Power Supplies Introduction for Hydrogen Energy System

Technical Service Center /Hank Lan
hank@meanwell.eu

1. Introduction

Global warming and extreme climate phenomena, net-zero carbon emissions has been the goal of countries in the world. Among alternatives solutions of fossil fuels, hydrogen energy has attracted widespread attention. The main reason is green hydrogen energy with zero carbon emissions which has significant application opportunities in the fields of renewable energy, industry and transportation. Therefore, hydrogen energy is considered one of the key solutions to address energy issues.

2. Introduction of hydrogen types

Hydrogen atoms are present in common compounds such as water, methane and ethanol. Currently, there are two hydrogen production technologies: electrolysis and steam reforming. According to hydrogen production method and carbon emissions, hydrogen can be categorized into gray hydrogen, blue hydrogen and green hydrogen. Gray hydrogen is the most common way of producing hydrogen. The raw materials for hydrogen production are fossil fuels such as coal, oil and natural gas. Converting hydrogen through chemical reactions, the cost is relatively low. However, this method generates a significant amount of carbon dioxide emissions. Similar to gray hydrogen, blue hydrogen also uses fossil fuels to produce hydrogen. However, it incorporates carbon capture processes to capture and store the produced carbon dioxide which can reduce carbon dioxide emissions. Green hydrogen utilizes renewable energy to electrolyze water, producing hydrogen with almost no carbon emissions in the process. Therefore, it is the most environmentally friendly way to produce hydrogen.

3. Introduction of electrolysis hydrogen and fuel cell

The field of hydrogen energy can be divided into electrolysis hydrogen production and fuel cell applications. Commonly used electrolysis hydrogen production technologies include [1-2]:

1) Polymer electrolyte membrane electrolysis, PEM-EL: It uses a solid acid polymer membrane as the electrolyte. Water is electrolyzed at the anode into hydrogen ions and oxygen and releases electrons. Hydrogen ions migrate to the cathode through the proton exchange membrane and combine with electrons conducted by the external circuit to generate hydrogen gas. This technology has the advantage of high electrolysis efficiency due to its high current density characteristics. The cell voltage range of PEM electrolyze is between 1.8 V and 2.5 V.

2) Alkaline electrolysis, A-EL: It uses potassium hydroxide as the electrolyte. Hydroxide ions migrate to the anode through the porous conductive membrane, where they undergo an oxidation reaction to release electrons to generate oxygen. Water is electrolyzed into hydrogen ions and hydroxide ions at the cathode and accepts electrons to release hydrogen. Currently, it is mainly used in large-scale electrolytic hydrogen production systems. The cell voltage range of AEL electrolyze is between 1.4 V and 3.0 V.

3) Anion exchange membrane, AEM-EL: It combines the low cost of an AEL with the simplicity and efficiency of PEM. Using non-noble metal catalysts and titanium-free components, it can operate under pressure differences like PEM. AEM has low conductivity, slow catalytic kinetics and poor electrode structure which affects the performance of AEM. The cell voltage range of AEM electrolyze is between 1.4 V and 2.0 V.

4) Solid oxide electrolysis, HT-EL: It uses ceramic materials that conduct oxygen ions as electrolytes. Water enters the electrolyze in the form of steam and it is electrolyzed into hydrogen ions and oxygen ions at the cathode. The hydrogen ions accept electrons conducted by the external circuit to generate hydrogen. This electrolysis method operates in a high temperature environment (700~1000℃). The cell voltage range of SOE electrolyze is between 1.0 V and 1.5 V.

Currently, electrolytic stack modules are mostly customized and towards high power development. Figure 1 is a structural diagram of an electrolytic stack. For example, a cell voltage is 2V and 48 cells are connected in series to form as 96V stack which means a DC 96V power supply is required for electrolysis. Therefore, the longer stack length which has higher voltage required. A larger number of stacks in parallel and a larger surface area imply that hydrogen electrolysis requires a higher electric current.

