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New MPPT Control Methods for Grid Connected PV System to Produce Green Hydrogen

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Abstract – In this document, we used Matlab 2022 software to design a 50 kW PV array and connect it to the grid with a single stage power converter. The power control strategy uses a combination of MPPT (P&O) and inverter control algorithms. For this reason, we changed the power control algorithm for current control. The next work is to connect this system to electrolyzers and fuel cells and find new optimization methods for grid-connected systems to produce green hydrogen.

Keywords – On-Grid, MPPT, Optimisation, Green Hydrogen, Photovoltaic, Control.

I. INTRODUCTION

Solar energy is one of the most important renewable energy sources that has received increasing attention in recent years. it has the highest availability compared to other energy sources. It is clean and has no emissions, as it does not create pollutants or harmful by-products to nature. Solar energy conversion is done through a solar collector or a photovoltaic panel. The I-V characteristics of the generated current and voltage are affected by radiation and temperature conditions [1, 2].

Autonomous PV systems are deployed in remote areas or where grid connection is difficult in less developed countries. On the other hand, grid-connected photovoltaic systems are used in developed countries to contribute to electricity sharing by clean fossil-free energy. In this paper, we used Matlab 2022 software to design a 50 kW PV array and connect it to the grid with a single stage power converter. The power control strategy uses a combination of MPPT (P&O) and inverter control algorithms. The basic structure of the PV system is shown in Fig. 1 [3–5]:

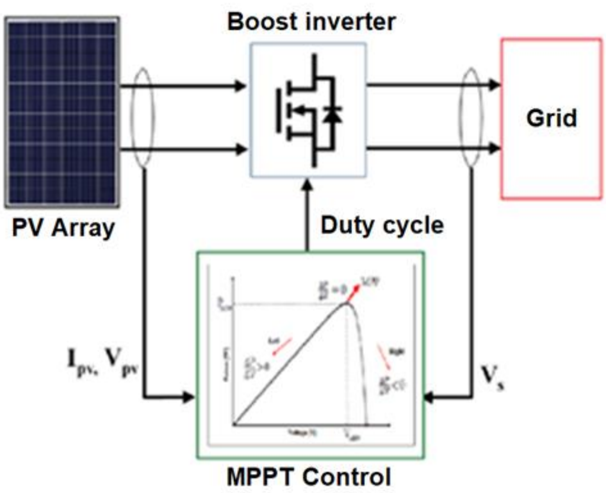

Fig. 1 Basic structure of the PV system

II. MODELING OF THE PROPOSED SYSTEM

First, we will present the model of the photovoltaic generator, filter converter and network. The objectives of this study include modeling the photovoltaic cell as well as the static transducers constituting our system.

A. *Model of a real diode panel with shunt resistor*

The equivalent diagram of the real photovoltaic module takes into account resistive effects this equivalent diagram consists of a diode (D), a current source (I_{ph}) characterizing the photo-current, a series resistance (R_s) representing the losses by effect Joule, and a shunt resistance (R_{sh}) characterizing a leakage current between the upper gate and the rear contact which is generally much greater than (R_s).

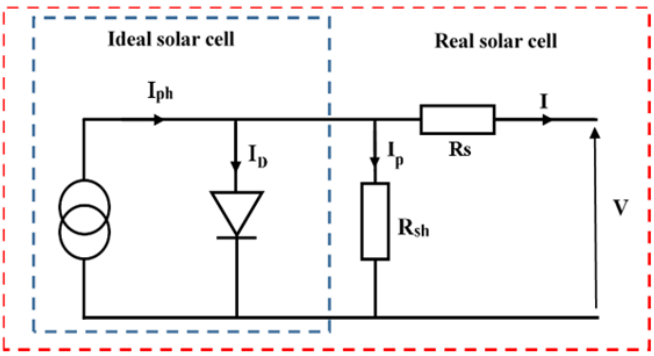

Fig. 2 Electric model of solar cell

When the solar cell is exposed to light, it exhibits its unique ability to act as an energy generator, supplying and sustaining electrical current. In fact, the electrical behaviour of the cell is the same as that of a diode when illuminated. Therefore, the electrical state of a solar cell with a PN junction can be expressed as :

