SPORE@REIDS – A MULTIFLUID MICROGRID DEMONSTRATOR IN SINGAPORE

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ABSTRACT

ENGIE, NTU and Schneider Electric have joined forces to develop the first multifluid microgrid among the REIDS initiative in Singapore. This complex microgrid is composed of various assets coming from a range of different suppliers, and their integration into one common system is a major challenge. The management system made up of the EMS and the PMS as well as the SCADA is a common development effort which has to align the different primary objectives of each sub-unit and make them work as one coherent system. The tropical climate in Semakau is also an additional stress applied on the assets and the operating staff. First tests results are expected in the second half of 2018.

INTRODUCTION

The **S**ustainable **P**owering of **O**ff-grid **RE**gions is a joint project started in 2015 between ENGIE, Nanyang Technological University (NTU) and Schneider Electric, with the goal of developing a multi-fluid microgrid among the REIDS initiative in Singapore. The **R**enewable **E**nergy **I**ntegration **D**emonstrator in **S**ingapore is an initiative led by the NTU on the Semakau Island, whose purpose is to facilitate the development and market penetration of the energy technologies suited for tropical conditions in Southeast Asia via the implementation and testing of various microgrid systems within the island.

Figure 1: Wind turbine & PV panels in Semakau Island

This initiatives includes many partners coming from all over the world and from all corners of the energy industry. ENGIE and Schneider Electric are at the forefront of this initiative, with the development of the first multi-fluid microgrid in the island. [1]

A COMPLEX MULTIFLUID MICROGRID

One of the objective of the SPORE microgrid, besides promoting renewable energy sources, is also to demonstrate the feasibility of dealing with several energy fluids in one system. Besides the classical elements found in most microgrids of today – typically a wind turbine, some PV panels, batteries to store the renewable energy produced and diesel generators (gensets) to ensure grid stability and reliability - the SPORE microgrid includes a Virtual Synchronous Generator (VSG), a complete hydrogen (H2) conversion and storage system with a hydrogen refuelling station as well as biogas driven generator set.

The Virtual Synchronous Generator is currently developed by Schneider Electric and will be tested in the challenging conditions of Semakau Island. The VSG is composed of a classic Li-ion battery, PV panels as the power source, a specific inverter and of course an innovative set of control algorithms. Its purpose is to eventually substitute the genset as the grid-forming element and thus allow a possible penetration of 100% of renewable energy within the microgrid. The idea behind this system is to replace the rotational inertia provided classically by generators with an artificial inertia provided by the inverter, with the help of the battery. [2] In fact, with its very-fast response time, the inverter could react to an unbalance between production and consumption by injecting/withdrawing power thanks to the battery which can deliver/accumulate a certain amount of energy over a limited period of time. This would allow other producing assets to adapt to any change in power required, the grid remaining stable in the meantime. This kind of technology is paramount in order to improve further the share of renewable energy resources, which are almost always non-rotating producing units (PV panels and wind turbines are connected to the power grid through inverters, thus without any actual inertia).