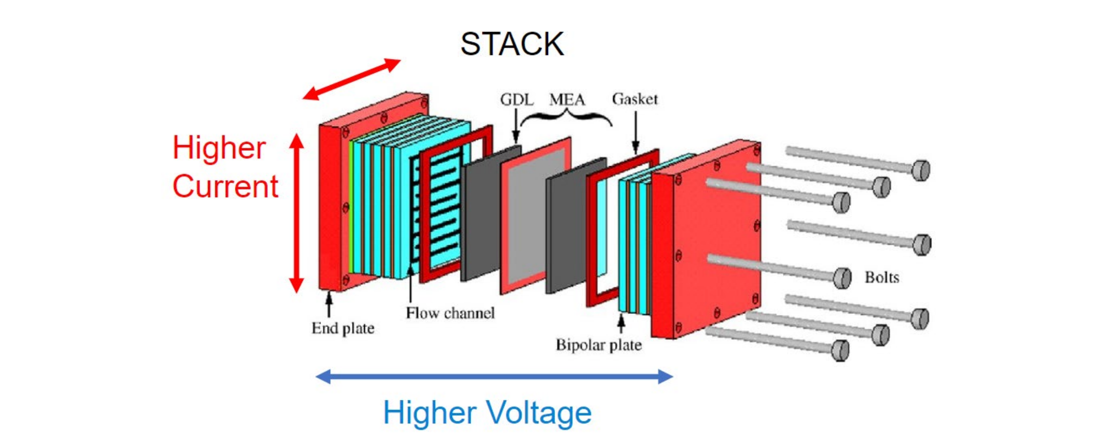

Fig.1 Structural diagram of an electrolytic stack

The hydrogen produced through electrolysis is transported either via hydrogen storage tanks or pipelines to various application sites. Currently, the most widely used application is in fuel cells. The fuel cell stack is composed of multiple plates and membranes. After adding hydrogen and oxygen into fuel cell, the chemical energy is converted into electrical energy for use. Fuel cell produces a typical voltage around 1V. Stacking these cells creates a higher usable voltage. Currently, fuel cell stacks are mostly customized to fit various applications. Fuel cell types include phosphoric acid fuel cell (PAFC), molten carbonate fuel cell (MCFC), alkaline fuel cell (AFC) and proton exchange membrane (PEM) cell.

Figure 2 shows the fuel cell polarization curve [3]. As the current increases, the first voltage drop represents a loss of cell activation. The second part represents the voltage loss caused by internal resistance. The third part represents the voltage drop due to gas delivery or concentration loss. Table 1 shows comparison of fuel cell stacks specifications from various manufacturers. The characteristic of a fuel cell stack is that the voltage decreases as the operating current increases. More stacks in a fuel cell stack means with higher power output of the fuel cell.

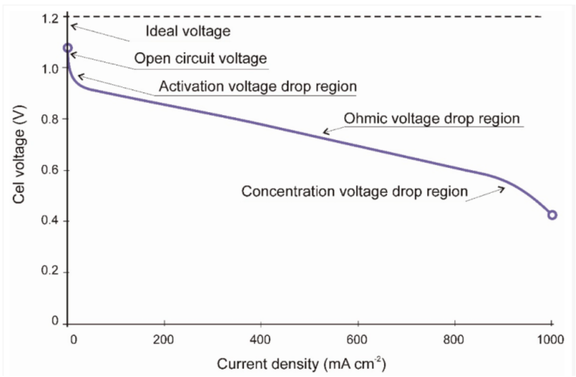

Fig. 2 The fuel cell polarization curve [3]

Company	Fuel Cell Rating	Cell No.	FC, V & I Range	Vmin/ Vmax	Ta
A	6.8kW	48pcs	47V to 29V 0A to 130A	61.7%	-20 to 55℃
B	13.6kW	96pcs	94V to 58V 0A to 130A	61.7%	-20 to 55℃
C	75kW	275pcs	267V to 167V 0A to 450A	62.5%	-30 to 70℃
D	125kW	455pcs	441V to 278V 0A to 450A	63%	-30 to 70℃
E	6kW	-	96V to 60V 0A to 83A	62.5%	-5 to 35℃
F	27kW	-	88V to 52.8V 0A to 352A	60%	-33 to 50℃

Table 1 Comparison of fuel cell stacks specifications from various manufacturers

4. Hydrogen Energy Systems and Power Supplies Requirements

Figure 3 shows the hydrogen energy system and power supplies requirements [4], which can be divided into two applications: electrolysis power supplies and fuel cell power supplies. Electrolysis power supplies can be converted into electrical energy by grid-connected AC-DC converters, wind turbine AC-DC converters, solar DC-DC converters and batteries DC-DC converters for electrolysis hydrogen. After a fuel cell generates electricity, it can be converted to the load through a DC-DC converter or a DC-AC inverter. In the selection of the electrolysis power supplies, constant current and programmable current control function of power supplies are needed. In the selection of fuel cell power supplies, wide input voltage range and high-power rating of power supplies are requested, and user should note that fuel cell stack voltage increase with using life and aging.

