Final report – SPGC

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1. Project details

Project title	SPGC
File no.	6401-0582
Name of the funding scheme	EUDP
Project managing company / institution	Ballard Power Systems Europe
CVR number (central business register)	30804996
Project partners	DTU, Energinet, Thy-Mors Energi
Submission date	23 April 2024

2. Summary

English

The project is regarding hydrogen feed backup power in the electric grid substations. The purpose is to develop and demonstrate backup solutions to secure communication and control of the electric grids substations to obtain high reliability a long with a cost-efficient way of increasing backup time by hydrogen as fuel for longer outages. The project will investigate and develop solutions that can handle peak power transient demands related to activation of the high voltage breakers. The project is based on 2 different concepts of backup systems with fuel cells. A battery free solution to be tested at DTU and demonstrated at Elværk (former Thy-Mors Energi (TME)) AC ad on solution demonstrated at Energinet (EN).

Dansk

Projektet omhandler nødstrømsforsyning baseret på brint og brændselsceller til transformerstationer i el-nettet. Projektets formål er at udvikle og demonstrere nødstrømsløsninger til sikring af kommunikation og styring i net-stationer i både transmissions- og distributionsnettet med et mål om høj pålidelighed, kosteffektivitet og mulighed for at forlænge backuptiden yderligere gennem brintforsyning under længerevarende strømudfald. Projektet søger specifikt at løse udfordringerne i levering af transient belastning fra nødstrømsforsyningen til aktivering af højspændingsafbrydere. Der arbejdes med 2 forskellige koncepter ifht. integration af brændselscellesystemet. Batteri fri løsning testes hos DTU samt som demonstration hos Elværk (tidligere Thy-Mors Energi (TME)). AC ad on løsning testes hos Energinet (EN).

3. Project objectives

The objective if the project is to simulate, develop, test end implement two different solutions for backup power at electric substations with the usage of fuel cell systems. Today the electric substations have backup supply consisting of multiple batteries coupled in series to gain a voltage of 220VDC which is the nominal operating needed to operate the high voltage breakers.

Both solutions in the SPGC project is based on Ballard's 5kW 48VDC air cooled fuel cell system with hydrogen supplied from std. 50L. cylinders. In the first concept the fuel cell system needs to be integrated as an AC ad-on backup for the existing 220VDC battery pack to extend the backup time to cape with longer outages.

The AC ad-on system is supposed to operate integrated with the sites existing 220VDC back up battery to extend the sites backup time. In figure 1 there is a one-line diagram of the AC ad-on concept with the fuel cell system connected to an inverter to supply the site with 230VAC.

