

## Contributing to the development of green hydrogen energy systems through digital twin technology!

### ◆What kind of research do you do?

I conduct research on water electrolysis for storing renewable energy, such as solar and wind power, in the form of hydrogen. My work includes designing polymer electrolyte membrane water electrolyzers (PEM WEs), which enable highly efficient and clean hydrogen production, as well as analyzing the principles of electrochemical CO<sub>2</sub> reduction to convert carbon dioxide into useful compounds. Through this research, I am involved in the development of energy systems that utilize green hydrogen (which is hydrogen produced from renewable energy sources).

National Research and Development Agency (RIKEN)

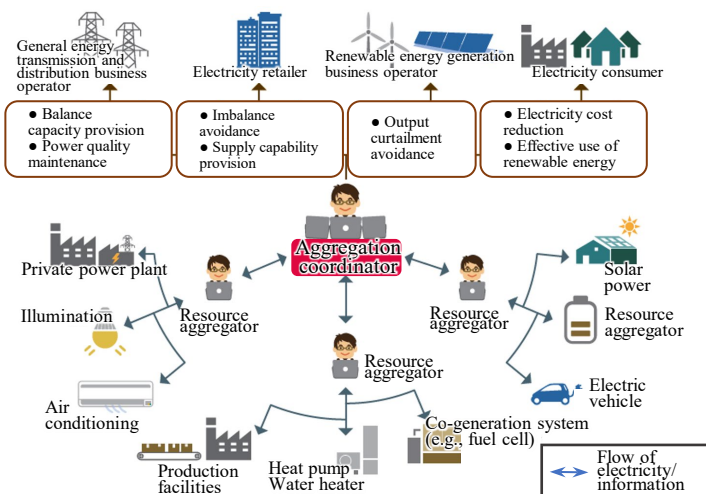


Center for Advanced Photonics  
Photonics Control Technology Team  
Mr. Katsushi Fujii, Research Scientist

### ◆What challenges are you facing in your research?

To put an energy management system into practical use, we ultimately need to reach a point where a virtual power plant can serve as an alternative to conventional power plants. That being said, when it comes to utilizing renewable energy, it's not realistic to build a single, large-scale facility like today's nuclear power plants. Instead, power generation needs to be distributed across multiple locations to some extent. However, conventional energy management systems (EMS) are fundamentally designed around centralized control within each individual system, making it impossible to treat data from different types of EMS in a unified manner. This is because the semantics of the data are not sufficiently defined, their meanings are not objectively defined in a machine-readable format, and each system uses a different language or data representation. As a result, conventional virtual power plants (VPPs) have had difficulty making efficient use of data collected from different energy sources, such as wind and solar power.

To enable users to access electricity reliably on demand, small-scale unit systems must be designed according to the region and intended application. In addition, because a certain level of energy storage capacity is required, we explored the development of a controllable VPP capable of predicting and managing the overall balance between electricity supply and demand through demand response (DR). In collaboration with Dr. Norio Kobayashi and his colleagues at RIKEN, we reviewed and redefined the concepts and control methods of EMS. We then represented measurement and forecast data not merely as numerical values, but in a machine-readable form based on a common ontology. This makes it possible for AI to process different types of EMS data in a unified manner. We believed that if demand response could be predicted and controlled using digital twin AI technology within a VPP, it would facilitate the deployment of distributed hydrogen energy systems tailored to specific regions and applications. Furthermore, by using the data accumulated after deployment to further refine the simulator, we could accelerate their real-world implementation.

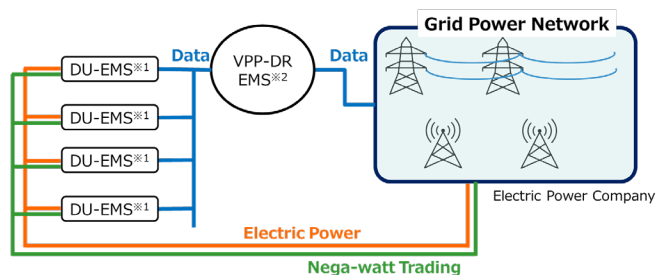


Conventional Virtual Power Plant- Demand Response

Source: Abstract from the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI)  
[https://www.enecho.meti.go.jp/category/saving\\_and\\_new/advanced\\_systems/vpp\\_dr/about.html](https://www.enecho.meti.go.jp/category/saving_and_new/advanced_systems/vpp_dr/about.html)

### ◆How did you approach solving these challenges?

The amount of electricity generated from renewable energy depends on the local climate conditions, while electricity consumption varies depending on the type of facility.