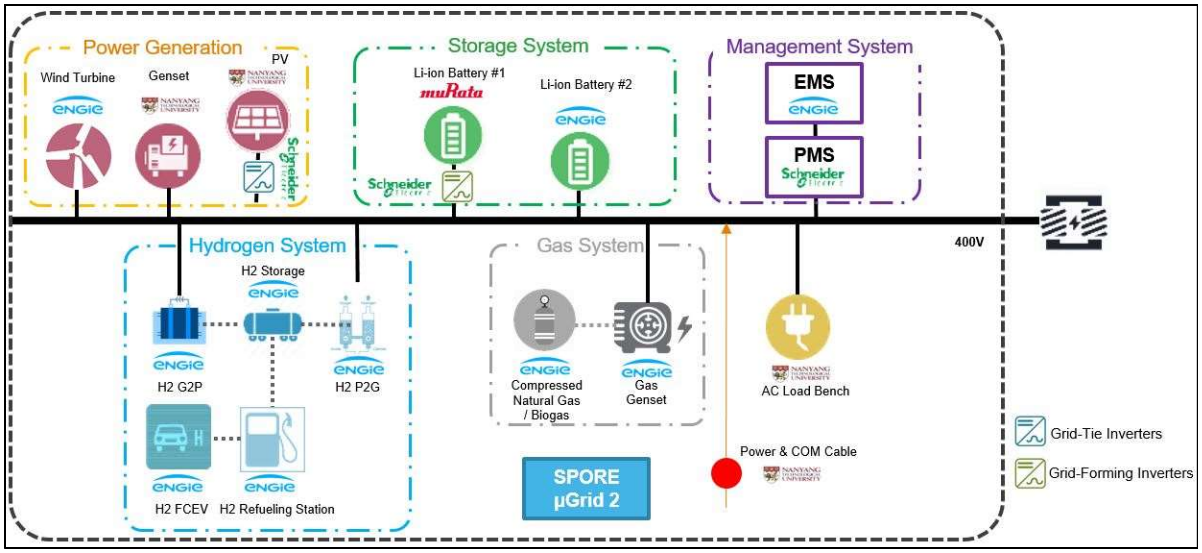

Figure 2 : Schematic of the SPORE microgrid

The H2 system is composed of the following elements: an electrolyser, a H2 storage tank, a fuel cell and a refuelling station for a fuel cell electric vehicle. The philosophy of the system is that it can serve two purposes. Firstly, the bundle electrolyser-H2 tank-fuel cell can be seen on a functionality level as the equivalent of a storage unit, which can store the energy produced by renewable sources as hydrogen in the H2 tank. Secondly, the refuelling station can use some of the hydrogen stored in the tank to refuel vehicles and thus promote an emission-free mobility.

The biogas generator is part of a simulated biogas system, which also includes Compressed Natural Gas (CNG) bundles. The biogas generator is similar to a classical genset in terms of functionality, the only difference being the use of biogas instead of diesel as fuel. The purpose of CNG bundles is to emulate the production of biogas through the disposal of organic waste. Energy is thus produced while disposing of wastes, a true *win-win* situation.

Due to the lack of suitable and flexible power consumption present on the island, another essential element of the microgrid is the load bench, which not only allows the power produced to be consumed (without this balance between production and consumption, the grid does not exist), but also permits to test various use-cases such as a sudden drop of the load or even worse a sudden increase, which is always challenging for the power grid since it endangers the power balance thus apply stresses on the grid.

Finally, all of these various units could not operate together and function as a whole without a proper management system. The main components of such a system are the Power Management System (PMS), the Energy Management System (EMS) and the Supervisory Control And Data Acquisition (SCADA), which will be detailed hereafter.

MANAGEMENT SYSTEM DESIGN

The management system scheme is illustrated in Figure 3. It can be seen that the three main bricks PMS, EMS and SCADA are sequential in their functionalities and interactions.
The PMS purpose is to ensure the stability of the grid at any moment, including but not limited to the aforementioned power balance and the power quality, which is notably about keeping the voltage and frequency levels within the admissible limits. [3] The PMS is straight connected to all the assets and is able to send instructions to all of them. Some assets are entirely controlled by this system while others are just getting set points which are then incorporated by their own internal control system. In order to ensure the power balance, the PMS must not only deal with the available power resources, which are not always predictable like notably the solar panels or the wind turbines, but also with the reactivity capabilities of each of them. A sudden change in the consumption will be managed only if the production assets can react fast enough and adjust their production.

The SCADA serves as the interface between the entire microgrid process and the user, or rather in this case the operators who will proceed with the academical tests. Its purpose is to be able to monitor and interact to some extent with the operations of the microgrid. Boundaries have to be clearly established between the responsibilities of the PMS and the parameters that can be controlled by the SCADA user. If some exchanges are foreseen in the management system design between the end-user and the PMS itself (internal parameters settings for example), this will occur via the SCADA interface.

The EMS purpose is threefold. First, the EMS aims at making the most of the multi-fluid aspect of the microgrid and thus maximizing the synergies between all the technology bricks.
Secondly and more classically, a focus is put on short-term optimisation, which consists in choosing among the assets available the most appropriate production and storage means to supply the power demand while minimizing OPEX and environmental impact. This second objective relies heavily on weather and consumption forecasts.

Finally, the EMS proceeds to a mid-term optimization on the use of the various assets and their maintenance schedule, with a view to maximize the lifetime of all assets and minimize replacement costs. Transversally to all these objectives, the EMS is expected to remain customer-focused, meaning that the expectations from the customers are taken into account in all optimizations to guarantee the quality of the electrical supply as well as the fine-tuning of the optimization priorities based on the customer choices.

