Review

HORIBA Institute for Mobility and Connectivity² for Contributing to the Transformation of Energy and Mobility Systems

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A new research institute was established in July 2021 at the University of California, Irvine with a donation from the HORIBA Group. The institute aims to promote research from a new perspective by integrating and rethinking the social infrastructure of energy and mobility, which will be deeply interrelated in the future. This article introduces the concept of the institute and some examples of its activities.

Figure 1 HIMaC² Opening Ceremony. (Oct. 11, 2022)
(from left to right) HIMaC² Inaugural Director Vojislav Stamenkovic, HORIBA, Ltd. Chairman & Group CEO Atsushi Horiba, UCI Chancellor Howard Gillman, HORIBA Ltd. Executive Corporate Officer Jai Hakhu, UCI Dean of Engineering Magnus Egerstedt.

Introduction -Trends in Energy and Mobility

The entire world is now facing an urgent challenge to cope with global warming. As of the COP26 summit, more than 150 countries including the G20 have set a deadline for declaring their carbon neutrality goals. In response to this, shifting to renewable energy has become a major trend, and energy procurement has become a major focus of attention from the perspective of national security. On the other end, mobility is one of the major sources of energy consumption and the rapid expansion of electric vehicles is progressing, especially in China and Europe, followed by the US and other regions.

In parallel, automobiles are becoming more automated and connected, and some attempts are being explored to save energy as a whole by having a group of vehicles run in a coordinated manner using these technologies. This situation can be seen as an indication of the process of integration of the three major infrastructures of energy, mobility, and information and communication. These structural changes are the basic background for the establishment of the HORIBA Institute for Mobility and Connectivity² (HIMaC²).

Research Direction at HIMaC[2] - Background and Concept

The energy supply system that forms the basis of today's society is based on the concept of a stable supply of electricity produced intensively at a rather limited number of power plants, as in the case of electric power generation > transmission > distribution. In contrast to this so-called one-way structure of power supply from the center to every corner of the entire grid, there is now a rapidly growing demand for expanding the use of renewable energy and local production for local consumption of energy. With this trend, elements such as photovoltaic cells and rechargeable batteries as intermediate energy storage are being added, and the electric power network which has been one-way and stably controlled, is changing to a more distributed, open and interactive form.

As is well known, renewable energies such as solar power, wind power, wave power, etc., all fluctuate greatly and are difficult to predict, which is a major challenge from the viewpoint of stable supply. It is not always clear how they should be arranged and operated, and how to guarantee the stable operation of the entire system. In addition to the placements of generation and storage capacities and the scheduling of charging and discharging, how to design and operate the network, including system stability assurance, resilience against unexpected fluctuations, and total cost including maintenance and renewal, are issues that should be fully considered.

On the other hand, automobiles have long derived most of their energy from gasoline and diesel fuel refined from crude oil, which exists unevenly on earth. Instead, we are now entering a period of change that is said to occur only once every 100 years, and the use of electric vehicles is expanding significantly. Future vehicles will also need to be seen as an integrated part of the network, storing electric energy and interacting with the electric power network through charging and discharging. In addition, hydrogen will play an important role as an energy medium, converted from electrical energy via water electrolysis and used as a medium for energy storage and transportation, or directly as an energy source for vehicle propulsion via onboard fuel cells or even internal combustion engines.

From this perspective, the energy network including automobiles is shown in Figure 2. First, a variety of renewable energy sources are provided as primary energy. In addition, automobiles will be equipped with large-capacity storage batteries, and hybrid and battery EVs will directly transfer energy to and from the network side. In such a "21st century type" energy network, it is necessary to explore a new front of technologies such as energy management method for decentralized and interactive energy network, and all the technology pieces for

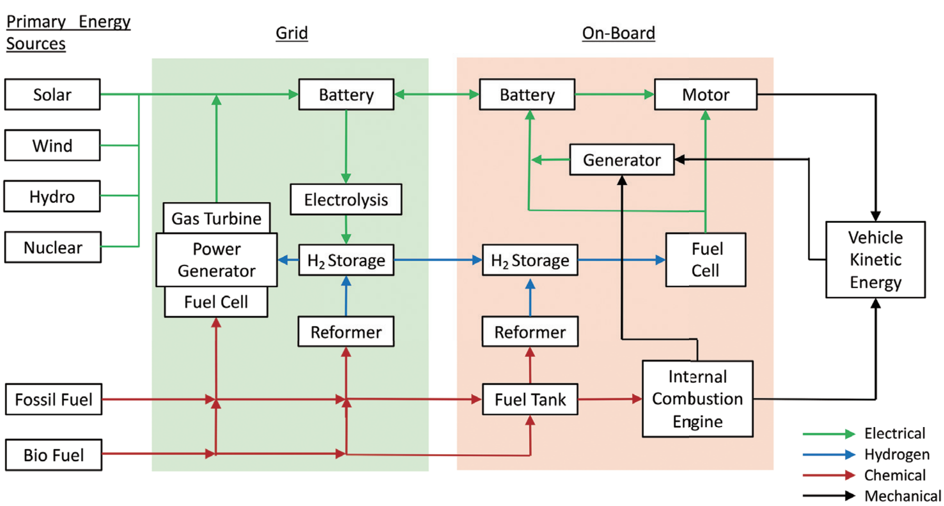

Figure 2 A Comprehensive View of Energy Network Integrated with Vehicles.

energy conversion systems by means of electrochemical reactions instead of combustion reactions.