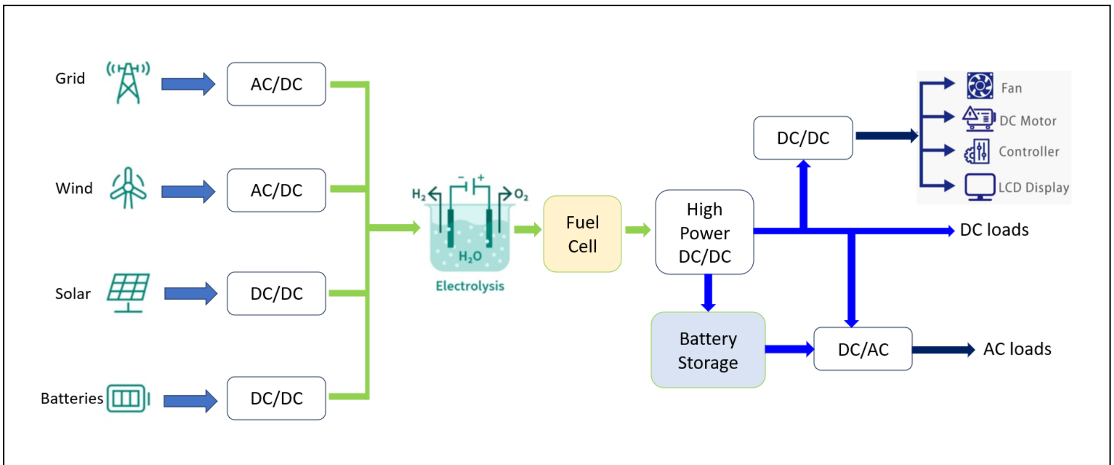

Figure 3 Hydrogen energy system and power supplies requirements

The feature of MEAN WELL power supplies is that single model has multiple voltage models with a wide voltage range design to fit market applications. Users can achieve programmable output voltage (PV) and programmable output current (PC) functions for power supplies which can be implemented through the communication interface and external voltage. The selection of power supplies for electrolytic hydrogen production can be divided into modular power supplies and centralized system power supplies. Figure 4 shows the modular power supplies used in electrolysis hydrogen. Taking MEAN WELL AC-DC power supplies products DPU-3200 series and PHP-3500 series as an example, a single power supply can be used to correspond to one electrolytic tank to form a module. Modular power supplies provide more flexibility, allowing users to choose multiple independent modules or multiple parallel modules for high-power electrolysis hydrogen based on system power or configuration requirements.

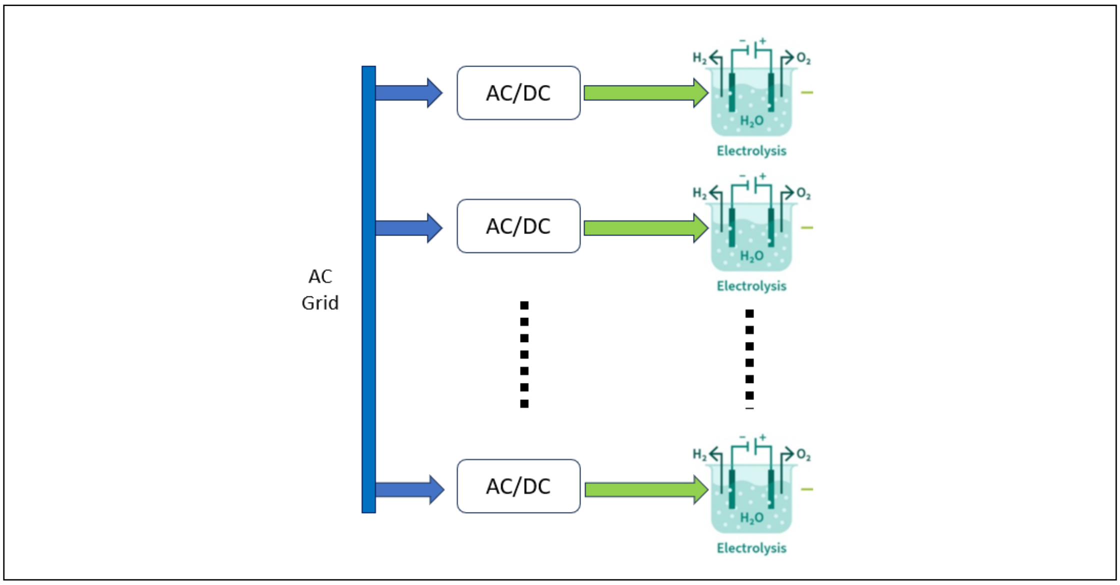

Fig. 4 The modular power supplies used in electrolysis hydrogen

Figure 5 shows applications of centralized system power supplies for electrolysis hydrogen. Taking the NCP-3200 series and SHP-30K series AC-DC power supplies as examples, they can be divided into two solutions: single-phase AC and 3-phase AC input:

