How the OmegaLand Integrated Environment for Dynamic Simulation Helps Achieve the SDGs

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Omega Simulation Co., Ltd. was established in 1997 as a joint venture between Yokogawa Electric Corporation and Mitsui Chemicals, Inc. Its mission is to serve customers with various products and services and improve customers' plant operation through advanced technology that integrates Yokogawa's instrumentation and control technologies with Mitsui Chemicals' modeling and simulation technologies. OmegaLand and Visual Modeler, an integrated dynamic simulation environment and its core plant simulator technology, are software packages developed by Omega Simulation. This paper describes how OmegaLand will help achieve the SDGs related to education, energy, and the environment, and shows application examples and future plans for the software.

INTRODUCTION

Omega Simulation has developed OmegaLand, an integrated dynamic simulation environment that enables realistic simulators to be built using advanced modeling and simulation technologies. Its core calculation engine is Visual Modeler, which offers high-fidelity simulation. OmegaLand targets a wide range of industries that face various issues such as safety improvement, resource conservation, and energy saving to respond to changes in the production environment. In addition, it provides solutions for various purposes such as education, operator training, operation support, and process analysis to customers in various departments such as research, production technology, and manufacturing.

This paper introduces how OmegaLand contributes to achieving the SDGs: training (SDG 4), energy (SDG 7), and water and sanitation (SDG 6).

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Quality Education

As stated in the SDGs[1], promoting equitable and quality training and lifelong learning opportunities (SDG 4) is one of the key issues to sustainable economic activities. OmegaLand is widely used as a platform for training plant operators. OmegaLand Trainer is high-quality, realistic operator training simulator (OTS) software. It provides an operator training environment for trainees to learn the operation skills required at customers' actual plants. OmegaLand Trainer also helps trainees learn the skills of experienced operators and non-steady operations such as start-up.

Customers understand that there is a need to arrange a learning environment in which workers can develop their knowledge about general chemical and engineering principles. In addition, it is necessary to offer hands-on training sessions to help workers retain what they have learned in the classroom. To satisfy such needs, we offer OmegaLand Educator, a total learning environment solution that provides classroom materials (workbooks) about the principles of unit operation and enables workers to experience operation using a dynamic simulator.

Solving Energy Issues

Energy is one of the major issues in the SDGs (SDG 7). As a support system for optimized energy-saving operation, we provide MIRROR PLANT, a simulator that runs simultaneously with an actual plant while capturing process data. MIRROR PLANT can import process data from the control system by connecting the control system to OmegaLand. Based on the actual data, it can calculate values at non-measured points and interpolate those in long sampling periods, on a real-time basis. These values can be used as indicators for safe, stable operation. MIRROR PLANT is a simulator that can accurately reflect the actual operating conditions. By using it off-line, it is possible to determine the optimal operating volume and control parameters, thus reducing the number of tests to be run at the actual plant.

Water and Sanitation Issues

The global provision and sustainable management of water and sanitation is one of the environmental goals of the SDGs (SDG 6) and also is an urgent issue in many parts of the world. As an application for solving this issue, we developed an operator training simulator for water purification plants. This simulator is designed to develop a water purification model and use it for training. The model takes into account the dynamic changes in water quality. With the model, operators can determine the appropriate timing of chemical injection and predict changes in water quality after chemical injection. The simulator not only provides a training environment that reproduces the operation and process behavior in a realistic manner, but also makes it possible to study changes in raw water quality, which helps improve operators' skills as well as stabilize water quality.

OmegaLand is based on the dynamic simulation technology described above. The following sections introduce its role in helping customers achieve the SDGs, referring to actual examples, and discuss future prospects.

OPERATOR TRAINING SIMULATOR

It is increasingly important to continuously offer training to operators for stable operation of plants. At many plants constructed during the period of high economic growth, operators well-versed in the facilities are retiring, and how to hand down operating techniques from veterans to unskilled workers and how to train these workers is becoming an urgent issue. Another problem is that operators have fewer opportunities to operate in non-steady conditions because advanced automatic control ensures stable operation and regular maintenance become less frequent. One of the solutions to these issues is OmegaLand Trainer, which is software for OTS.