In addition to the improvement of the efficiency of energy conversion as a basic challenging research issue, understanding and controlling the dynamic behavior of the system as a whole is also an unexplored area. Because of the interdisciplinary nature of the problem and the fact that it involves not only individual elements but also multiple layers of systems, a cross-disciplinary approach is indispensable in order to understand the essential aspects of the problem and to consider the direction of next-generation infrastructure.

Laboratory Structure of HIMaC^2

The Advanced Power and Energy Program (APEP) at the University of California, Irvine (UCI) has a long history of leading research in the energy field. UCI has pioneered a variety of research projects, such as combustion research as early as 1970, when the Muskie Act was introduced, power grid research, and hydrogen energy utilization technology. On the basis of these long-standing achievements, HIMaC^2 was established being aware of the aforementioned energy network issues, and Prof. Vojislav Stamenkovic, a world leader in the field of electrochemical materials science, was appointed as the inaugural director of the institute.

HIMaC^2 is composed of the following four laboratories, reflecting the recognition of the issues described in the previous chapter.

- Vehicle Evolution Laboratory (VEL): This laboratory evaluates and researches on-board electric vehicle elements and system technologies. For this purpose, the VEL is equipped with HORIBA measurement systems, dynamometers, and environmental chambers for rechargeable battery evaluation (Figure 3).

- Grid Evolution Laboratory (GEL): This laboratory is for conducting research on the grid level problems, including Grid-to-vehicle and Vehicle-to-grid power network dynamics. The GEL is equipped with a grid simulator that can reproduce dynamic phenomena in various power systems.

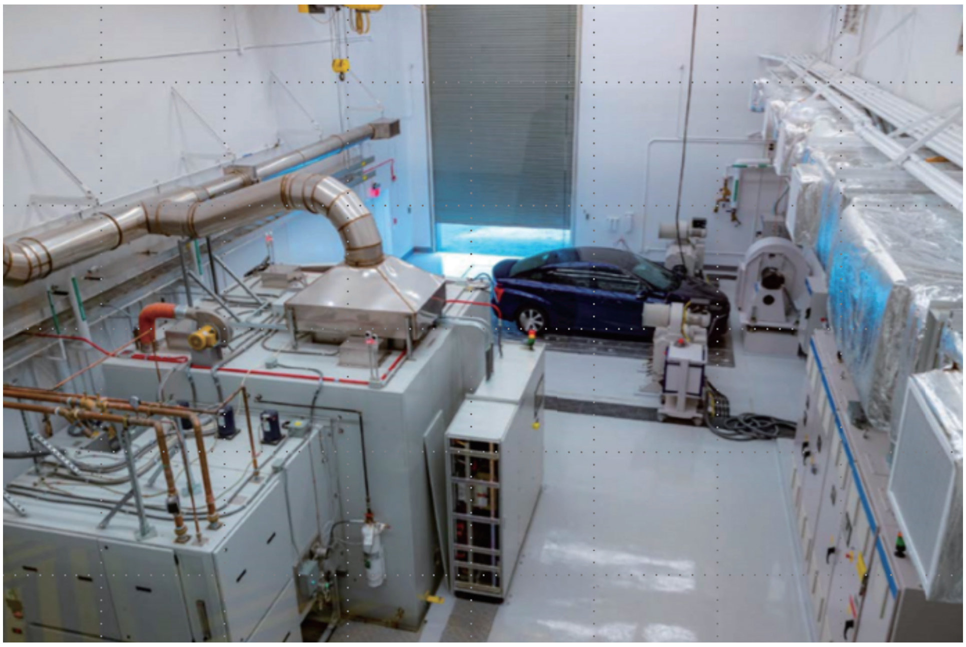

Figure 3 Vehicle Evolution Laboratory.

• Connected and Autonomous Mobility Laboratory (CAML): This laboratory conducts research on the impact of Vehicle-to-vehicle and Vehicle-to-infrastructure communication on individual vehicles, traffic flow, energy efficiency, etc., as well as AI-based control, which includes the possibility of automated driving. The CAML has introduced a simulation platform for cooperative driving control developed by HORIBA MIRA.