1) Single-phase AC input → NCP-3200 series + DHP-1UT-B(HV)shelf + Controller_CMU2 + Rack Cabinet.
2) 3-phase AC input → SHP-30K series + Controller_CMU2 + Rack Cabinet.

Above MEAN WELL (3+N) centralized system power configurations can provide up to 300KW. Multiple centralized system power supplies can also be configured according to factory requirements to achieve multiple high-power electrolysis hydrogen. Table 2 shows MEAN WELL AC-DC power supplies solutions for electrolysis hydrogen.

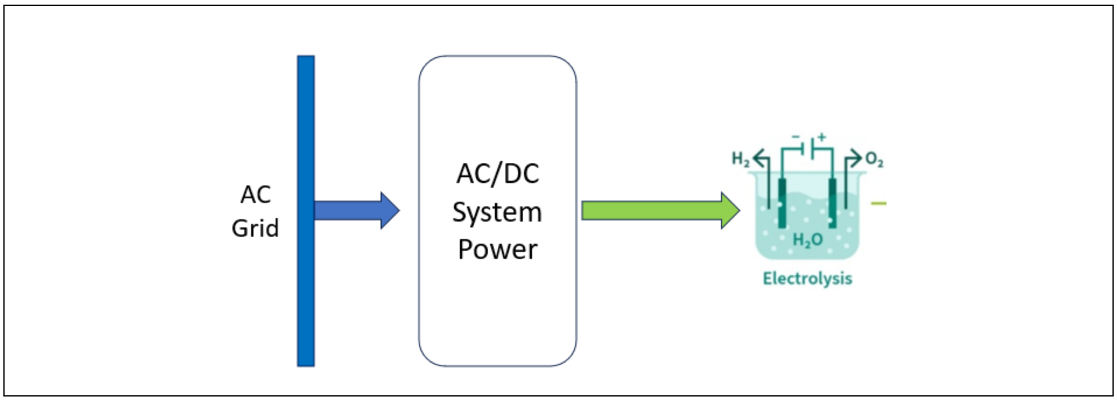

Fig. 5 Applications of centralized system power supplies for electrolysis hydrogen

Modular Power Supplies			
1): 3200W; Single phase AC input		2): 3500W; Single phase AC input	
DPU-3200 series		**PHP-3500 series**	
	DC output: 24V, 48V		DC output: 24V, 48V, 115V, 230V, 380V
Centralized system power supplies			
1): Max. 320KW system power; DC output: 24, 48, 380VDC; Single phase AC input			
NCP-3200 series	**DHP-1UT-B (HV)**	**CMU2**	**19" Rack Cabinet**
			
2): Max. 360KW system power; DC output: 55, 115, 230, 380VDC; 3 phase AC input			
SHP-30K series		**CMU2**	**19" Rack Cabinet**
			

Link: System Power Solution.pdf (meanwell.com)

Table 2 MEAN WELL AC-DC power supplies solutions for electrolysis hydrogen

Figure 6 is an example of hydrogen electrolysis power supplies control. MEAN WELL (3+N) centralized system power supplies are used to perform hydrogen electrolysis with stacks. During the initial electrolysis process, the system power supplies current is adjusted according to the internal impedance and gas reaction of the electrolytic tank. Power supplies current changes from low current to high current over time to perform electrolysis. The advantage of MEAN WELL system power supplies is that the programmable output current (PC) which has adjustable wide range is 20%-100% of load. Therefore, the system controller can control MEAN WELL system power supplies to perform electrolysis at a lower current level through communication. During electrolysis process, system controller will detect parameter of gas and output current & output voltage of power supplies any time into system control loop, and then system controller can control MEAN WELL system power supplies through communication to adjust the output current and voltage to achieve the optimal electrolysis efficiency.