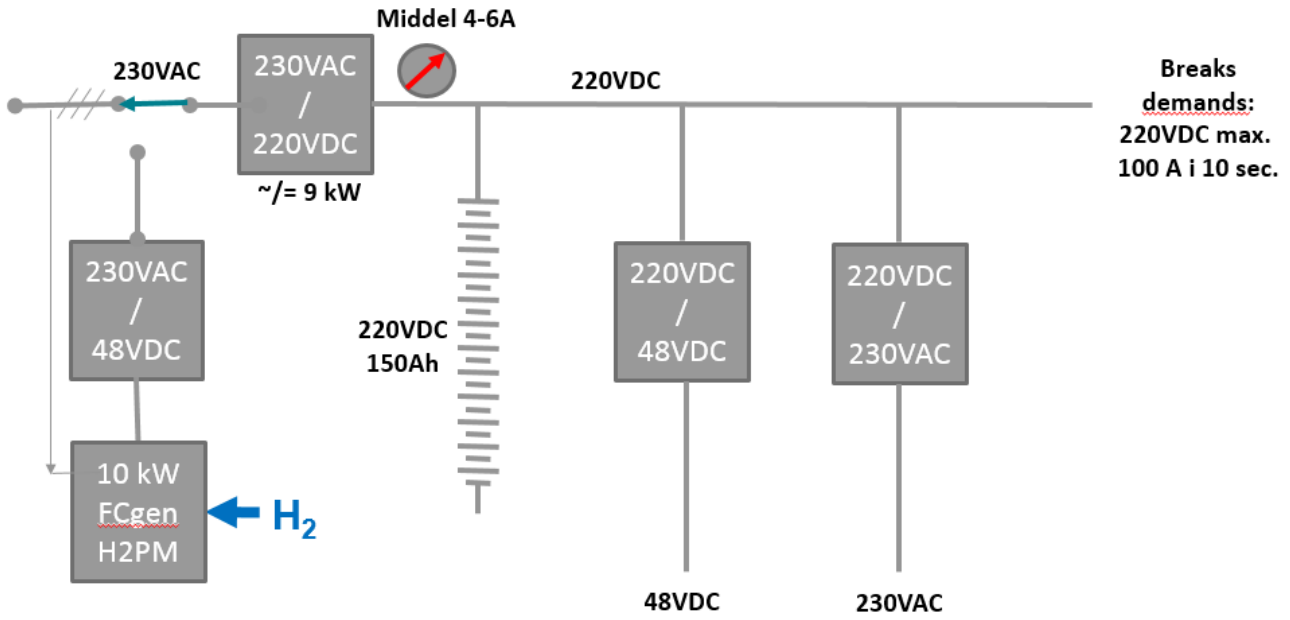

Figure 1 - AC ad-on one line diagram

The AC ad-on demonstration unit that has been developed and demonstrated in the project is an outdoor Power shelter solution with technical room and integrated gas storage to have a complete outdoor installation. The SPGC Power shelter solution is designed and equipped with an integrated 3 phase inverter for AC power. The power shelter solution capable of delivering >8kW AC as requested for the test site by Energinet. In figure 2 a picture or the technical room of the power shelter are displayed.

Figure 2 - Technical room Power shelter

In the SPGC project, the battery free system is supposed to substitute the electric substations existing battery pack with the use of a 5kW fuel cell system to cope with long outages. The fuel cell system needs to be

integrated with super caps in order to cope with the power demand of the high voltage breakers. In figure 3 a one-line diagram of the battery free integration is shown.

