ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium
for Informatics and Mathematics

Scientific Report

First name / Family name	Maximiliano Bueno-López
Nationality	Colombia
Name of the *Host Organisation*	NTNU
First Name / family name of the *Scientific Coordinator*	Marta Molinas
Period of the fellowship	01/05/2017 to 30/04/2018

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During the fellowship, my scientific activity includes three main research contents:

1. Hilbert-Huang Transform for EEG signal analysis

The Hilbert Huang Transform (HHT) is composed for the Empirical Mode Decomposition (EMD) and the Hilbert Spectrum (HS). The EMD is an adaptive time-frequency analysis method, which is very useful for extracting information from noisy nonlinear or nonstationary data. The applications of this technique to Biomedical Signal analysis has increased and is now common to find publications that use EMD to identify behaviours in the brain. During the fellowship, I have advanced in this field looking for ways to extract information from Electroencephalography signals (EEG). The main result in this topic has been the identification of frequency components that are associated with activity in the brain. Some of these frequencies present the effect called mode mixing and therefore it has been necessary to discuss the challenge of this problem when using the EMD to identify intrinsic modes from EEG signals for neural activity reconstruction.

The tests carried out to the implemented algorithms have used real and simulated databases. The relevant results have been published in [1], [3], [4], [5], [6], [7] and [8].

2. Power Quality in Low-Voltage distribution systems with high penetration of photovoltaic generation

Nonlinear and non-stationary properties have been observed in measurements coming from modern power systems. A few years ago, research in this area did not have many applications in power systems because in general the voltage had an excellent quality with a constant frequency. This is gradually changing and now the integration of vast amounts of Photovoltaic generation leads the distribution feeder to shift towards higher voltages and frequency changes. The use of Renewable Power Generation brings new challenges related to power quality issues, such as stability of voltage and frequency. Furthermore, with the changing power system nature, due to the presence of new components such as power electronics in large numbers and control dominated systems, the tools that have been used for more than a century, are no longer providing accurate information to solve the system problems. In an attempt to contribute with a new view of the problem, we propose the use of Hilbert Huang Transform for the analysis of oscillations in Low Voltage distribution systems considering Photovoltaic generation. The aim is to characterize the behavior of the system in a time-frequency domain analysis. The validation of the methodology is carried out in a Real-time digital simulator of a distributed system with Photovoltaic generation. The relevant results have been published in [1], [2], [9] and [10].

3. Energy Transition

Latin America have been presenting changes in the way of generating electricity. These changes have been motivated by environmental issues and by the need to increase the coverage of the basic services required by any human being. The case of Colombia is very interesting because it is a country that is living the termination of an internal conflict of more than 50 years. In this topic, the approach has been to the way to adapt the technology in search that the communities in rural areas of Colombia have access to a continuous electricity service. We have been studying the technical needs of the rural areas of Colombia, and thanks to this we have begun the design and implementation of a monitoring platform for generation systems. The purpose of this device is to know the operating conditions of the system and how the generated energy is being used. We are working in this field with two master students from NTNU and with Universidad de La Salle in Bogota, Colombia. In November of 2017, we submitted a project to the Administrative Department of Science and Technology and Innovation-Colciencias, in search of founding. The relevant results have been published in [11].

Finally, I want to mention that during this year we are established a cooperation network which has generated the following actives:

- Student activities in Colombia for the design and implementation of a monitoring interface for solar generation systems in rural areas. In this activity, we have included two Master students from NTNU.
- A cooperation agreement was signed for the exchange of students and professors between NTNU (Trondheim, Norway) and Universidad de La Salle (Bogotá, Colombia).
- We submitted two projects to The Department of Science, Technology and Innovation in Colombia, looking for funding to continue our research.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

During the fellowship, I have written several papers. At the beginning, we focus on conference papers because the subject is novel and we wanted to validate with some experts our results. Then, we started to write the journal papers and now we have four under review and two more in process. The papers are listed as follows:

[1] **M. Bueno-López**, M. Molinas and G. Kulia. Understanding Instantaneous frequency detection: A discussion of Hilbert-Huang Transform versus Wavelet Transform. *International Work-Conference on Time Series Analysis*. Granada, Spain, September 18-20, 2017.

