# Advanced Analytical and Measurement Technologies for Efficient Control System to Maximize the Performance of Electric Power and Batteries Usage

Keijiro IWAO

Advanced control technologies are required to stabilize power supply and demand especially grid system using renewable energy such as solar power having large fluctuations. Hybrid electric vehicles combing engine / battery / motor also require system control technologies to improve energy efficiency. In order to “generate”, “store” and “utilize” the energy smartly, it is necessary to coordinate the sub-systems with overviewing the behavior of entire system and predicting the time fluctuation of power supply and demand. The theme of 2019 Masao Horiba Awards focused on the technologies to manage this complex system. Along with background of theme, this paper summarize the award-winning technologies such as practical model realizing to be compatible accuracy and simplicity.

## Introduction

At the second meeting of the Strategic Commission for the New Automotive Era that the Ministry of Economy, Trade, and Industry (METI) has hosted since April 2018, METI released a “Well-to-Wheel Zero Emission*1” policy recommendation with the long-term goal of achieving it by 2050. This policy seems to indicate Japan’s intention to participate in the tug of war between Europe, the United States, and China to lead the new mobility industry that advocates concepts such as CASE*2 and MaaS*3. The policy has 3 pillars: achieving the highest level of environmental performance in the world, innovative ways to use vehicles, and changing the world’s energy supply to zero emissions. The target is to establish a society, in which low carbonization, dispersed energy sources, robust vehicles and energy are integrated, to improve the global environment, and to invoke a virtuous cycle of growth.

*1: Means “Exhaust gas is not emitted from the oil well to the vehicle wheel.”

*2: CASE: A collective name for next-generation automotive technology that uses the first letter of each of these words: Connected, Autonomous (self-driving), Shared & services, Electrification

*3: MaaS (Mobility as a Service): A new transportation concept in which users only pay the fees for transportation, such as vehicles, when necessary and use this as a service

In anticipation of this era of revolutionizing the automotive industry, HORIBA is also actively investing in the following business areas, and is strengthening its activities geared towards achieving a society that generates, stores, utilizes, and circulates energy smartly (Figure 1):

- Expanded our vehicle development business and the vehicle testing that uses test courses, and acquired the UK company MIRA to contribute toward developing next-generation mobility, such as self-driving cars (July 2015)[1]

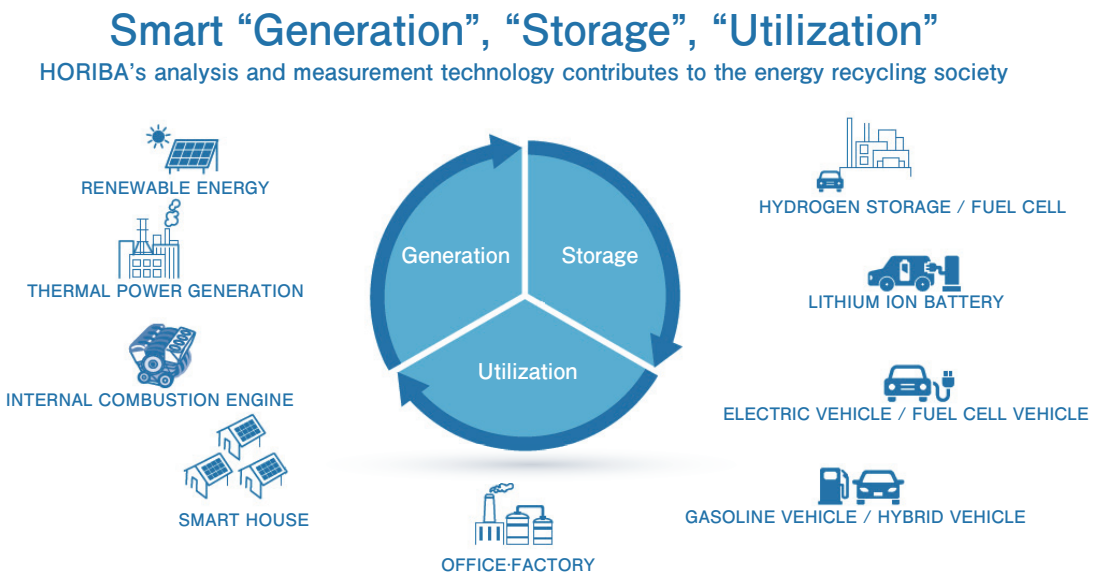


Figure 1 For smart “Generation”, “Storage”, and “Utilization, HORIBA contributes energy recycling society