Photo-current :

$$I_{ph} = [I_{sc} + k_i \cdot (T - 298)] \cdot \frac{G}{1000} \quad (1)$$

Saturation current

$$I_0 = I_{rs} \cdot \left(\frac{T}{T_n}\right)^3 \cdot \exp\left[\frac{q \cdot E_{g0} \cdot (1/T_n - 1/T)}{n \cdot K}\right] \quad (2)$$

Reverse saturation current

$$I_{rs} = \frac{I_{sc}}{e^{\left(\frac{q \cdot V_{oc}}{n \cdot N_s \cdot K \cdot T}\right)} - 1} \quad (3)$$

Current through shunt resistor

$$I_{sh} = \left(\frac{V + I \cdot R_s}{R_{sh}}\right) \quad (4)$$

Output current

$$I = I_{ph} - I_0 \cdot \left[\exp\left(\frac{q \cdot (V + I \cdot R_s)}{n \cdot K \cdot N_s \cdot T}\right) - 1\right] - I_{sh} \quad (5)$$

B. *Modeling of the DC/AC converter (Inverter)*

The main function of the inverter is to transform the current produced by the solar generator into single-phase or three-phase alternating current.

In our case we choose the three-phase inverter, The phase-to-phase voltages V_{ab}, V_{bc}, V_{ca} are obtained from these relations:

$$\begin{cases} V_{ab} = V_{ao} + V_{ob} = V_{ao} - V_{bo} \\ V_{bc} = V_{bo} + V_{oc} = V_{bo} - V_{co} \\ V_{ca} = V_{co} + V_{oa} = V_{co} - V_{ao} \end{cases}$$

Where: V_{ab}, V_{bc}, V_{ca} are the voltages at the inverter input (DC). We took the point "O" as a reference for these last tensions. The three DC input voltages are given by the following relationships:

$$\begin{cases} V_{ao} = V_{an} + V_{no} \\ V_{bo} = V_{bn} + V_{no} \\ V_{co} = V_{cn} + V_{no} \end{cases}$$

Where: V_{an}, V_{bn}, V_{cn} are the phase voltages of the load, or output of the inverter and V_{no} is the voltage of the neutral of the load with respect to the point "O".

We assumed that the load is balanced, i.e:

$$V_{an} + V_{bn} + V_{cn} = 0$$

By replacing (II.46) in (II.45) we will have:

$$V_{no} = \frac{1}{3} \times (V_{an} + V_{bn} + V_{cn})$$

Then by replacing (II.47) in (II.44) we will have:

$$\begin{cases} V_{an} = \frac{1}{3} \times (2V_{ao} - V_{bo} - V_{co}) \\ V_{bn} = \frac{1}{3} \times (2V_{bo} - V_{ao} - V_{co}) \\ V_{cn} = \frac{1}{3} \times (2V_{co} - V_{ao} - V_{bo}) \end{cases}$$

If we assume that:

$$\begin{cases} V_{ao} = V_{dc} . S_a \\ V_{bo} = V_{dc} . S_b \\ V_{co} = V_{dc} . S_c \end{cases}$$

If S_i is the state of the switch K_i such:
S_i = 1 if K_i closed.
S_i = 0 if K_i open. SO:

$$\begin{bmatrix} V_{ar} \\ V_{br} \\ V_{cr} \end{bmatrix} = \frac{VDC}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} . \begin{bmatrix} S_a \\ S_b \\ S_c \end{bmatrix}$$

The current modulated by the inverter is given by:

$$I_{ond} = S_a . i_a + S_b . i_b + S_c . i_c$$

C. *MPPT Control strategy (Perturbation & Observation control)*

The P&O algorithm is the most widely used in the literature and is especially used in practice because it is easy to implement. This procedure takes the input voltage Vpv and current Ipv values and generates the duty cycle value.

By manipulating the duty cycle and calculating the power delivered by the panel and comparing it to the previous power, we create a perturbation in the Vpv voltage. As the power increases, it approaches (MPP) and the duty cycle variation stays in the same direction. Conversely, when the power drops, it moves away from the MPP. Next, we need to reverse the direction of duty cycle change.

The figure below shows how the power and voltage characteristics of a photovoltaic generator change with weather.