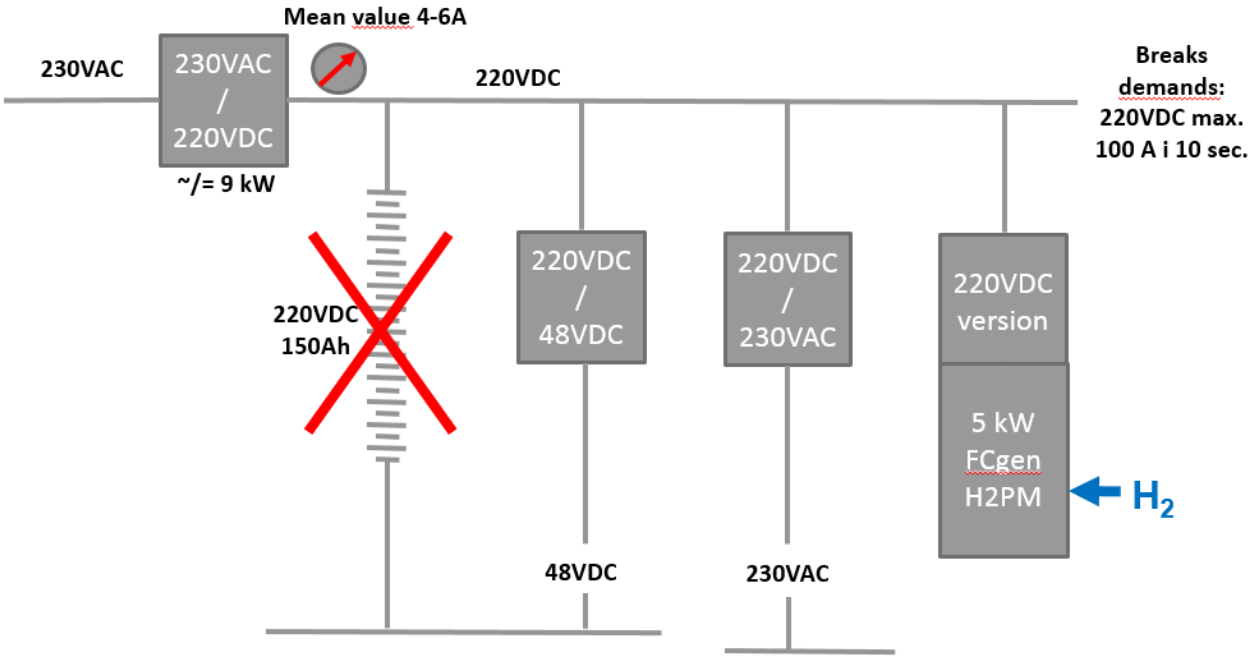

Figure 3 - Battery free one line diagram

The battery free solution that is developed and demonstrated in SPGC is slightly different form the original concept. The developed system is based on a 5kW fuel cell system and a booster (supercapacitors) to meet the peak demands. The system is with inverter for AC power to provide the nominal load. The fuel cell system is supplying the test sites existing rectifier as well as delivering charging power for the supercapacitors during power outages. The 220VDC booster in the SPGC project is based on 4 x Ballard super cap modules which nominally is designed for 48VDC applications these are coupled in series and individually adjusted in voltage to meet the electric substations required voltage level. For the SPGC project a controller for power and charging handling has been developed. The booster is connected to the sites fuse box instead of the existing battery pack. In figure 4 the one-line diagram of the developed battery free system is shown.

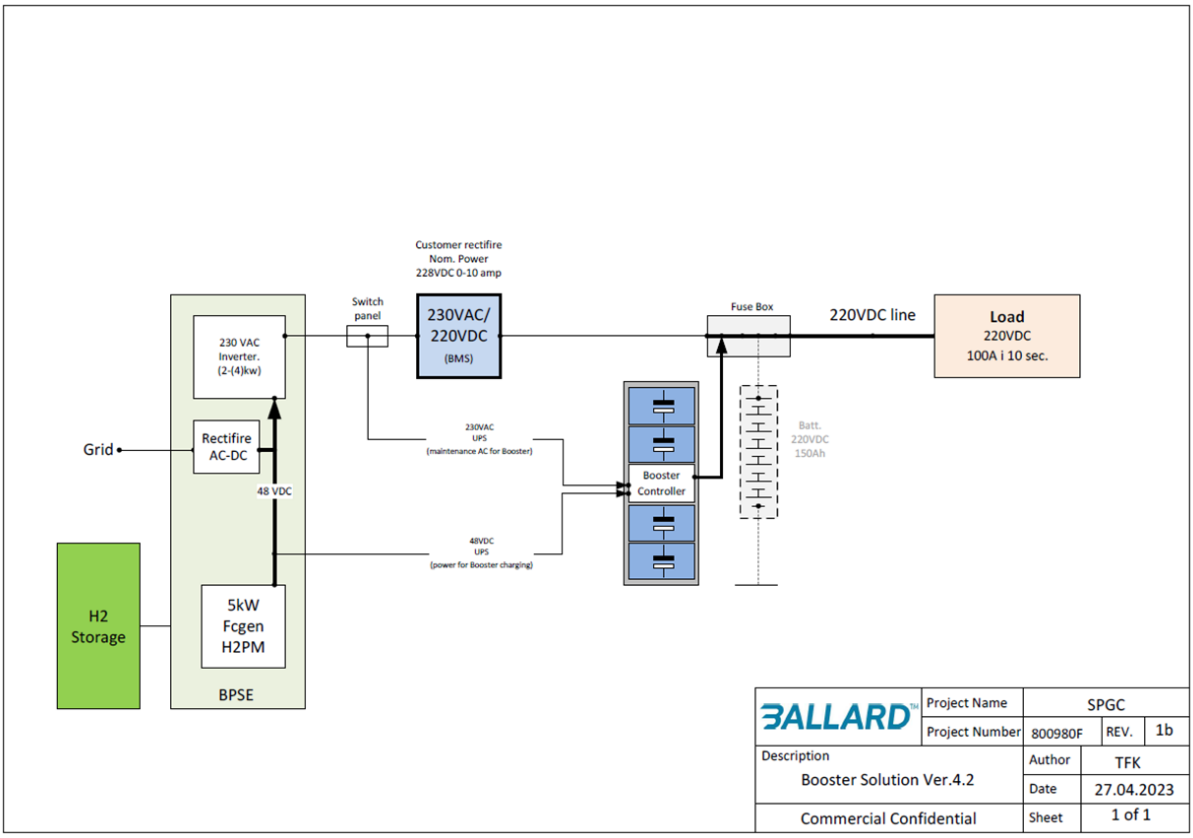

Figure 4 - Battery free system with booster

4. Project implementation

The project did not evolve as fast as originally planned, due to the fact that the ad-on solution originally was planned as an indoor solution, but in order to integrate with the test site Energinet would like an outdoor solution instead. It took longer to design, build, implement and modify a Power Shelter solution that could match the Energinet test site.

