli “Parthenope”
- Politecnico di Torino

References

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[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.
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[7] R. Billinton, R.N. Allan, Reliability evaluation of power systems. Springer Science & Business Media, New York, USA, 2013.
[8] J. Blancarte, M. Batton-Hubert, X. Bay, M.A. Girard, and A. Grau, “Short Term Load Forecasting in the Industry for Establishing Consumption Baselines: A French Case,” in Modeling and Stochastic Learning for Forecasting in High Dimensions, A. Antoniadis, J.M. Poggi, and X. Brossat eds., Springer, Switzerland, 2015.
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[11] IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators, IEEE Std. C57.91-2011, 2012.
[12] IEEE Guide for Loading Dry-Type Distribution and Power Transformers, IEEE Std. C57.96-2013, 2014.
[13] D.R. Swatek, “An expected per-unit rating for overhead transmission lines,” Int. Journal of Electrical Power & Energy Systems, vol. 26, no. 4, pp. 241-247, 2004.

4. Products

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

International journal papers

- A. Bracale, G. Carpinelli, and P. De Falco, “A new finite mixture distribution and its expectation-maximization procedure for extreme wind speed characterization,” Renewable Energy, vol. 113, pp. 1366-1377, 2017.

International conference papers

- A. Bracale, G. Carpinelli, P. De Falco, and T. Hong, “Short-term industrial load forecasting: a case study in an Italian factory,” in proc. of IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe) 2017, Torino, Italy, 26-29 September 2017.

Papers in preparation or waiting for approval

- A. Bracale, G. Carpinelli, P. De Falco, and M. Pagano, “A probabilistic approach for forecasting the allowable current of oil-immersed transformers,” submitted to IEEE Transactions on Power Delivery (second round review).
- A. Bracale, G. Carpinelli, P. De Falco, and T. Hong, “Developing models for industrial load forecasting” (to be submitted to a relevant journal).

5. Conferences and Seminars

Pasquale De Falco attended the following conferences:

- 3rd IEEE International Forum on Research and Technologies for Society and Industry (IEEE RTSI 2017). Modena, Italy, 11-13 September 2017.
- IEEE International Conference on Innovative Smart Grid Technologies (IEEE ISGT Europe 2017). Torino, Italy, 26-29 September 2017.

6. Activity abroad

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

7. Tutorship

Pasquale De Falco was involved in tutorship activities for a duration of 40 hours for the preparation of two Ms. Sc. thesis and one Bachelor Degree's thesis. Pasquale De Falco was also involved in the academic tutorship program for first-year students for a duration of 50 hours.