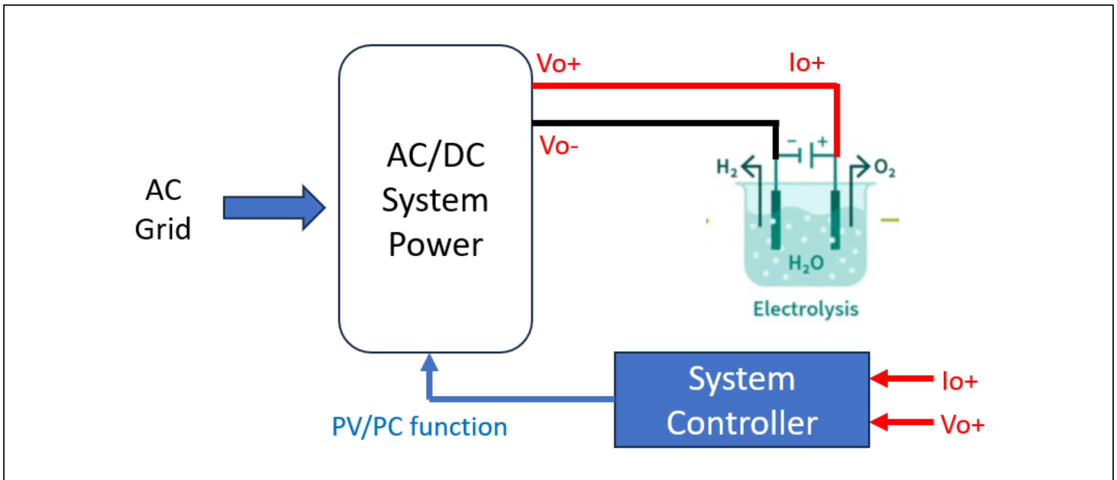

Fig. 6 Example of hydrogen electrolysis power supplies control

An example of fuel cell power supplies is shown in Figure 7. The characteristics of the fuel cell stack are a wide voltage range, and the voltage range of fuel cell stacks varies among different manufacturers' designs. Therefore, taking MEAN WELL wide voltage range DC-DC power supplies DDRH series as an example, power energy generated by fuel cell will be converted into low voltage through the DDRH series high-voltage DC-DC converter and supply to various loads such as fans, DC motors, controllers and LCD monitor applications.

Generally, fuel cell systems will also be equipped with another high-power DC-DC converter to store the fuel cell energy into backup battery storage system for other DC loads. The new product of MEAN WELL is preparing to launch, the 2 in 1 design of high-power AC-DC bidirectional inverter and charger, NTN-5K series, highlights its advantages. The wide DC input voltage range of DC-AC inverters can fit fuel cells applications. Inverter converts DC power into AC power, it can also support single-phase AC or 3-phase AC 220KW system applications through series-parallel connection at input DC side and parallel connection at output AC side. Table 3 shows MEAN WELL DC-DC and bidirectional DC-AC power supplies for fuel cell solutions.