In the battery free solution, the project concept was based on the usage of a converter 48VDC/220VDC. The problem was that it is a non-commercial product and could not be acquired right away and would require special developed parts at a high risk and exceeding the system budget. A small change in system concept was discussed and agreed with the project partners to fulfil the task of developing and test the battery free solution.

The global pandemic COVID-19 with lockdown had a severe impact on the SPGC projects evolvement. Collaboration between partners was challenging as travel was restricted and workplaces and laboratories was shutdown. After the lockdown there was an extreme long lead time on parts from the industry which extended the time required to build the systems.

With the help from EUDP in terms of granted project extension it was possible to adapt the project timeline and finish the SPGC project after a project period of 5 years The Gannt chart is shown in figure 5.

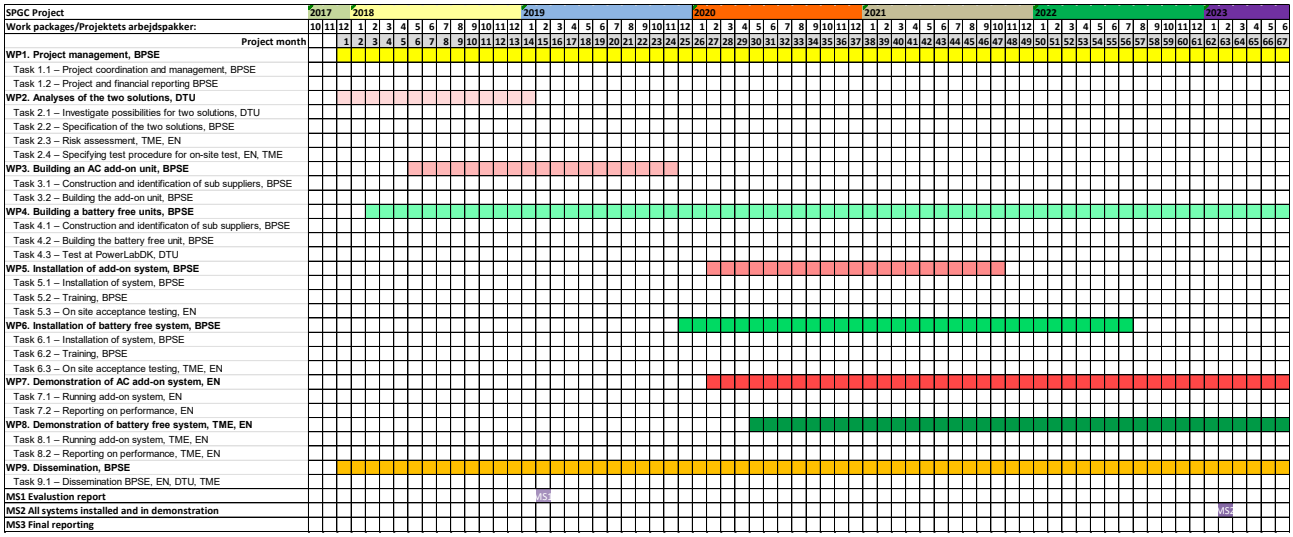

Figure 5 - Gannt chart

There was a good collaboration among project partners throughout the project and the milestones were fulfilled.

Milestone 1. DTU shared simulation results and findings gathered the information in a report as well as the risk assessment report that was shared.

Milestone 2. Both system concepts were installed, tested, and demonstrated in the field at the Energinet and Elværk (Thy-Mors Energi).