Figure 1 shows an example of OmegaLand that is connected to an actual distributed control system (DCS). This DCS connection type allows the actual control logic and parameters to be used with a virtual plant having high reproducibility, which is constructed by Visual Modeler. Since the operator console in the actual plant is used, a realistic operator training environment can be achieved. The system can also be connected to safety instrumentation systems and advanced control systems for operator training.

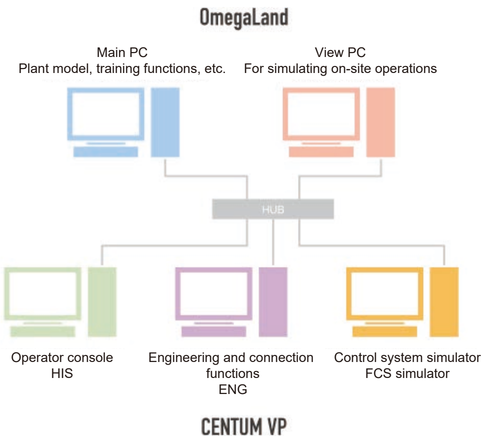

Figure 1 Configuration of DCS connection type OmegaLand

OmegaLand Trainer enables operators to not only learn the procedures of normal plant operation, but also improve their operating skills for non-steady operations such as plant start-up, shutdown, and abnormal conditions. In addition, they can experience team operations using the monitoring screens of the actual control system.

EDUCATIONAL SIMULATOR

OmegaLand Trainer provides an environment for learning the process behavior principles and operational skills at customers' plants. Meanwhile, there is a need for an environment in which people can learn basic chemistry and engineering. Specific subjects are the principles of general processes, the process behavior principles and performance of equipment, proper operation, and the basic knowledge required for plant operation. To meet such needs, we offer OmegaLand Educator. Figure 2 shows its outline.

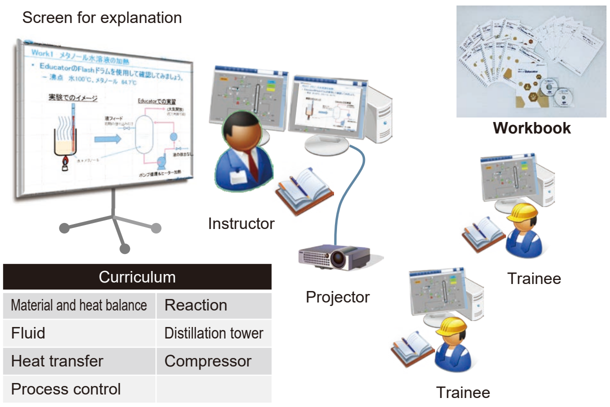

Figure 2 Outline of OmegaLand Educator

OmegaLand Educator is a high-fidelity simulator for process training that uses the same Visual Modeler calculation engine as OmegaLand Trainer. The simulator provides a realistic, hands-on learning environment, which cannot be achieved through e-learning instructors, and thus enables higher-quality and more practical education. The system offers workbooks to trainees, and answers and supplementary documents to instructors. Therefore, the person in charge of training does not need to spend time on developing training materials and can concentrate on other arrangements for education. The system also offers educational courses for instructors and system maintenance staff. Currently, seven curriculums are available: material and heat balance, fluid, heat transfer, process control, reaction, distillation tower, and compressor.

OmegaLand Educator allows each trainee to operate the simulator individually or multiple trainees to operate the simulator cooperatively. Instructors can monitor on a screen the operations of all trainees, so the system can be used for group training regardless of the number of trainees. Trainees can also choose any curriculum and study by themselves; self-learning deepens the knowledge gained in group sessions. It is a highly effective learning system for trainees.

We are planning to use networks and the cloud to provide a flexible educational environment that can be used in a wider range of areas.

MIRROR PLANT

MIRROR PLANT is a digital twin solution. While taking in data from the control system, it performs simulation with OmegaLand that is connected online to the control system. The data are always synchronized with the actual plant conditions. Even if sensors are not installed, the simulator calculates state quantities such as temperature and composition and MIRROR PLANT displays them for operators in real time. In addition, by accelerating the calculation of the simulator, MIRROR PLANT predicts the near-future state quantities and thus helps operators to take actions before the operating conditions go out of the operating range.

