Engineering Solution for Distributed Resources in Power System

Masahiro Watanabe
Yasunori Ono
Tomoharu Nakamura
Hidehiko Shimamura

OVERVIEW: Distributed resources influence the electric supply reliability and the power quality of distribution systems. Therefore, we need to conduct initial evaluations and investigations of countermeasures. The Tokyo Electric Power Co., Inc. and Hitachi, Ltd. developed a power quality analysis system that enables calculating the power quality effect in advance and that supports analyzing improvement plans. However, customers who introduce distributed resources need a scheme to maintain economic efficiency, to control the heat and power of a co-generation system, and to optimize the active and reactive power control. Hitachi, Ltd. experimentally developed an operation system to optimize the operation of co-generation systems. Its effectiveness in a real-time simulator was evaluated. In this paper, the overview of a power quality analysis system and an operation system for the co-generation system is described, and a micro-grid system control scheme is introduced.

INTRODUCTION

NATURAL energy and co-generation are needed to prevent global warming and to allow for high-efficiency usage of energy. Additionally, new energy resources are increasing due to the impact of the renewable portfolio standard. Distributed resources influence the electric supply reliability and the power quality of distribution systems. Therefore, we need to conduct initial evaluations and investigations of countermeasures. The Tokyo Electric Power Co., Inc. and Hitachi, Ltd. developed a power quality analysis system that enables calculating the power quality effect