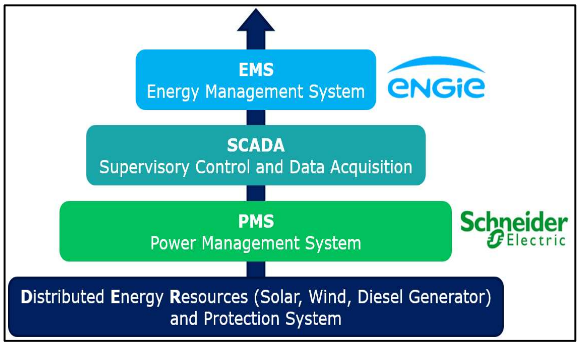

Figure 3: Management system scheme

THE CHALLENGE OF INTEGRATION

A major challenge in the making of the SPORE microgrid is the integration of different technologies in one coherent and functional system.
The various elements in the microgrid, including but not limited to the assets, are brought by various partners and have to be integrated in one common system. This induces significant challenges in terms of interoperability among the assets, the communication chains and the management systems.The interface between the EMS and PMS is, notably, a key development in this project. Two systems designed by two different companies, each having their own set of proprietary algorithms and coding languages, with a different set of objectives, must be brought together in order to obtain a functioning global system. This global system is thus expected to achieve both sets of objectives.
In order to achieve this goal, both development teams have to reach a common vision on the principles behind each individual units, otherwise no common solution can be figured out. Indeed, before deciding which signals will be sent from one unit to the other (and the corresponding technical modalities), which is the interface in itself, an agreement has to be found on the inner logics of each unit. Some fine-tuning (up- or downgrade) may be required and a clear boundary has to be drawn between the two systems responsibilities in the management system, otherwise no interface can be developed.
In other words, before agreeing on the interface itself, the development teams must agree on what each individual unit can or cannot do.

Of course there are other intercompatibility issues, notably regarding communication protocols between each assets and the unified communication architecture, with the PMS in charge. A single database must be built to integrate all inputs and outputs (I/O) signals. These can vary widely among the command signals, the measurements or the status and alarm signals. It is thus not a small feat to assemble all of these and correctly establish a map of the communications among all different units (EMS, PMS, SCADA and the assets).

Another point of attention regarding the integration is the global operating modes of the overall system, which has to be carefully built based on each asset’s features, regulation and technical limits, but also on the basis of the general vision of the microgrid operations. What does this system aim to test? What will be automatically controlled and what will be controlled by the user through the SCADA interface? Those are examples of questions that need to be addressed when designing the global operating modes of the system.

IMPACT OF CLIMATIC CONDITIONS

The tropical climate on Semakau Island induce challenges not only for human work but also on a technical level. It is a euphemism to say that the climate is harsh on the Singaporean Island. With an average relative humidity above 97% and a temperature never below 25°C during a whole year and often exceeding 30 degrees, the strain on the human body is severe. [4] Working shifts have to be carefully determined in order to limit the burden on the workers, otherwise there is an increased risk of reduced attention and focus capability, which in the context of a research project with dangerous voltages could prove to be catastrophic.

But more importantly these conditions consist in a threat to the microgrid assets themselves. These assets include components that were not specifically designed and tested for such climatic extremes. The power electronics notably, which are part of almost every assets on the microgrid, present a myriad of components which could be harmed at some point.

For PV panels inverters, the damages would likely be limited, at worst the destruction of the asset itself. However for more critical assets like the H2 elements for example, such failures could again be catastrophic, endangering potentially not only the entire microgrid infrastructure, but the safe-keeping of the staff as well.

A careful maintenance has thus to be performed on every component and this issue must be a major point of attention during the operations of the microgrid. The analysis of the impact of such extreme climate on the assets behaviour, efficiency and lifetime will be one of the project outputs, along with a characterization of the microgrid technical capabilities and the performance of the EMS optimization scheme.

CONCLUSION

The SPORE @ REIDS project aims at facilitating the development and market penetration of renewable energy technologies in Southeast Asia, via the implementation and testing of various microgrid systems in Semakau island, a landfill located in Singapore Bay. The unique properties of this megawatt demonstrator lie in the capability to handle multi-fluid technologies, the incorporation of a special developed EMS/PMS management system, the incorporation of a virtual synchronous generator and the ability of the technologies to resist the harsh tropical climate. The virtual synchronous generator, which is PV-inverter based and extended with a battery storage on the DC-bus, enables grid-forming capability and stability thanks to an increase in artificial inertia. The demonstrator setup is a test-bench for different technologies, to be tested thoroughly in the coming months/years, and to be evaluated on different technological aspects, such as integration inside multi-vendor, multi-fluid microgrids.

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