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Innovative controls for renewable source integration into smart energy systems

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D3.1

WP3 Annual Scientific Report

WP3 – Control Strategies for RES Integration

Grant Agreement no 675318

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DEFINITIONS

- Beneficiary partners of the INCITE Consortium are referred to herein according to the following codes:
  - **IREC**. Fundacio Institut de Recerca de l'Energia de Catalunya (Spain)
  - **UPC**. Universitat Politècnica de Catalunya (Spain)
  - **TU Delft**. Technische Universiteit Delft (The Netherlands)
  - **VITO**. Vlaamse Instelling Voor Technologisch Onderzoek (Belgium)
  - **UniBo**. Universita di Bologna (Italy)
  - **UGA**. Université Grenoble Alpes (France)
  - **GE Global Research**. General Electric Deutschland Holding GmbH (Germany)
  - **Efacec Energia**. Efacec Energia - Maquinas e Equipamientos Electricos SA (Portugal)
- **Beneficiary**. The legal entity, which are signatories of the EC Grant Agreement No. 675318, in particular: IREC, UPC, TU Delft, VITO, UniBo, UGA, GE and Efacec Energia.
- **Consortium**. The INCITE Consortium, comprising the above-mentioned legal entities.
- **Consortium Agreement**. Agreement concluded amongst INCITE Parties for the implementation of the Grant Agreement.
- **Grant Agreement**. The agreement signed between the beneficiaries and the EC for the undertaking of the INCITE project (Grant Agreement n° 675318).
- **Partner Organisation**. Legal Entity that is not signatory to the Grant Agreement and does not employ any Researcher within the Project and namely, 3E NV (Belgium).

ABBREVIATIONS

- **CA**. Consortium Agreement
- **CMO**. Central Management Office
- **EC**. European Commission
- **ESR**. Early Stage Researcher
- **GA**. Grant Agreement
- **INCITE**. Innovative controls for renewable source integration into smart energy systems
- **IRP**. Individual Research Project
- **WPs**. Work Packages

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EXECUTIVE SUMMARY

This report summarises the progress of WP3 “Control Strategies for RES Integration” from ESR recruitment until M23 of the Action. WP3 comprises three IRPs carried out at IREC and UGA, and the ESRs are working hard to complete and achieve all expected objectives within their tasks as well as maximize their impact. The progress of WP3 up to now can be considered as satisfactory.

Progress and impact of each IRP is presented, as well as networking and dissemination advances within this WP.

1. STATUS OF WP3

1.1 WP objectives

The increase of RES (mostly wind and solar energy) in the participation of electricity generation may affect the stability of voltage and frequency in power distribution systems. With participation close to 20% in some European countries, grid codes are starting to impose strong requirements for the integration of RES. In this context, wind and solar plants are required to shift their objective from harvesting as much energy as possible to providing grid support services. The research activities in WP3 are centred on new control strategies for RES integration considering electric aspects such as the stability of electric variables (e.g. frequency and voltage).

The contributions of the work carried out within such tasks are closer to applications of real smart grids and electric aspects but with a clear focus on control and applied mathematics theory application within the electric grid world. Thus, the objectives of this work package are:

- Modelling of smart grids for stability analysis.
- Development of control strategies for integration of RES.
- Proposing distributed control strategies for grid support.

With the aim of achieving such objectives WP3 is organized in the following three tasks including interactions among partners:

- Task 3.1: Model and stability analysis of smart grids (UGA, IREC, VITO)
- Task 3.2: Control strategies for grids with high penetration of RES (IREC, UGA, GE-GR)
- Task 3.3: Develop control schemes for large RES to provide grid support (IREC, TUDelft, GE-GR)

1.2 WP general progress

The general progress of the work package is fully satisfactory. Most of first year was dedicated to the recruitment of the ESRs; thus from the 24 months, about 15 have been used for familiarization and definition of the project objectives and workplan of each Individual Research Project.

During this period, all positions have been successfully assigned and the ESRs are working hard to complete and achieve all expected objectives within their tasks as well as to maximize their impact.

It is worth noting that according to the original plan all ESRs should be currently on their secondment. However, due to delays on the recruitment and the current status of their work, two ESRs have shifted their secondments to maximize their impact. One exception is ESR33 who is at TU Delft, working together with other key people of the same institution.

In brief, each ESR has carried out the following advances:

- In IRP3.1, different models of HVDC systems and AC grids have been carried out, showing some potential interactions among both grids through a sensitivity analysis.
- Within IRP3.2, research about the modelling of power systems as complex systems, mainly as Kuramoto-Like oscillators has been carried out, and studies on the stability analysis of grid connections and grid shape have been started.

