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AN059
Hydrogen stacks directly fed in DC from solar panels and batteries

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Application Note – AN059

Hydrogen stacks directly fed in DC from solar panels and batteries

1. Hydrogen electrolysis and solar energy.

AN059 explains the different options for an electrolyzer to be fed in DC from solar panels and/or batteries. This supply needs also to ensure the operation of the stack even in the event of sudden power changes.

To produce green Hydrogen, it is mandatory that the electrolysis uses energy obtained from renewable sources. The H2 obtained would be a green vector of energy that could contribute to decarbonisation of related industrial processes.

Along with the use of modular bidirectional DC/DC converters with MPPT functions, it's possible to create efficient, resilient, and power optimized solutions. DC/DC converters are power electronic components with similar technology to DC/AC inverters. They are generally used in the battery and solar panel sector.

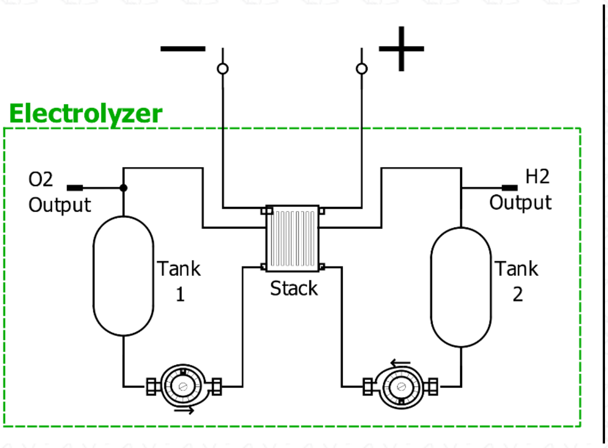

Figure 1: General drawing of electrolizer stack

As shown in Figure 1, electrolyzers use water and energy as input to obtain Oxygen and Hydrogen as output. The stack is built by multiple cells that perform the electrolysis process. These stacks need to be very accurately fed in DC to extend the life of the membranes and to ensure the maximum H2 production.

2. Feed an electrolyzer by building a modular DC solution. Why?

As electrolyzers and fuel cells need to be fed in DC, a system capable to accurately regulate the current and voltage is required. Considering the need of feeding these stacks from renewable sources, also typically producing energy in DC, converters working directly in DC are normally preferred.

The main features these converters provide are the following.

1. Modularity: It's possible to optimize the operation of the renewable sources by having converters connected to different strings. Also, thanks to the flexibility of the converters, resilient solutions with configurations N+1 can be implemented to reduce risk of failure.

2. Efficiency: Reaching efficiencies over 98 % in the nominal operation is critical to ensure maximum production from limited resources. Conversion steps of different technologies are avoided to ensure the renewable plants work in optimal manner.

3. Simplicity: Plug & Play designed units with specific control methods for each market lead to an easy integration and management of the plant.

4. Isolation: Choose your option according to your market and needs. Galvanic isolation between the solar panels, batteries and H2 stacks could be beneficial to segregate the problems and protect the rest of the installation in case of local failures.

5. Control: Industrial solutions with embedded turn-key controls to ensure the life expectancy of the stack is optimized. Features such as dynamic response, high current accuracy and very low ripple (< 1%) are critical for the long term well-being of the stack.

6. Voltage Limitations: Long cable distances between the source and the load require the operation at very high voltages to reduce energy losses. Given the current technology available, working with DC/DC converters sets the voltage limitation at 1500 Vdc. If higher voltage is required alternative architectures should be considered.

3. Electrical systems configurations with DC/DC converters

The solar strings and the stacks never match the range of operation in terms of voltage and current. On the solar panel side, the objective is to increase the voltage of the MPPT (Maximum Power Point Tracking) block as much as possible to reduce the current requirements. The stack voltage is defined by the number of cells it comprises and it is still not standardized.

In Figure 2, a representation of the differences in voltage and current requirements is shown. The **DC/DC converters couple both technologies matching voltage and current** to fit the power required.