- Established a testing and evaluation facility at HORIBA MIRA in the UK to support advanced battery development (May 2018)[2]
- Started building a new evaluation and testing laboratory in the R&D center in the city of Otsu in Shiga Prefecture for electric vehicle batteries, fuel cells, etc. (May 2018)[3]
- Donated to the University of California, Irvine to support the establishment of a new research center that promotes the blending of the energy and mobility fields (August 2018)[4]
- Acquired the German company FuelCon AG that manufactures and sells things like batteries for electric vehicles and test benches for fuel cell (October 2018)[5]

With this background, the 2019 Masao Horiba Awards chose the fundamental technologies that are always necessary for the new generation of energy and mobility industries in the future as the theme. This article will explain the background behind setting the 2019 Masao Horiba Awards theme, the target technical fields, and the application results.

## Theme for the 2019 Masao Horiba Awards

Target theme: Advanced analytical and measurement technologies for efficient control systems to maximize the performance of electric power and batteries usage

The demand of vehicle using electric power in the automotive industry provides unique challenges. Combustion engine designers have been consistently focused on the same factors for decades and need to change them. They must consider new ways to design systems in electrified vehicles that simultaneously meet energy consumption, emission and cost targets under a range of variables and conditions such as acceleration profile, battery charge/discharge management, engine speed and torque, thermal energy balance and so on.

Multiplying the number of calibration parameters creates added demands for the battery as it charges and discharges energy. Autonomous vehicles are

another example of an innovation currently being tested by many manufacturers to generate more desirable, high-quality automobiles.

Electric power generation by renewable energy is gaining momentum. That includes solar and wind power, and the development of electric cars with exponentially enhanced energy efficiency. There is also a strong movement towards energy security. These trends are directed by tough national policies and social interests designed to cut $CO_2$ emissions. Examples include fuel consumption regulations in Europe, policies to support the development and spread of electric cars in China, and technical developments for next-generation energy sources, such as the utilization of hydrogen to store renewable energy.

Renewable energy is also facing a critical stage due to factors outside of the operator's control. At a power plant in Kyushu, Japan, where renewable energy accounts for 20 percent or more, there was an occasion the output of solar power generation was halted due to the disproportionate balance between supply and demand. Natural occurrences can also create havoc when anomalies occur, such as a recent earthquake in Hokkaido, Japan. Due to the damage in one plant, a chain reaction occurred with the connecting power plants, resulting in a widespread shut-down.

Renewable energy demands also change due seasonal temperature fluctuations, daytime and nighttime temperature variations, and the disparity of wind and sunlight, based on weather conditions. It's becoming more urgent to control these fluctuations in response to these occurrences.

With the background described above, we are keen to support young researchers and engineers in academia who will lead the advancement of these technologies for the future society.

We look forward to learning as many promising ideas as possible in the 2019 Masao Horiba Awards.

Eligible Field of Technology:
(1) Technology field 1: New measurement technologies that will attain the unified control over the mechanical, electrical, and chemical sections of the energy supply system, which will contribute to the effective and robust controls of electric vehicles and grid power supply. The proposed method is expected to include the following technological aspects:

- New measurement methods to visualize an internal state of a battery as it is being used.
- New monitoring technologies for an entire electric power system from a bird's eye view to enable predicting power demand.
- New statistical methods to identify appropriate monitoring points within the energy network that represent the behavior of the whole system.

(2) Technology field 2: New analytical methods utilizing data science that will contribute to a range of energy management applications in future, such as effective and robust controls of a grid power supply including electric vehicles. The proposed method is expected to include the following technological aspects:

- New approach of simulation modeling that does not employ only deduc-

tive, physical models, but also inductive, data driven models using statistical techniques.
- New technologies for precise estimation of the internal state and dynamics of a battery beyond impedance method.
- New modeling technologies for electrochemical reactions during battery charge/discharge process that can be integrated into mechanical, system level control.
- New inductive verification methods for identifying "interference faults" of a complex system such as automobile powertrain control system that conventionally employs "IF-THEN" control.
- Control technologies that will contribute to more stable and resilient grid energy supply network that could be far more distributed than it is today.