Furthermore, by using this simulator off-line, it is possible to analyze the process and improve the controllability without affecting the actual plant.

For example, when determining the parameters of a controller, it is common to give allowable variations to the actual process and estimate the parameters from the response. However, it is difficult in practice to give sufficiently large variations to determine the parameters of the controller because doing so may affect the operation of plants. Furthermore, although multiple tests are needed to determine the control parameters, it isdifficult to make enough time for this during operation. To address this issue, we have developed a support system for verifying the effectiveness of control algorithms and determining parameters by combining the initial state created by MIRROR PLANT with an off-line simulator.

Simulators have been widely used to test various plant responses. In particular, analysis engineers have made a great deal of effort to simulate a state close to the actual operating state in preparation for analyses. Since MIRROR PLANT retains an actual initial state, analysis engineers can concentrate on analyzing phenomena and verifying algorithms. For details, please refer to Reference 2.

AN OPERATOR TRAINING SIMULATOR FOR WATER PURIFICATION PLANTS

High-level skills based on experience are required for managing and maintaining waterworks facilities and equipment. However, the number of workers in the waterworks industry is on the decline. In particular, the mass retirement of baby boomers makes it difficult to maintain skills and pass them on to less experienced workers. In addition, many other issues have arisen in recent years. For example, unusually high rainfall causes great fluctuations in the quality of water sources and requires flood control. To address these issues, there is a need to secure personnel with the expertise who can properly manage water quality and respond to abnormalities such as loss of power supply, and various measures are being considered. As a solution, we have developed an operator training simulator using OmegaLand. This system allows personnel to learn how to deal with high-turbidity raw water (which requires high-level skills), how to switch pumps and injectors in unusual operating conditions, and how to address failures of chemical injection equipment[3].

Different from existing simulators for water purification plants, the simulator using OmegaLand has the following features.

- Equipment model developed for operator training
  We developed a unit model to represent the equipment specific to water purification facilities, setting the dimensions and other factors as parameters. The model can be easily customized to actual equipment.
- Models with dynamic characteristics
  We use models that can reflect dynamic behaviors. For example, ion equilibrium, turbidity, chlorine consumption, and concentration propagation are represented by such physical models.

Figure 3 shows an example of the simulation. The rate of injecting flocculant (poly-aluminum chloride: PAC) into a mixing basin is varied in steps and the actual dynamic behavior of pH values and the simulation results are compared. The graph shows that the direction of the behavior at the time of the step change is consistent, and the difference of the values, including transient changes, is within 0.02. This indicates that the simulation results are accurate enough for operator training.

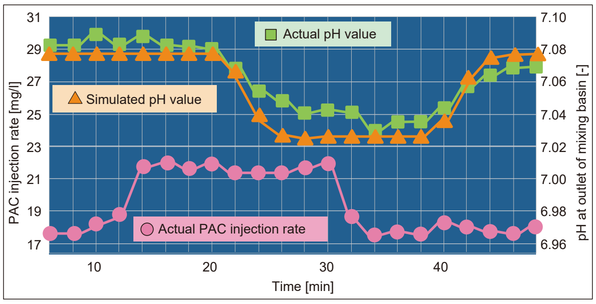

Figure 3 Example of simulation

FUTURE APPLICATIONS OF OmegaLand

OmegaLand, which was developed based on advanced modeling and simulation technologies, has the potential to help customers solve various issues including the SDGs. We are working on the following themes for dynamic simulation technology and its utilization in the near future.

- Expansion of the training environment for each level
- Advanced monitoring of plant conditions using MIRROR PLANT (online simulator)
- Process analysis and optimization of operating conditions

These efforts are explained in the following sections.

Expansion of the Training Environment for Each Level

To provide an advanced training environment, we actively adopt technologies from other fields. For example, we are improving the sense of reality in the training environment by using 3D visualization and AR technologies and haptics devices. We are also trying to use human sensing technology to apply the characteristics of human behaviors, which could not be evaluated in the past, to training and education.