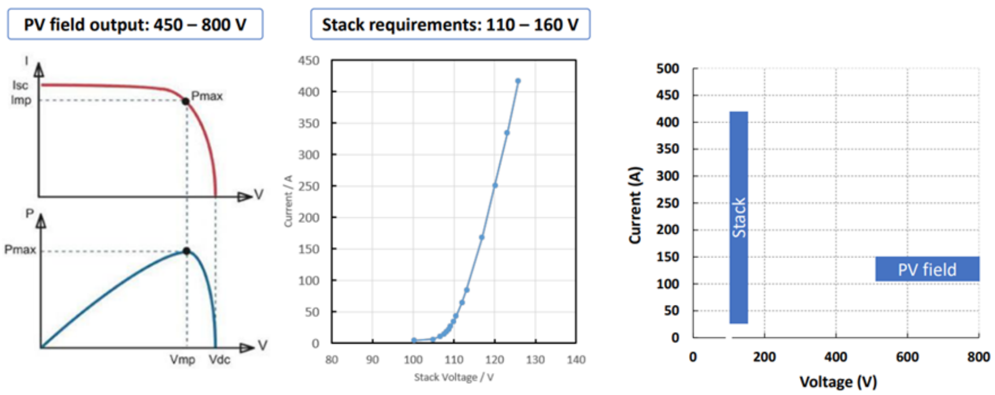

Figure 2: Solar farm and electrolyzer requirements.

1. DC/DC converters with no-storage available

Each solar string is connected to a DC/DC converter that performs MPPT algorithms to extract the maximum energy from the solar farm. Also, shades, problems and maintenance are reduced and localized per string.

In Figure 3, a simple layout of the plant is depicted. Each DC/DC converter provides the maximum power per solar string to maximize H2 production. Strong variability of the production may occur depending on the solar irradiation.

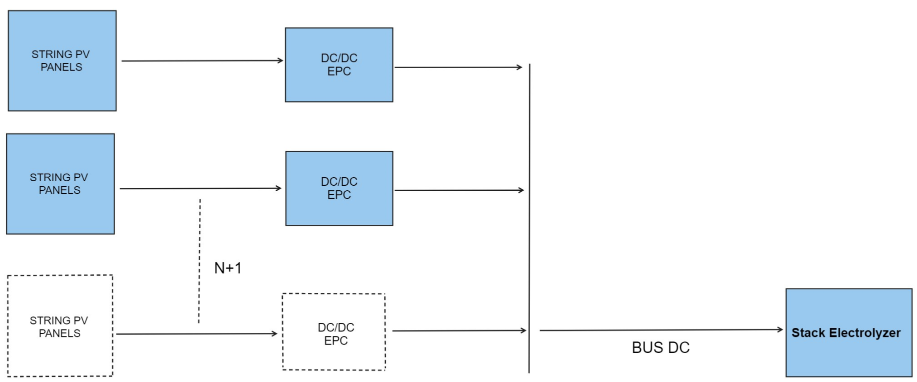

Figure 3: DC/DC converter per string connected directly to electrolyzer stack.

2. DC/DC converters with storage available

To extend the time and the reliability of the renewable plant production, certain amount of energy storage is normally recommended. Based on the location, type of electrolyzer, size of solar farm, epic power personnel can guide you on the dimensioning required for the energy storage.

The controllability of the off-grid plant is optimized by including energy storage, typically by means of an electric battery, as the solar excess production can be saved. When the solar output power fades, the DC/DC converter can maintain the H2 generation by extracting the previously stored energy.

In Figure 4, a general layout of the system considering a common DC connection (also known as DC bus) directly on the electrolyzer stack side.