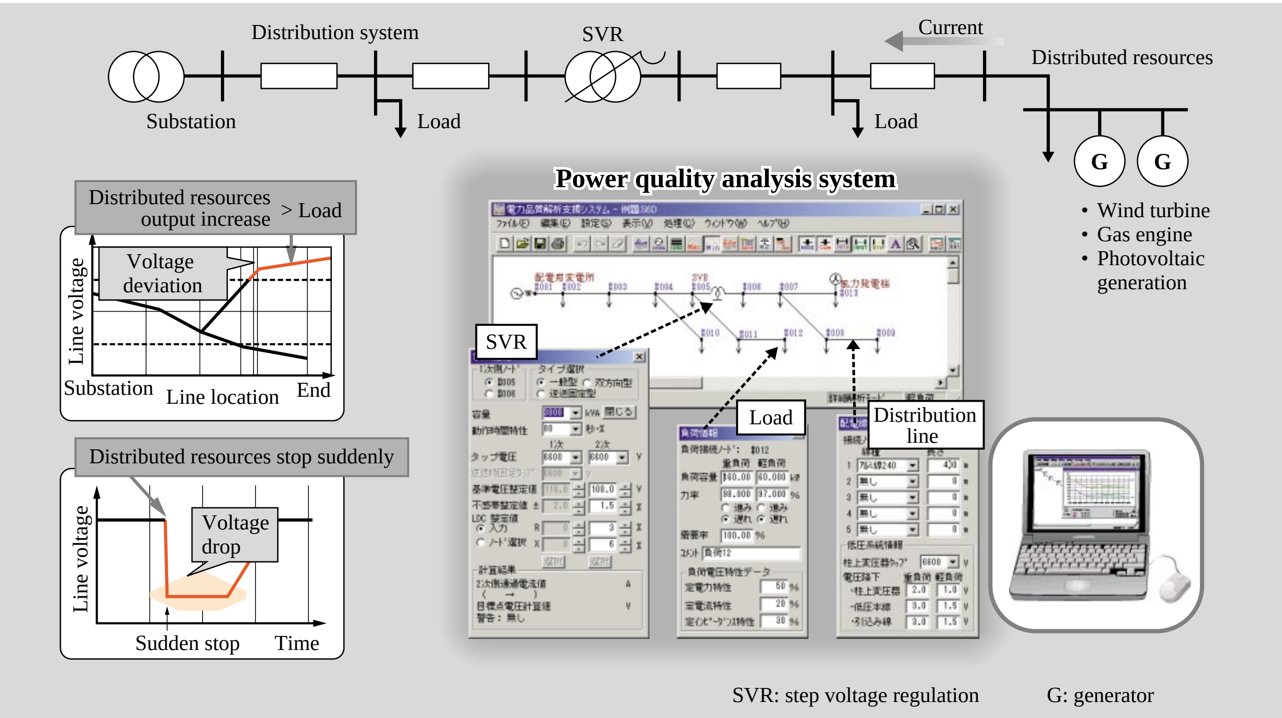

Fig. 1—Overview of Power Quality Analysis System.
We have developed a simulation system that includes various functions to reduce unbalanced voltage and to support advanced examination, such as recognizing the influence of voltage fluctuations, instantaneous voltage drop, flicker caused by a change in distributed resources, and special loads.

in advance and that supports analyzing improvement plans.

However, customers who introduce distributed resources need a scheme to maintain economic efficiency, to control the heat and power of a co-generation system, and to optimize the active and reactive power control. Hitachi, Ltd. experimentally developed an operation system to optimize the operation of co-generation systems. Its effectiveness in a real-time simulator was evaluated.

In this paper, the overview of a power quality analysis system and an operation system for the co-generation system is described, and a micro-grid system control scheme is introduced.

POWER QUALITY ANALYSIS SYSTEM

We describe the functions of the power quality analysis system in this section. The overview of the system is shown in Fig. 1.

Power System Information Management

An operator can compose or edit distribution system models by means of a GUI (graphical user interface). The system prepares several component models for the distribution system in the dialog box. The operator can save time and effort with the interface. Examples of the main window and dialog boxes are shown in Fig.1.

Calculation of Voltage Fluctuation

The system has a simulation function for a SVR and SVC (static var compensator). The system calculates the voltage profile for a stable condition and the condition of a load change. The results, such as the voltage profile and transition of the SVR tap, are indicated by graphs and numbers. Examples of the simulation setting and result dialog windows are shown in Fig. 2.

Protection System Coordination for Short-circuit Contingency

The system has these evaluating functions for system protection:

(1) Calculation of a short-circuit current with a link to distributed resources

(2) Investigation of protection system coordination by means of a link to distributed resources

(3) Investigation of protection relay settings

(4) Support to arrange the switchgear with over-current protection relays on the feeder

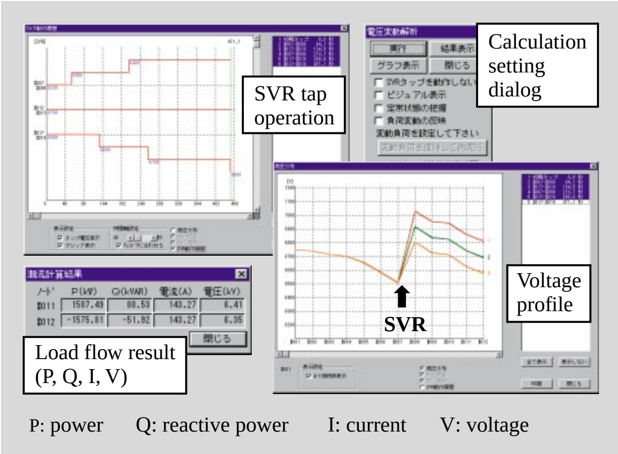

Fig. 2—Example Results of Voltage Fluctuation Simulations. Trends in SVR tap operation, line power flow, and profile of node voltage are indicated both by numeric values and charts.

Evaluation of Instantaneous Voltage Drop and Flicker

The system has models that cause voltage drop or flicker, such as an induction motor, a crane, an X-ray device, a resistance welding device, a compressor, and an arc furnace. The influence of these models can be investigated.

A function to calculate an instantaneous voltage drop can clarify the voltage variation caused by an induction motor when it starts. ΔV, the voltage deviation before and after the motor starts is calculated as an evaluating index, which is calculated twice by the load flow. Load models for the calculation include information of the rate capacity, consuming active/reactive power and some other characteristics.

An index of ΔV_{10} is used for evaluating flicker influence, as is usual in Japan. It is calculated from the amount of voltage fluctuation, the frequency of fluctuation, the luminous coefficient curve, and the load flow calculation results.