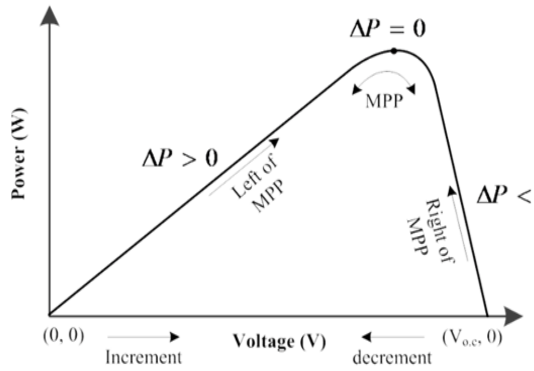

Fig. 3 Typical Power-Voltage characteristic

The Impairment and Observation Control Algorithm is expressed as:

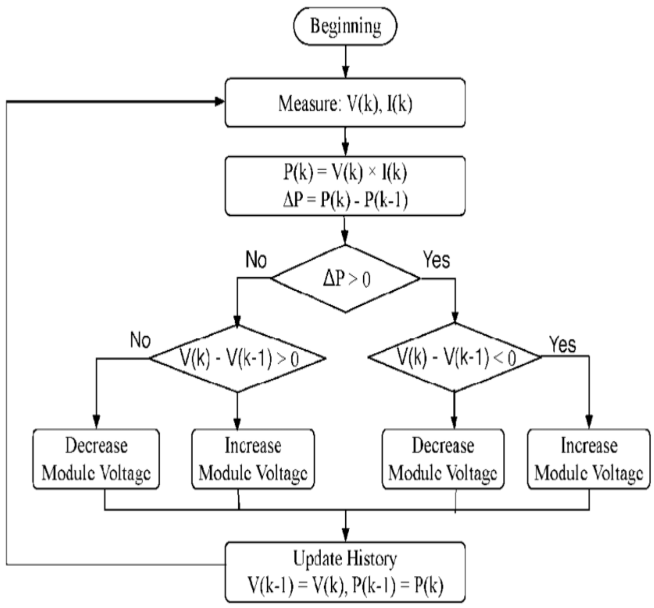

Fig. 4 Perturbation and observation control algorithm

We want to combine MPPT and inverter control algorithms. Because of this, we modified the power control algorithm for current control.

III. SIMULATION RESULTS

We want to test this system in everyday lighting conditions.

A Park transform is used to obtain the currents of the dq frames. Id indicates the peak value of current. We want to control it. For this reason, we compared it with the reference. The error is then applied to the PI controller.

Reactive power must be controlled. For this we use the Iq parameter. And we want to transmit zero reactive power.

- At the start of the simulation the irradiance is zero. Therefore, the reference current of the inverter is zero. Then the irradiation increases and the reference current increases accordingly.

- As you can see from the graph, the MPPT algorithm works well.
- THD is less than 5% at powers above 15kW.
- Approximately 100A at maximum irradiation reference current.
- Now the radiation dose is decreasing.
- Reactive power near zero