These above two fields need to be used for industrial applications, and contribute to the reduction of time-to-market and energy efficiency.

## Application Results for the 2019 Masao Horiba Awards

HORIBA received a total of 36 applications (14 of those were from overseas universities or public research institutions) during the application period from February 18 to May 10, 2019. Out of those, 11 applications were related to stable control technology for grid power (electric power from the overall equipment, such as power generation and power transmission distribution equipment) that uses multiple means of storing energy, including electric vehicles. There were 10 applications related to technology for analyzing and measuring the electrochemical reactions in secondary batteries and fuel cells, and 7 applications related to modeling[*4], including system identification (mathematical tools and algorithms). The remaining 8 applications were related to developing battery materials or original control technology for motors, batteries, or inverters.

*4: Modeling: Preparing abstract models (mathematical formulas) that simplify complex systems

There were no applications related to the optimal design for solving the issue of increasing development man-hours in the automotive industry due to the complexity of vehicle systems, which was one of HORIBA's major motivations for making a public invitation for submissions. HORIBA suspects that this is because this is in an area related to the design know-how of automotive companies and design companies, and it is a theme that is difficult for universities and public research institutions to handle.

The 2019 Masao Horiba Awards had three winners and two honorable mentions. Out of the five winners, three of the submissions were related to stable control of system power, and two were related to modeling for battery control.

All of the winners this year had the perspectives of an overall view of a complicated system as a whole that has multiple sub-systems (such as the charging/discharging characteristics of the batteries installed in vehicle systems or power storage systems for power grids), clarifying the positioning and an outline of the issues to be resolved, and indicating a direction for resolving them. To do this, the perspective of deductively building a physical model and that of inductively verifying the model, for example, using statistical analysis or

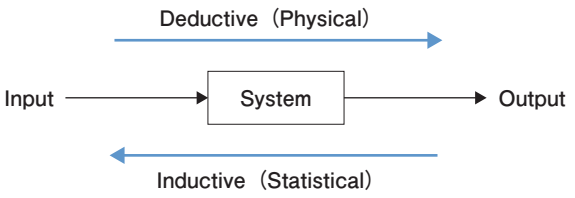


Figure 2 Modeling approach

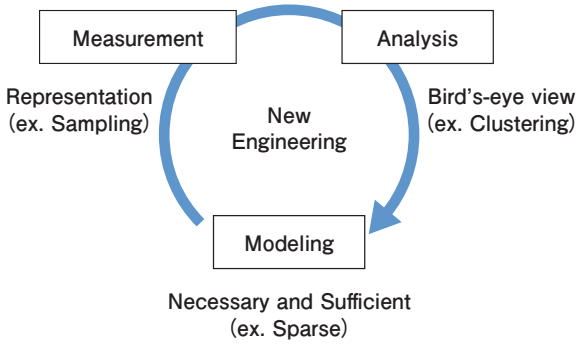


Figure 3 Necessary and sufficient modeling for new engineering

data science are required (Figure 2). For example, to utilize renewable energy such as solar power generation, a sub-system that stores energy flexibly based on demand that fluctuates in units of minutes, days, and years is needed. The conditions necessary for the capacity, performance, and so on required for this sub-system and the important conditions needed for the power system as a whole in terms of implementing it in society were investigated, such as sufficiently investigating things like optimizing the cost for the system as a whole. Further, with regard to system control modeling, there were also technologies that can be expected to have promising industrial applications in the future, such as techniques (Figure 3) for designing models that not only simply increase the accuracy of the model but also have an overall view of the system as a whole, clarify the typical parameters and balance the accuracy and simplicity of the model within the necessary scope.

In other words, the winners were the young researchers who developed new engineering areas for optimizing the relationships between sub-systems in complicated systems, such as design techniques for control models that don't waste effort beyond what's necessary, and guidelines for designing sub-power-systems that won't burden the system power.