Figure 4 shows an example of these efforts that we have already started. This solution visualizes and displays the movement of the trainee's viewpoint on a live image and determines whether or not the trainee actually looks at the points that need to be visually checked. We have also developed a system that enables more realistic field operator training by displaying 3D walk-through contents, which are conventionally expressed in 2D drawings and maps. These systems are already used by some customers.

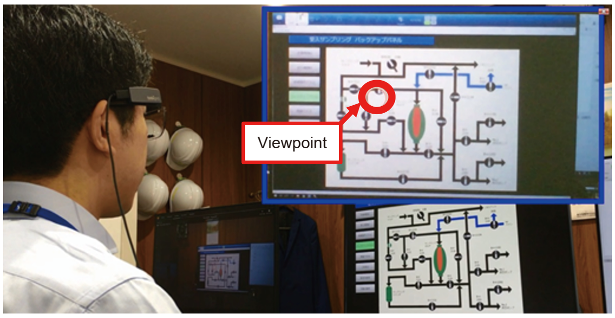

Figure 4 Example of evaluation of viewpoint movement

By integrating 3D and AR technologies, as well as haptics device technologies such as force feedback, OmegaLand is expected to improve the reality of simulation and help workers be involved in more sophisticated cooperative tasks. We are also planning to integrate network, cloud, and Telexistence technologyes to provide a training environment even in situations where group sessions are impractical due to COVID-19 or similar difficulties.

Advanced Monitoring of Plant Conditions Using MIRROR PLANT (Online Simulator)

We are planning to improve the functions of MIRROR PLANT, focusing on strengthening the power of expressing dynamic behaviors and enhancing the online functions, in order to leverage our strengths of modeling and simulation technology in an actual operating environment.

This will visualize specific energy consumption, monitor product specification tolerance, and provide a mechanism to sustain efficient, stable operation.

Process Analysis and Optimization of Operating Conditions

In recent years, technological innovations in the field of computer science, including AI technology and big data analysis, have been accelerated by the efforts of various vendors and research institutions. As pointed out in reference 4, it is not easy to apply these technologies to plant monitoring and operation because available data in continuous operating plants only slightly fluctuate around the steady state under normal operating conditions. On the other hand, the dynamic simulator can produce data under a wide range of operating, even near-abnormal, conditions. By using the simulator and the actual plant data to complement each other, we can provide a mechanism to support more advanced, accurate operation.

In addition, by combining the simulator with an optimization solver that can obtain solutions faster and more stably, it will be possible to provide operators with the optimal operating conditions, which can be obtained by trial and error using the simulator.

CONCLUSION

Applications of OmegaLand will expand greatly if the simulation technology described in this paper and field digital and control system engineering are combined; the mechanism is built into the control system; and the latest information and operation data of the process equipment are kept fed to the simulator. OmegaLand can be used for a broad range of solutions throughout the plant lifecycle. These include: verifying control algorithms when updating actual plants and control systems, offering training sessions for operators before system updates, reducing the cost of remodeling and tuning simulation models, improving the prediction accuracy of MIRROR PLANT, and improving the accuracy of support for optimal and energy-saving operation.

By combining the highly advanced simulator described in this paper with control systems, we will help customers to achieve safe operation, improve production and related technologies, innovate operation technology, and achieve the SDGs.

REFERENCES

(1) United Nations Development Programme, “Sustainable Development Goals,” https://www.undp.org/content/undp/en/home/sustainable-development-goals.html (accessed on October 15, 2020)
(2) Toshiaki Omata, Takayasu Ikeda, et al., “Case Examples of MIRROR PLANT for Chemical Process,” Yokogawa Technical Report English Edition, Vol. 62, No. 2, 2019, pp. 97-102
(3) Makio Ishikawa, et al., “Dynamic Simulation of Water Quality in Water Purification Facilities,” Proceedings of the 2018 National Conference of the Japan Water Works Association (in Japanese)
(4) Yoshiyuki Yamashita, “Three AI Challenges to Achieve Plant DX,” Yokogawa Technical Report English Edition, Vol. 62, No. 2, 2019, pp. 55-56