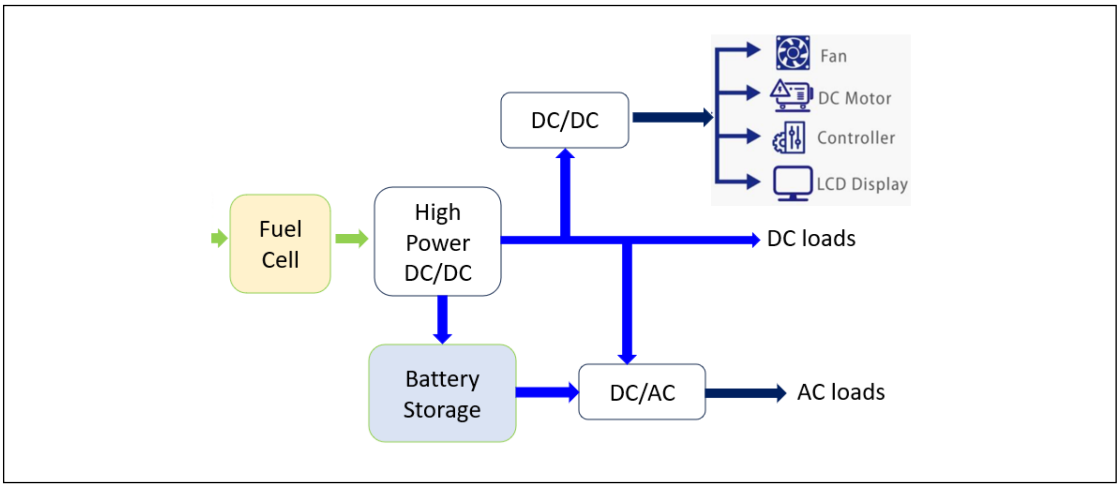

Fig. 7 Example of fuel cell power supplies

DC-DC Power Supplies	DDRH series	DDRH-240 	• DC input: 250-1500V • DC output: 12V, 24V, 32V, 48V • 4 units parallel application
	SD series	SD-1000 	• DC input: 19-72V or 72-144V • DC output: 12V, 24V, 48V
AC-DC Bi-directional Power Supplies	NTN series	NTN-5K (developing) 	• DC input: 20-33V, 40-66V, 280-430V • AC output: 200-240VAC • Off grid type

*For more details, please refer to MEAN WELL Virtual Expo

Table 3 MEAN WELL DC-DC and bidirectional DC-AC power supplies for fuel cell solutions

5. Conclusion

The feature of MEAN WELL power supplies is that single model has multiple voltage models with a wide voltage range design to fit market applications. Users can achieve programmable output voltage (PV) and programmable output current (PC) functions for power supplies which can be implemented through the communication interface and external voltage. Figure 8 shows the application combination of hydrogen energy system and MEAN WELL power supplies. MEAN WELL power supplies have deployed AC-DC modular and 3+N system power products in the field of electrolytic hydrogen with a maximum capacity of up to 510 kW. DC-DC power supplies can provide up to 2KW, AC-DC bi-directional power supplies can provide up to 220KW and DC-AC inverter power supplies can provide up to 90KW for fuel cell applications. Currently, MEAN WELL can provide more power supplies solutions based on customer application needs in the field of hydrogen electrolysis, fuel cells and renewable energy.

For inquiries about related products and application requirements, you can directly contact MEAN WELL sales or technical staff. In addition, please stay tuned for MEAN WELL online exhibition hall relevant products and online courses for solutions."

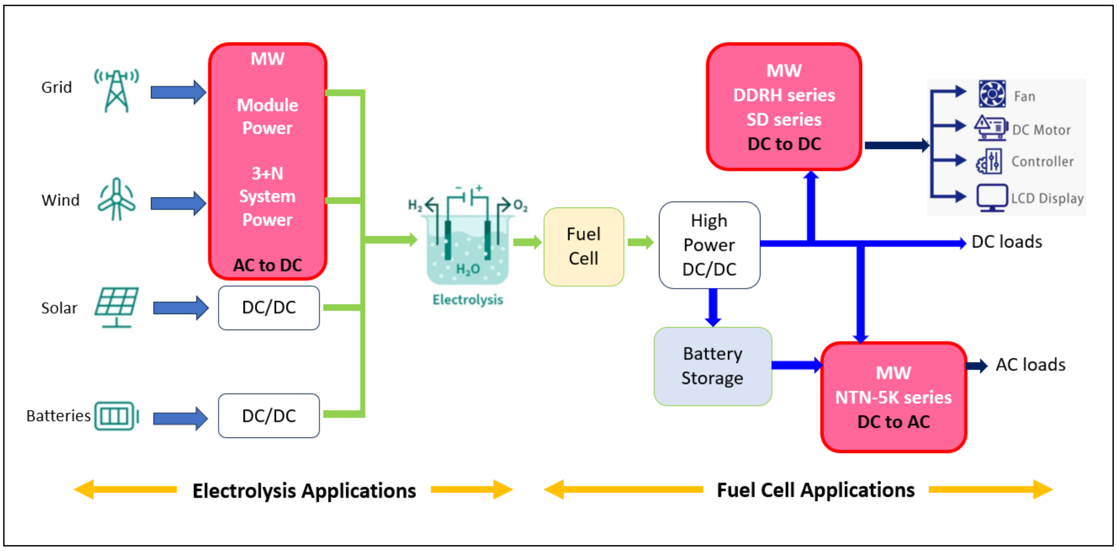

Fig. 8 Application combination of hydrogen energy system and MEAN WELL power supplies

References:

[1] 經濟部能源署，再生能源電解產氫之技術發展狀況。

[2] 太原麗子，電解產氫技術簡介及日本發展現況研析。

[3] H. E. A, A. C, C. S, A. P. N and E. G.”Thermal and Electrical Parameter Identification of a Proton Exchange Membrane Fuel Cell Using Genetic Algorithm”, 2018.

[4] Hydrogen Technology Expo Europe 2023.