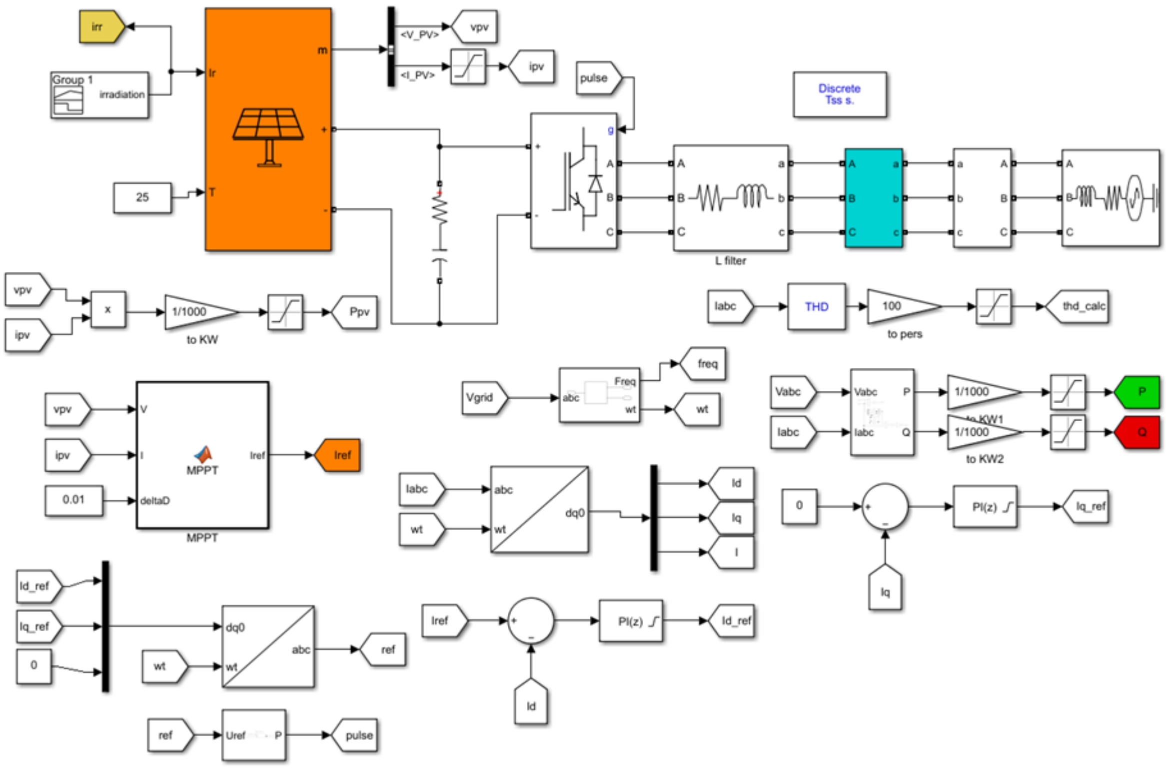

Fig. 5. Schematic of Simulink model

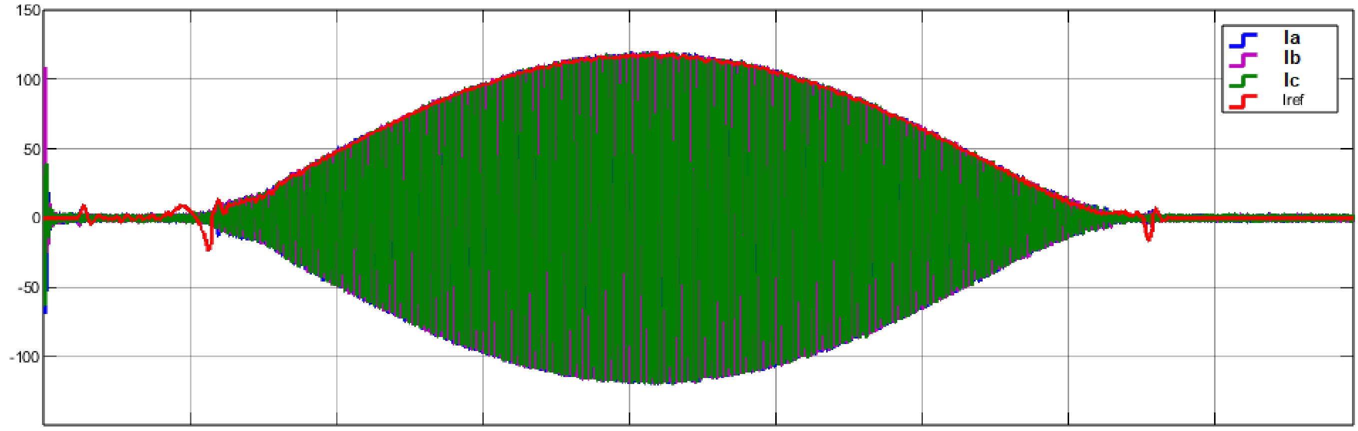

Fig. 6. Output Current Graph

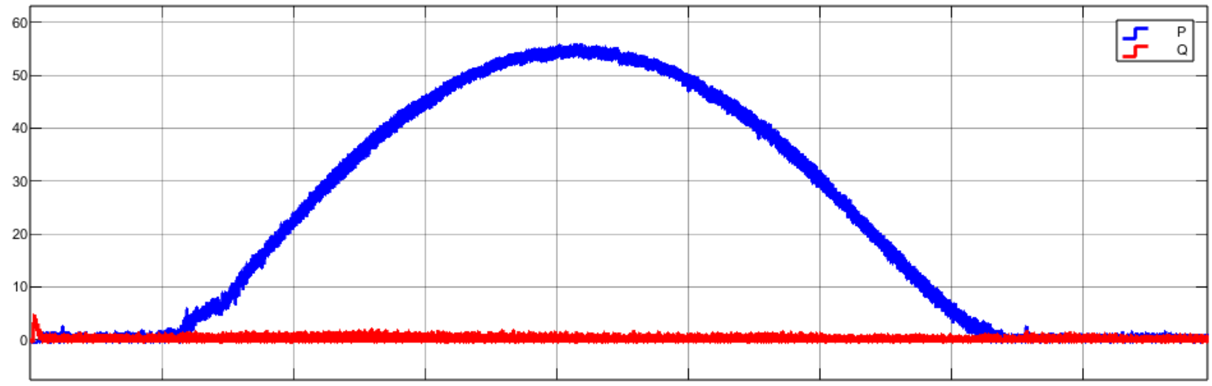

Fig. 7. Active and Reactive Power Graph

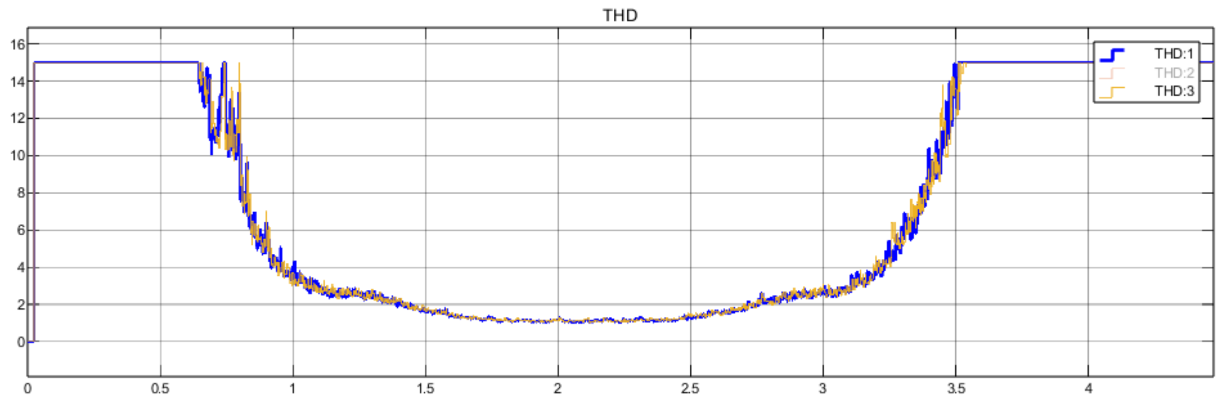

Fig. 8. THD Graph

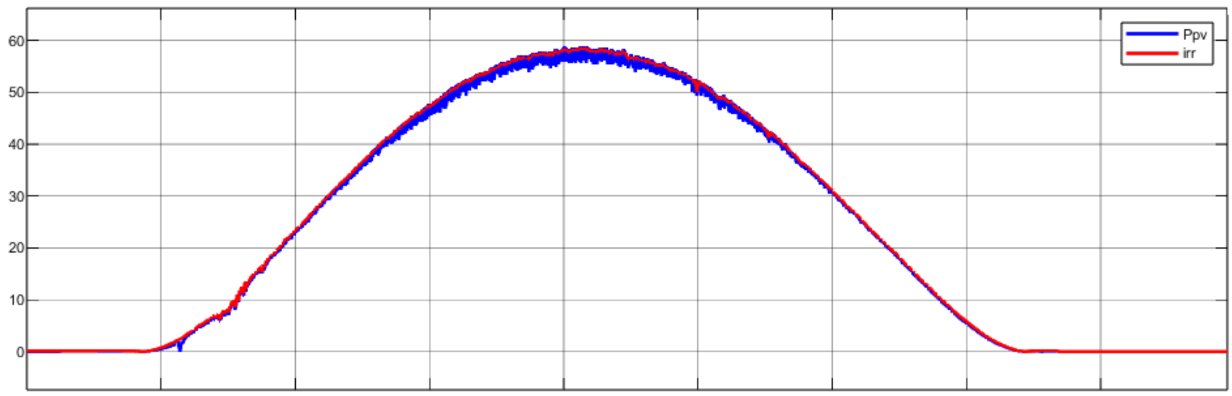