- Finally, in IRP3.3, several centralized controllers have been proposed to maximize the energy reserves within wind farms; and a start has been made in the development of distributed control strategies for distributed resources.

1.3 WP impact

The work already done in WP3 has already contributed to enhance the research and networking skills of the PhD fellows. Consolidation of the obtained skills and further enhancement is expected during the up-coming years with the continuation of the scientific tasks and the first months spent at the premises of the other partners.

While very few publications have been achieved in this period, the results obtained are very encouraging and should lead to several conference or journal publications soon.

2. PROGRESS OF THE IRP

In this section, a detailed explanation of the progress made by each ESR and their individual projects is given.

2.1 IRP 3.1 – Control strategies for hybrid AC-DC grids

As expected within the first year, the main tasks for the IRP included, amongst others, modelling of hybrid AC/DC grids for control design purposes, detecting interactions among AC and DC systems, designing control systems for DC grids to support AC power systems. This task required a literature review to get an insight of the problem and find gaps in the existing literature considering the topic in question. An extensive review revealed several gaps. One particular item is related to the complexity of modelling both AC and DC grids together. Most authors either simplified the AC side in studies where DC was the major consideration; or simplified the DC grid where the AC grid was the major consideration. In very few cases were both grids considered in detail. In the same vein, there were gaps in the modelling methodologies that combined both grids, permitting to study one, while simplifying the other. The first year of work has been devoted to the development a suitable methodology or combination of methodologies that met the discussed criteria, validating it for simple cases, and, in a typical fashion, extend to more complex cases. It is expected that, at the end of the second year, a realistic hybrid AC/DC grid model or models for various studies are developed and the most important results and insights from studies are published. In particular, we aim at meshed AC/DC grids with a high level of complexity.

2.2 IRP 3.2 – A new modelling approach for stabilisation of smart grids

During the first year, the ESR focused mainly on the existing scientific progress made in the field. At first, a rigorous and comprehensive literature review about stability and synchronization in power systems was carried out. The models most commonly used in the study of synchronization have been identified and the scientific results have been understood. Some computer experiments were

performed to reproduce the analytical results from literature. Next, weaknesses in the models studied before were identified. It was necessary to consider which simplifications had an impact in the properties of synchronization of the network. Using this insight, an extension of the model used was formulated. Afterwards, the ESR stated the open questions regarding the extended model and derived strategies on how to answer these questions. The project is meant to be exploratory work. During this fundamental work, the ESR was able to improve his knowledge of power systems, smart grids and electrical engineering. This knowledge will be helpful in the further work expected within the INCITE project.

2.3 IRP 3.3 – Distributed control strategies for wind farms for grid support

As it is expected within this IRP, the main objective is to propose distributed control strategies for wind farms aimed to regulate both the active and reactive power injected into the grid in order to provide ancillary services (i.e. frequency support and voltage stability) to fulfil the TSO's demands. Accordingly, a comprehensive literature review on the state of the art of the Grid Code requirements related to ancillary services has been carried out, and an extensive technology review of control strategies for the wind power plants has been made. Next, with the aim of improving the participation of wind power in ancillary services, a centralized control strategy has been proposed in order to maximize the active power delivered to the grid after a frequency event. Initially, a model predictive control strategy was cast as a multi-objective optimization problem and evaluated for a low number of wind turbines facing only one wind profile. Last, the scheduling of power generation for wind power plants has been provided to optimize primary frequency responses. This optimization problem has been tested for a wind power plant of twelve wind turbines and several wind profiles.

3. INTERNAL AND EXTERNAL COLLABORATIONS

In order to maximize internal collaboration within the work package and the project, the IRPs objectives and developments have been presented to all the ESRs with a special focus on potential interactions. This work package is foreseen as having the most potential for interactions with the rest of the WPs since it focuses on grid stability with other technologies to be integrated within the future power systems, such as energy storage, new market agents, and distribution network control. Such internal collaborations within INCITE will be further exploited throughout the secondments of these projects.

Additionally, external collaborations have already been started with some experts that are collaborating with the consortium partners as UPC (experts on HVDC), TU Delft wind control group, and contacts have been established with the SuperGrid Institute, among others. Such external collaborations help maximize the impact of the IRPs and the project itself.

4. PUBLICATIONS/CONFERENCES

Agbemuko, A.J. et al. “Harmonic Stability and Interaction in HVDC Dominated Power Systems” NEIS 2017 Conference, Hamburg, Germany – Poster presentation + full paper. Online publication pending.

Agbemuko, A.J. et al. “Harmonic Stability and Interaction in Meshed VSC-HVDC Dominated Power Systems” Large Wind Integration Workshop, 2017, Berlin, Germany – Oral presentation + full paper. Online publication pending.