## Conclusion

HORIBA thinks that the era of seeing the spread of electric vehicles, the practical application of autonomous cars, and increasing the overall energy efficiency of society by connecting those to the power system is close at hand. In order to achieve this, it is essential to develop technology that can efficiently use complicated systems. The 2019 Masao Horiba Awards established the theme of "Advanced analytical and measurement technologies for efficient control system to maximize the performance of electric power and batteries usage" for the purpose of carving out this new era and encouraging young researchers. HORIBA is thankful for all applications received from many researchers. The new-era perspective that all researchers from whom HORIBA received applications have is the necessity of performing research combining "bird's-eye view", "insect's-eye view", and "fish-eye view". HORIBA noticed that all three perspectives are needed: not only the "insect's eye view", which is the conventional research perspective of making the things we can't see visible, but also the "bird's-eye view" that impartially identifies what kind of positional relationship that research has in the overall system, as well as the "fish-eye view" that identifies the overall system dynamics or changes over time (Figure 4). HORIBA expects good things from the young researchers who work hard and will shoulder the responsibility for future generations of technologies.

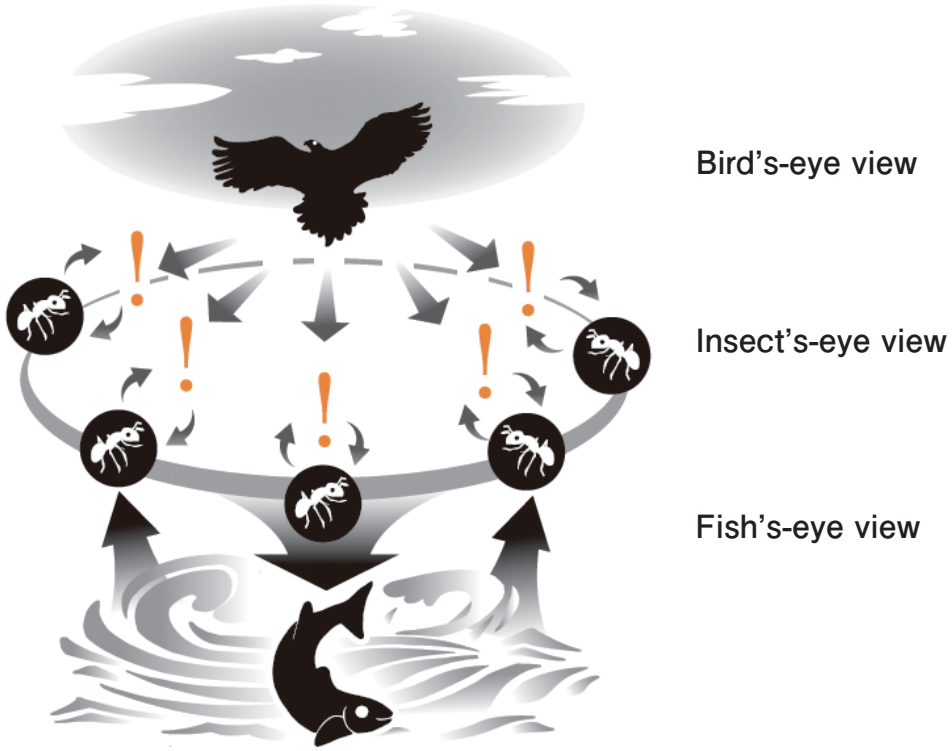


Figure 4 Three points of view for new engineering

* This content is based on our investigation at this publish unless otherwise stated.

## References

[1] http://www.horiba.com/jp/corporate-news/news/article/mira-ltd-39541/
[2] https://www.horiba-mira.com/facilities/advanced-battery-development-suite-abds/
[3] http://www.horiba.com/jp/corporate-news/news/article/54291/
[4] http://www.horiba.com/jp/corporate-news/news/article/54933/
[5] http://www.horiba.com/jp/corporate-news/news/article/fuelcon-ag-55977/

**Keijiro IWAO**
Business Owner
Automotive Global Business Strategy Office
HORIBA, Ltd.
Ph.D.