• Analytic Laboratory (AL): The following state-of-the-art HORIBA analytical instruments are installed to analyze and study the advanced electrochemical materials that form the fundamental basis of the above-mentioned systems and grid-level phenomena.
    • LabRAM HR Evolution Nano: AFM Raman Spectrometer
    • XGT-9000: X-ray Analytical Microscope (Micro-XRF)
    • nanoPartica SZ-100V2: Nanoparticle Analyzer
    • GD-Profiler2: Glow Discharge Optical Emission Spectrometer

Since future issues in the energy field will cover a deep multi-layered structure ranging from materials properties to devices, systems, and even to the entire grid, each laboratory is organized according to the respective hierarchical level. By organically combining these laboratories, it is possible to tackle new issues and phenomena by traversing the hierarchy, which may not have been sufficiently addressed in the past. In addition, UCI can conduct actual experiments at the grid level by using its on-campus energy network itself as an independent microgrid. This microgrid is also connected to photovoltaic cells and hydrogen-related facilities, providing an environment that can handle an extremely broad and comprehensive range of studies. With the unique research functions and configurations described above, the institute has great potential for future research horizons.

HIMaC² Research Project Examples

Although HIMaC² is still in the start-up phase shortly after its opening, various research projects have already been initiated, including many funded by major government agencies. The following is a list of major projects underway at the time of this writing.

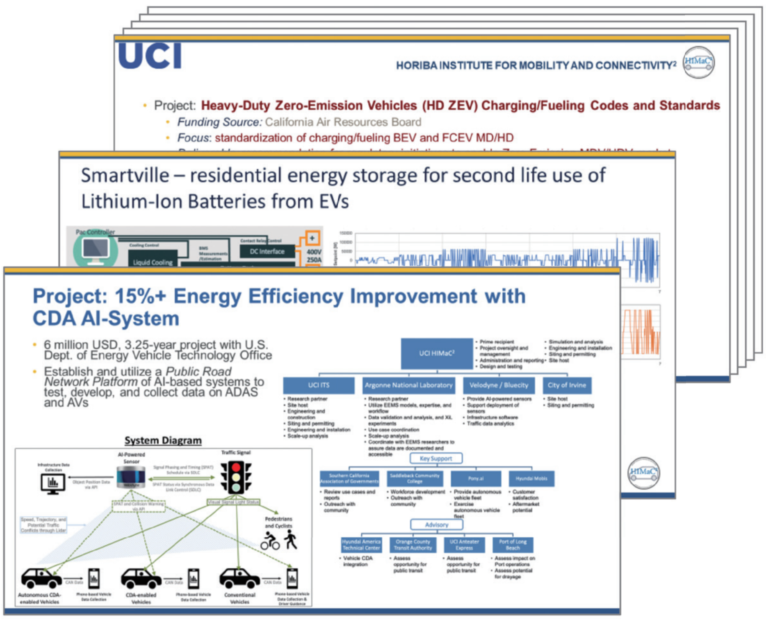

Figure 4 Examples of Research Projects at HIMaC².

1. Smartville: Research on technologies to utilize used batteries with a spin-off company from University of California, San Diego
2. Microgrid-in-a-Meter: Research on technologies to cope with dynamic events such as power outages in isolated grid systems including photovoltaic cells
3. HD-ZEV Charging/Fueling Codes and Standards: Basic research for standardization of energy fueling codes for heavy-duty electric and hydrogen vehicles
4. Aqueous, air breathing long-duration energy system: Research on a new type of non-Li-ion battery
5. Smart Cities and Connected and Autonomous Vehicles: Research on AI-based traffic control infrastructure coordination to improve energy efficiency with a view to self-driving vehicles
6. M^2CFT: Research on catalytic materials for the anode as part of the Million Mile Fuel Cell Truck Consortium
7. Break Dust Project: Evaluation study on the effects of brake and tire dust

Many of the above projects are supported by public organizations, e.g., 3 is publicly funded by the California Air Resources Board, and 4 and 5 are funded by the federal Department of Energy. In addition, many joint projects with other universities and research institutes are underway.

Conclusion

As mentioned above, the HORIBA Institute for Mobility and Connectivity^2 has started its activities at a right timing, when the energy and mobility networks are undergoing major changes. The institute is already taking a leadership role at the forefront of unprecedented research into the diverse issues that society as a whole will face in the future. It is expected to pioneer new knowledge that will contribute to solving future issues through specific research projects in collaboration with various stakeholders, including government, academia, industry across the energy and mobility sectors.

Lastly, in preparing for the establishment of this institute, we owe much to Professor Scott Samuelsen, the founder of APEP and a long-time leader in energy research in the United States. I conclude this article by expressing our gratitude to Professor Samuelsen for his forward-looking leadership through all the steps that enabled this landmark institute.

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