Overview of the evaluation system  
(Source: Institute of Physical and Chemical Research)

\*1 DU-EMS: distributed unit energy management system (EMS)

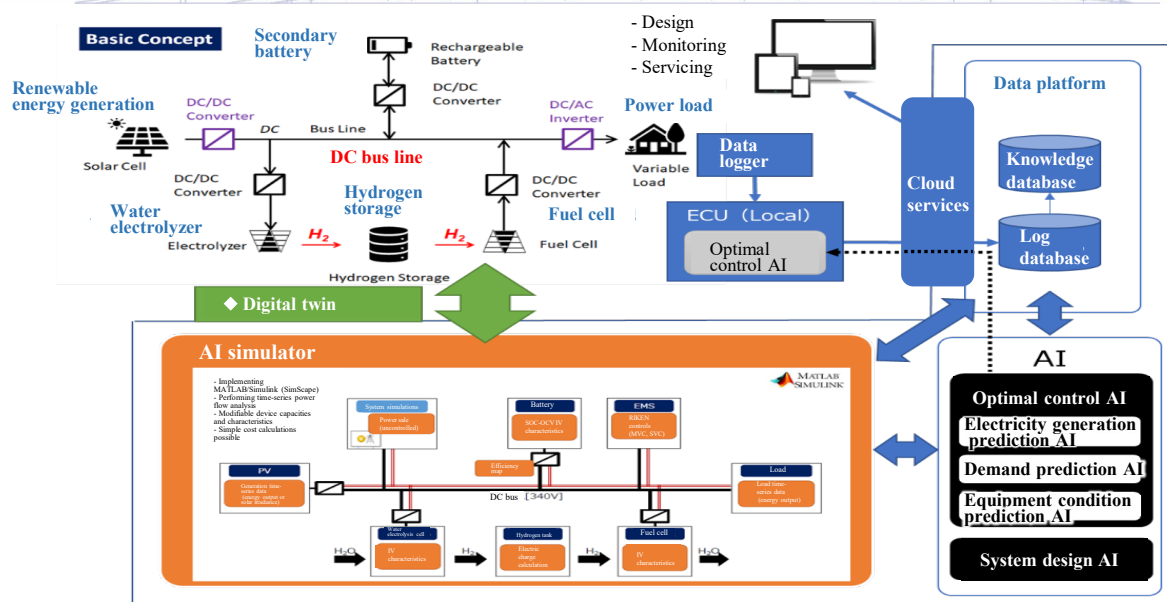
\*2 VPP-DR EMS: virtual power plant - demand response energy management system

Because a DU-EMS can perform energy management autonomously, it reduces the amount of communication with the VPP-DR EMS, enabling the VPP-DR EMS to manage a larger number of devices.

### ◆Could you tell us why you choose TTDC?

I was aware of TTDC's expertise in digital twin technology, and we had previously collaborated on exploring a digital twin for a water electrolyzer.

# Achieving power generation forecasting and optimal control using AI-powered digital twins!



Conceptual diagram of the overall DU-EMS system (source: RIKEN)

Through that project, I came to know that TTDC had a good understanding of the terminology and concepts behind hydrogen energy. We reached out to TTDC after our proposal to apply digital twin technology to the optimal design and control of hydrogen energy systems was selected for the AI Technology Program under the Cabinet Office's Public/Private R&D Investment Strategic Expansion Program (PRISM), which led to the launch of the project. Although many researchers have deep expertise in individual technologies, such as fuel cells or water electrolyzers, relatively few have a broad understanding of how to integrate those technologies into a complete system and implement it in society. I believed that with a strong technical foundation and a willingness to learn, those gaps could be overcome.

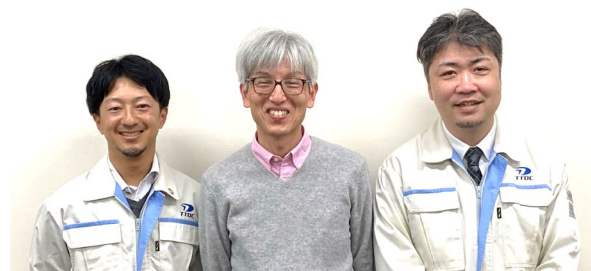
## ◆What were the benefits of adoption?

We believe we've reached a point where we can use digital twins to design a system that uses a variety of data to support control, such as publicly available data for power generation forecasting, along with demand forecasting and efficiency degradation forecasting for optimal control. At first, I didn't have a clear picture of what a digital twin was. However, working with TTDC helped me organize my thinking, gave me a much better understanding of the DU-EMS, and even helped us identify the next steps for the project. Future EMS development will require expertise not only in electrochemistry, but also in materials chemistry. Many of the challenges cannot be solved without knowledge spanning a wide range of disciplines, so there is still much for the various stakeholders to learn from one another. I believe the TTDC team also put a great deal of effort into learning the concepts involved, including ontologies. Digital twins may already be fairly common in the automotive industry, but I don't think that's the case in many other industries.

This project reinforced my belief that digital twin technology can be valuable in other fields as well, and I strongly feel it should be applied more broadly. I believe there are many people who are looking for technology like this.

## ◆Could you tell us about your plans for the future?

Considering the data has been given different meaning based on ideas developed through collaboration with many people, it can be expanded in countless ways simply by assigning different meanings. As the system continues to learn and the value of its control capabilities evolves, we hope to use it not only for energy management but also as a platform for advancing a sustainable circular society. It all begins with data. When data is properly organized, it becomes information. Information then becomes knowledge, and ultimately, wisdom. I envision applying this knowledge hierarchy not only to energy, but also to a wide range of fields, including transportation, agriculture, and fisheries. By integrating and optimizing these domains while respecting the unique characteristics of each region, we can create a social system that enables a sustainable, circular economy. Our goal is to develop a concept that represents an expanded version of Germany's Stadtwerke model (municipally owned utilities and public-private enterprises). We would be delighted to have TTDC participate in projects like this again in the future.



From the left: Mitsui (TTDC), Mr. Fujii, and Sakai (TTDC).