[2] E. Bernal, **M. Bueno-López** and M. Molinas. Decentralized Fuzzy-Based Voltage Control for LV Distribution Systems. *33rd European Photovoltaic Solar Energy Conference and Exhibition*. Amsterdam, The Netherlands, September 25-29, 2017.

[3] **M. Bueno-López**, E. Giraldo and M. Molinas. Analysis of Neural Activity from EEG Data using EMD frequency bands. *The 24th IEEE International Conference on Electronics, Circuits and Systems (ICECS)*, Batumi, Georgia. December 5-8, 2017.

[4] **M. Bueno-López**, E. Giraldo and M. Molinas. A new method for localizing activity in the brain based on Empirical Mode Decomposition and entropy function. *7th International BCI Meeting*. Pacific Grove, California, May 21-25, 2018.

[5] M.V. Gasca, **M. Bueno-López**, M. Molinas and O. B. Fosso. Time-Frequency analysis for nonlinear and non-stationary signals using HHT: A mode mixing separation technique. *IEEE Latin America Transactions*. Paper accepted in April 2018.

[6] **M. Bueno-López**, E. Giraldo and M. Molinas. Localizing the Focal Origin of Epileptic Activity Using EEG Brain Mapping Based on Empirical Mode Decomposition. 26th *European Signal Processing Conference (EUSIPCO)*, 2018. Under Review.

[7] **M. Bueno-López**, E. Giraldo, M. Molinas and O. B. Fosso. Mode mixing problem and its influence in the neural activity reconstruction. *IEEE Transactions on Signal Processing*, 2018. Under Review.

[8] **M. Bueno-López**, E. Giraldo and M. Molinas. Localizing the Focal Origin of Epileptic Activity using EE1G Brain Mapping based om Empirical Mode Decomposition and a classic method. *IEEE Transactions on Biomedical Engineering.* 2018. Under Review.

[9] **M. Bueno-López**, E. Bernal and M. Molinas. Oscillation analysis of Low-Voltage distribution systems with high penetration of photovoltaic generation. *IET Renewable Power Generation*. 2018. Under Review.

[10] **M. Bueno-López**, E. Bernal and M. Molinas. Control method to reduce oscillations in LV distribution grids with high penetration of PV Systems. *IEEE Transactions on Sustainable Energy.* 2018. Extended Abstract Under Review.

[11] **M. Bueno-López**, P. Rodríguez, C.A. Correa and M. Molinas. Energy Transition in Colombia: a new model of rural development based on energy cooperatives. *Applied Energy.* 2018. Under Review.

[12] I. Forseth, V. Aabrek, **M. Bueno-López** and M. Molinas. Design and implementation of a monitoring interface for productive systems based on solar energy in rural areas. *GHTC 2018, IEEE Global Humanitarian Technology Conference*, 2018. Under Review.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. **International Work-Conference on Time Series Analysis**, 18-20 September 2017. Granada, Spain.
2. **33rd European Photovoltaic Solar Energy Conference and Exhibition**, 25-29 September 2017, Amsterdam, The Netherlands.
3. **The 24th IEEE International Conference on Electronics, Circuits and Systems (ICECS)**, 5-8 December 2017, Batumi, Georgia.
4. **The Seventh International Brain Computer Interface Meeting,** 21-25 May 2018, Pacific Grove, California, USA.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Inria Grenoble Rhone-Alpes at ENS de Lyon

Paulo Gonçalves, Senior Researcher Inria, September 21-28, 2017

I have done the Research Exchange Programme (REP) at Inria Grenoble Rhone Alpes-ENS de Lyon, France, on September 21-28, 2017, where I was working in the research team of Prof. Paulo Gonçalves. During this time I had the opportunity to meet also with the Professors Patrick Flandrin and Nelly Pustelnik. This team have made great contributions about Empirical Mode Decomposition. The publications of Professor Flandrin are very well known, mainly their influence on the subject of Mode mixing is very high.

During the week of the REP, I presented my advances in detecting instantaneous frequencies and applications with EEG signals. In this way, it was possible to validate our progress about Empirical Mode Decomposition and Mode Mixing. In addition we discussed possibilities of improvement of our algorithms.