Fig. 9. Pv Panel Power and Reference Current Graph

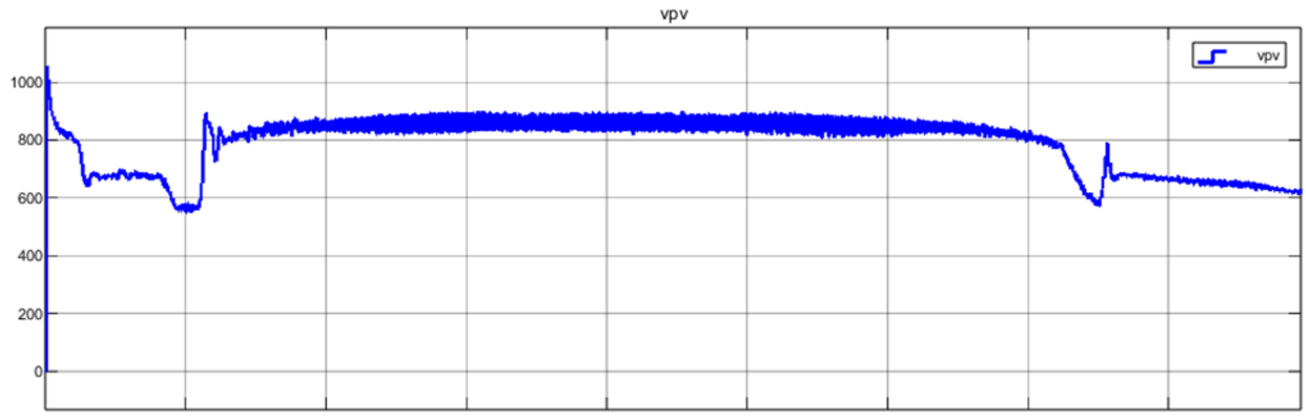

Fig. 10. Pv Panel Voltage Graph

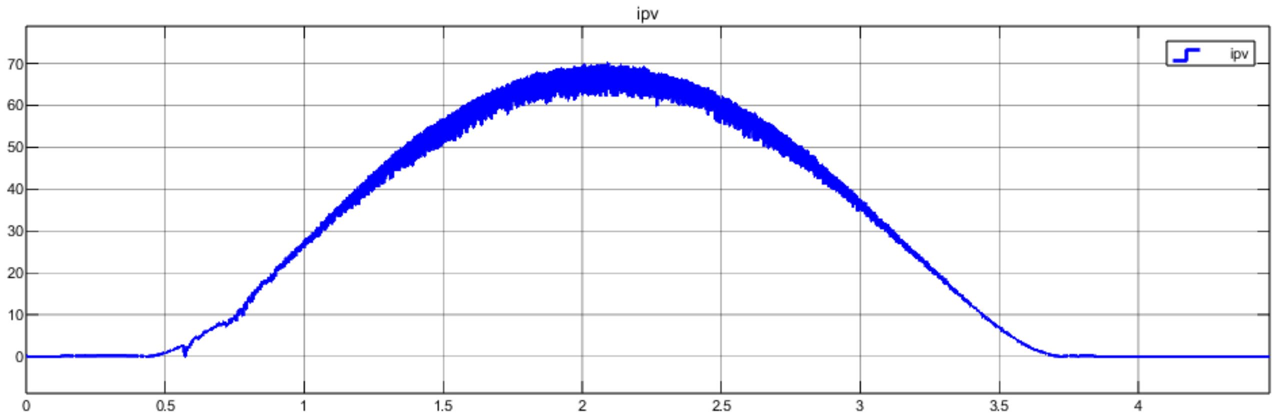

Fig. 11. Pv Panel Current Graph

IV. CONCLUSION

In this work, a grid-connected PV system was simulated using a single-stage power converter. The power control scheme uses a combination of MPPT (P&O) and current control algorithms. As you can see, it works well above 15kW with THD < 5%. The next step is to combine this system with electrolyzers and fuel cells to find new ways of optimizing grid-connected systems to produce green hydrogen.

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