5. Project results

DTU (PowerlabDK) have performed the planned simulations of the 2 concepts and compared with measured data from test sites and laboratory breaker tests. Data shows that the Ad-on solution with 10kW fuel cell system and the existing battery pack, would be fully capable of maintaining backup during the specified 24h. In the battery free solution, the simulation showed that it was possible to fulfil the project objective and substitute the existing batteries with a 5kW fuel cell system in combination with supercapacitors (250V 165F).

Due to the integration and physical space conditions at Energinet's site in Idomlund, there was a desire to design/build a solution with an outdoor technical room. The solution was a Power shelter that is a technical room with combined hydrogen storage. The Power shelter integration was, among other things equipped with a 3-phase inverter to be able to connect to Energinet's AC installation. However, integration at the Idomlund site turned out to be too problematic as the site had been greatly expanded since the start of the project and it was therefore decided to move the Power shelter to the Fredericia site. The system was installed and tested on site Nov. 2021 and is still part of Energinet's emergency power supply at the Fredericia site. Picture of the Power Shelter on site is shown in figure 6.

Figure 6 - Power shelter

One of the technical obstacles is that the transformer station's emergency power supply is based on 220VDC. In the battery-free solution, it was therefore necessary to find equipment that could convert the fuel cell systems 48VDC to 220VDC. Equipment for this is not commercially available, so in collaboration with the project partners we made a solution which consists of a setup where the fuel cell system together with an inverter supply the substations nominal load at 230VAC connected to the site's existing rectifier/battery charger for 220VDC. using an inverter. The peak load is supplied from a 220VDC booster (supercapacitors). The 220VDC Booster is a part developed in the project. The supercapacitors are based on Ballard's standard supercapacitor block connected in series and connected to a new developed controller box. After the solution was designed, developed and built, this was tested according to the project specification's worst-case scenario, which is to maintain the supply for 10s. at 100A peak load. The peak load indicated is intended to simulate a large outage at a substation with the activation of numerous high voltage breakers. Picture of the 2 SPGC battery free systems without fuel cell during function test in BPSE can be seen in figure 7.

Figure 7 - SPGC battery free systems without fuel cell

After the test of the battery-free system, it can be concluded that the overall system can maintain a voltage that meets DEFU's requirements for voltage level for electric substations.

The battery-free system has been installed and tested at Elværk's site in Sindbjerg since May 2023. However, Elværk has chosen to disconnect the booster part and re-establish the existing battery backup, as it is the solution, they are most familiar with in terms of function and servicing, but does not rule out that, if necessary, the upcoming future backup requirements will require them to once again switch to the solution with fuel cells. Picture of the system installation at Elværk site Sindbjerg can be seen in figure 8.

Figure 8 - Battery free system installation

6. Utilisation of project results

The system solutions that have been developed and tested in the SPGC project and the results from this will contribute to Ballard's work in delivering solutions with fuel cell systems that were previously not possible.

The competitive situation has increased as there are now more commercial products within fuel cell as well as more developed solutions with batteries in the market. With the SPGC demonstration it has been proven that the developed systems are fully capable of meeting the future requirements for backup power for substations.

In the SPGC project DTU had a part-time Pd.D. together with visiting associated professor from Fuzhou University in China working on the project. Regarding dissemination DTU generated a conference paper:

Y. Zong et al., "Identifying the System-related Conditions and Consequences of Power-to-X Solutions for a High Renewables Penetration in Denmark," 2020 IEEE 4th Conference on Energy Internet and Energy System Integration (EI2), Wuhan, China, 2020, pp. 955-960, doi: 10.1109/EI250167.2020.9346867

7. Project conclusion and perspective

In connection with the project and the associated site inspections, it has been concluded that fuel cells as Back-up will be a good solution for electric substation as it can be used as an ad-on to increase backup time but also as a battery substitute with the battery free solution. At substations there is typically limited indoor space versus large outdoor areas. An increase in the back-up time will be relatively easy with a fuel cell system versus existing battery backup solutions, as the fuel cell system's backup time is determined by the gas storage which is located outside.

8. Appendices

Transformerstationer i Fredericia og Sindbjerg tester ny nødstrømsløsning baseret på brint og brændselsceller - Leverandører, Nyheder og Viden (altomteknik.dk)

To transformerstationer tester nødstrømsløsning baseret på brint og brændselsceller | Installatør (installator.dk)