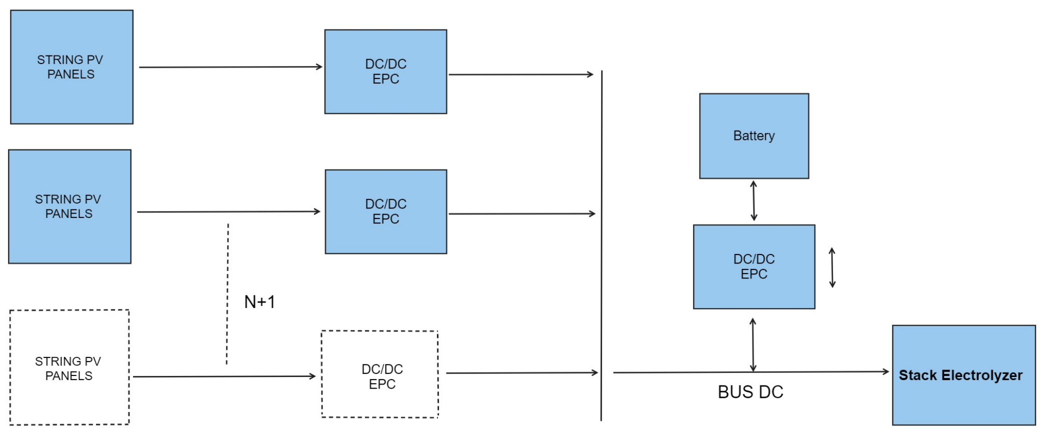

Figure 4: DC/DC converter per string and battery connected directly to electrolyzer stack.

Epic power converters include UPS functionality via their current and voltage regulation to avoid a sudden lack of power in the stack that could deteriorate it. Also, the communication with the plant controller enables the use of the battery DC/DC converter as a peak smoother. This operation is also critical in renewable plants with big fluctuations in available power.

4. Off-grid DC-powered electrolizer. Example of existing installation

Figure 5 : Enclosure with integrated epic power modules

The installation of an off-grid 50 kW electrolyzer fed in DC with epic power's DC/DC converters is introduced below in Figure 5. The installation included 48 V batteries with a DC/DC converter as well to compensate the dips of the solar injection from the solar plant and extend the quality and production time.

In Figure 6, the power provided by the converters connected to each the solar string in a short period of time and in Figure 7 , the power profile of the complete solar farm. As it can be seen, the production is fully optimized per string to maximize the energy absorption.

