PhD Thesis
"New methods for Frequency Signal Modelling and Impact Evaluation of New Resources"
Answers to reviewers

Reviewer 1: Prof. Stefano Massucco

> ***Comment 1.A)*** *I really appreciated this Thesis work. It addresses an important and timely subject like the participation of BESS to frequency control. The thesis provided a large and thoroughly literature review which poses the bases for its new contributions. The presentation of theoretical work is rigorous and the two applications regard existing networs (Sardinia in Italy and the Irish networks) although the models adopted are simplified ones. It would have been of interest to test the suggested approaches for larger models of these systems.*

Thank you very much for your appreciation. In chapter 6, the Irish network was simulated by using a model with more than 1000 buses and hundreds of grid elements such as transformers and power lines. The synchronous generators and the other elements are described by algebraic-differential equations in a dq axis frame of reference depicting the major dynamics for transient stability analysis. The software used was Dome which solves this system of equations by making use of the proper numerical integration method. I added few rows describing the software in Section 6.2.1

Clearly it would be interesting to simulate also the Sardinian case with full models to have more insights on the analysed techniques.

> ***Comment 1.B)*** *I suggest to change/adapt a sentence at page 24: "The machine will lose its synchronism if the angle becomes greater than 90°".Actually in transient stability oscillations the angle may transiently go over 90° if a sufficient recovery electric power is available depending on the initial working point (which must be below 90°) and the amount of the perturbation.*

Yes, I agree with your suggestion. While reaching an angle greater than 90 % is surely dangerous for the machine stability, synchronism can be still retained depending on the perturbation and synchronous machine characteristics. The generator, after a transient, can return to work in stable point under 90° degrees. The sentence was duly changed in the text of the Thesis

> ***Comment 1.C)*** *Chapter 7 is somewhat not well linked to the previous part of the thesis. It is of interest to control and manage such a large and distributed quantity of storage like the one available from EV. The thesis tries to identify the different roles of TSO and DSO but the presentation is less convincing than the previous chapters that better adressed BESS applications at Utility level.*

I understand the point raised. Please, refer to the comment 2.D where I explain the peculiarities of this chapter.

Comment 1.D) *Some minor text changes are: to use the word "large" instead of "big" in some points of the text. Before equation 4.10 at page 67, HESS should be HBESS. At page 150 (3 lines from the bottom) there is a mistyping of the word leads*

Thanks for your comment. These and other small mistakes were corrected while proof-checking again the Thesis.

Reviewer 2: Prof. Massimo La Scala

Comment 2.A) *the subject of the thesis is relevant and interesting, and the proposed methods are good and innovative. The form of the work is adequate and well understandable. The specific application examples, referring to real cases, have a significant value and provide proof of the presented methodologies.*

Thank you for your appreciation of this work.

Comment 2.B) *In the summary the candidate utilizes the first person to describe the work; I believe it would be better to use of the third person;*

The summary was changed according to your suggestion.

Comment 2.C) *I would also propose to include a brief conclusion at the end of each chapter summarizing the main results.*

A brief conclusion paragraph was added at the end of each chapter summarizing the main results.

Comment 2.D) *This latter aspect is particularly necessary in Chapter 7 where the work results not well-defined and still incomplete. I understand that this is just the beginning of a further investigation neverthless a proposal for the future work on the same subject with motivations and directions seems unavoidable. In other words, section 7.3.3 needs to expanded and well motivated. As a matter of fact "Integrating frequency control into Priority based logic" is the link between this section and the previous part of the thesis and need to be corroborated by some additional considerations and discussion. If some on-going well-proved test results are available, it may be considered the possibility to insert them.*

It is indeed true that the last chapter needs further work. While the final goal is always the analysis of frequency control, the use of EVs is not straightforward as in the case of Utility scale BESSs. Stochastic behaviour, grids limitation and markets strategy are all elements which need to be taken into account for a rigorous assessment of the resource potentiality.

For this reason I built a framework composed of several passages to study the problem. I added few notes in the new section 7.4 in order to integrate and improve the previous sub-section 7.3.3 and to present all the ideas and methodologies I devised to conclude the studies. These passages would require additional time to be simulated.

From 1st December 2019 I started to work for Terna, and I have been involved in other projects. In the meantime, I had the possibility to finish writing my Thesis, to work on the revision of the paper on Power to Gas and prepared a conference paper about "frequency control in normal operation in the Sardinian system" currently under review for UPEC 2020. The main results of this last work have been added in Chapter 5 in section 5.4. Another PhD student in Turin is currently pursuing and continuing the research on EVs enlarging and implementing a bigger market strategy as presented in the second case study of chapter 7.