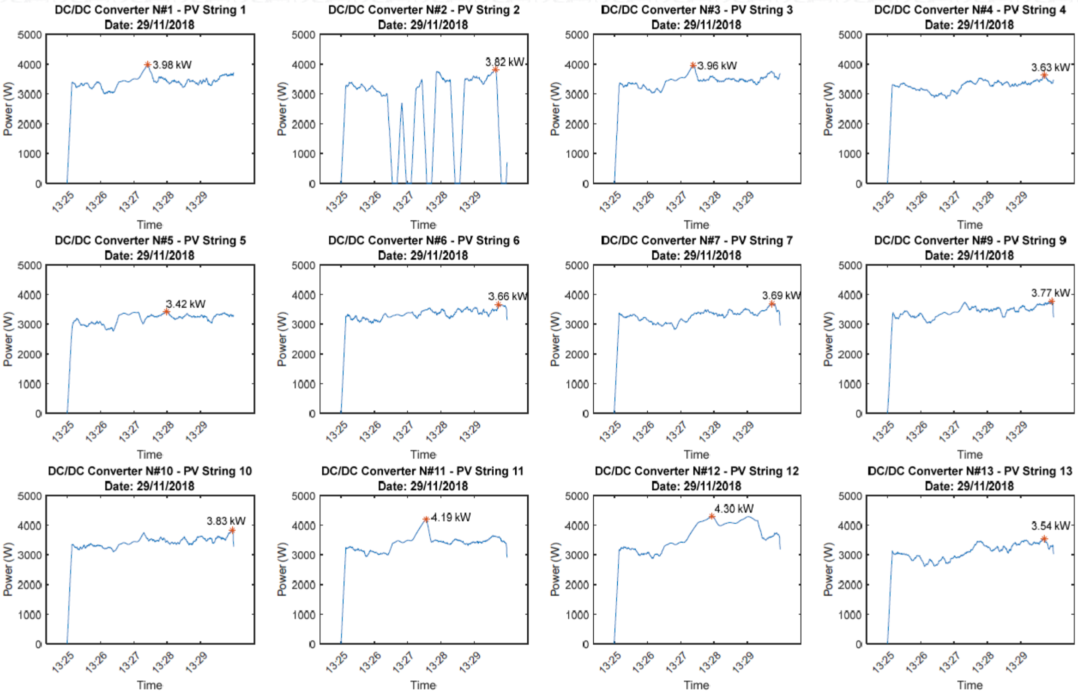

Figure 6: Output power of each PV string

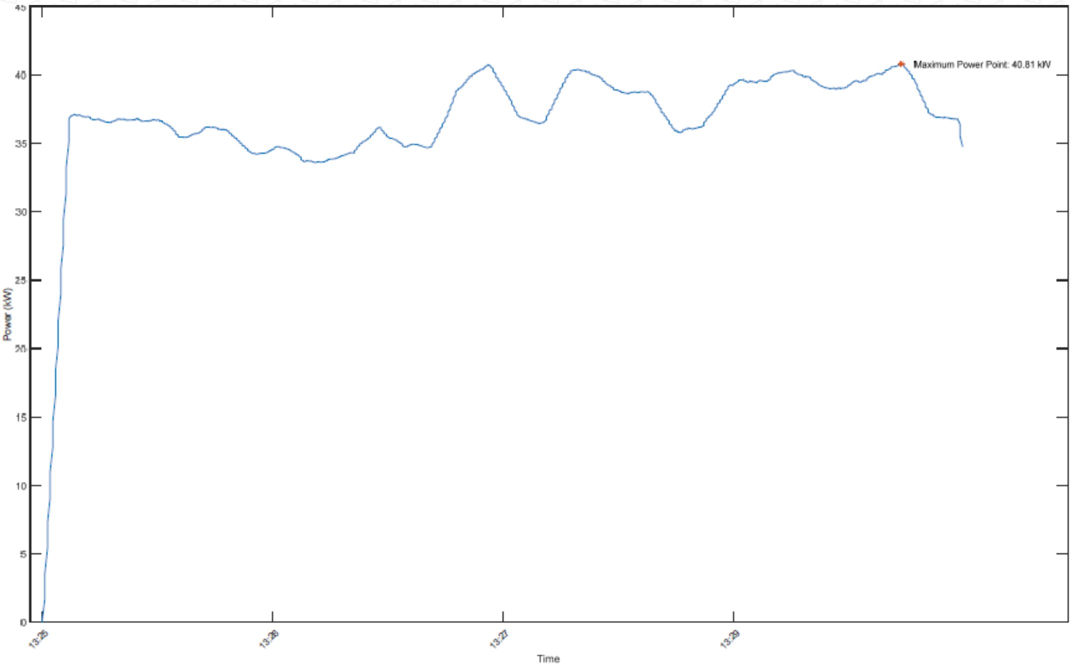

Figure 7: Output power to H2 Electrolyzer coupled with DC converters from solar panels

This configuration of direct connection in DC to the stack ensures maximum efficiency and control of the plant. The reduced ripple and continuous operation extend the life-expectancy of the stacks.

5. Electrolyzer fed in DC from solar panels and batteries. Conclusions.

An architecture based on DC-DC converters avoids unnecessary AC-DC and DC-AC conversions so that the entire system can be highly efficient. By including an accurate voltage and current control, it's possible to feed the electrolyzer without major degradation extending the life expectancy of the membrane.

The individual control of each string of solar panels can optimise the solar production. The converters perform the MPPT algorithms, so no additional elements are required.

Due to the DC microgrid system configuration, including additional units acting as UPS is easy to perform. The converter would adapt the voltage and current levels of the battery to the supply required by the electrolyzer. By sizing the plant correctly, an off-grid system that reduces CAPEX and OPEX can be defined.

We must consider the restrictions of DCDC converters in terms of high voltages. If we must work above 1500 Vdc to avoid energy losses in cables, energy DC-DC solution will no longer be optimal and other alternatives would need to be studied.