Support Function to Reduce Unbalanced Voltage

This function calculates the amount of load required to be moved to another phase in order to reduce the unbalanced voltage. The system calculates the amount of load transfer using actual monitoring values on objective nodes and using sensitivity of load changes, and it optimizes the calculation program.

Influence of Wind Turbine Connection

The system can estimate a voltage drop when the generator is connected to a distribution system and when a voltage fluctuation or flicker occurs due to the tower shadow effect or wind speed variation. The amount of the voltage drop when a wind turbine starts is calculated by the wind turbine-generator considering the consumed active/reactive power. It is similar to calculating an instantaneous voltage drop. The influence of the voltage flicker caused by tower-shadow effects of a wind turbine is calculated approximately considering the rotation speed, number of blades, and measured active/reactive power variation.

STUDY ON OPTIMAL OPERATION TECHNIQUE OF DISTRIBUTED RESOURCES [2)]

Prediction and Optimal Operation Based on Consumer Data

In the energy system shown in Fig. 3, when adjusting the distributed resource supply with demand and performing output control, time is needed to respond to control instructions for a consumer. If such time can be eliminated, the apparatus can be operated more efficiently. In prediction-based optimal control, the demand is monitored in real time, and the near-future demand (after several minutes) required for control of a distributed resource is anticipated. The neural network method was used for the prediction.

Next, the optimization problem of the electric power that is used (shaded) as shown in Fig. 3 is considered. Energy balance, demand-and-supply conditions, the amount of purchase power, the amount of consumption, and other factors. are formulated. At this time, the amount of power generation is determined by drawing the purpose function for minimizing the cost of the electric power supply. An example of time variation in dynamo outputs and purchase power for performing the prediction-based optimal control is shown in Fig. 4.

Optimal Operation System with Distributed Resources

Equipment that controls distributed resources was made for an experiment and was applied with the prediction-based optimal control. The equipment is shown in Fig. 5. It consists of dynamo controllers that manage distributed resources using the signal with demand forecasting and using an optimization calculation from the server. It also consists of a real-time simulator that imitates the operation of dynamos to functional verification. Active/reactive electric power of dynamos was found to be controllable based on the control instructions from the server.

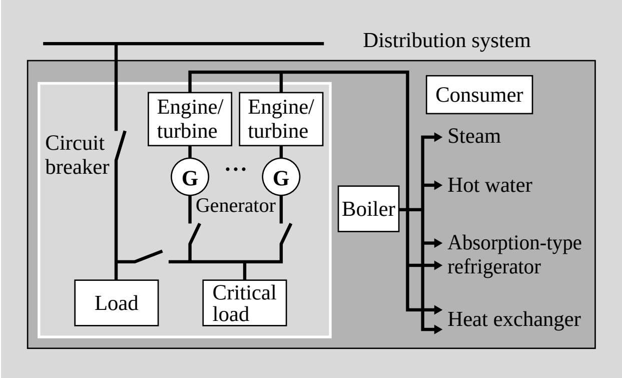

Fig. 3—Example of Consumer Energy System.
Two or more distributed resources supply electric power and heat. Optimal operation is achieved by adjusting outputs according to demand.

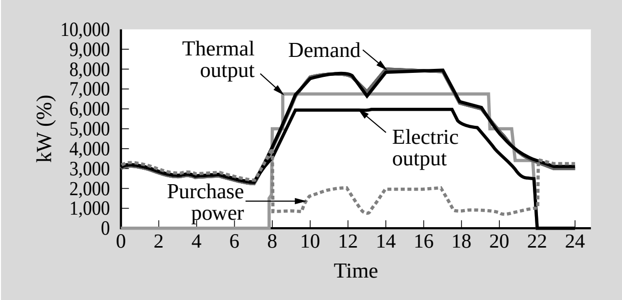

Fig. 4—Example of Optimal Operation Pattern.
The output of the distributed resources becomes optimal every two or three minutes, and the minimum cost operation is performed.

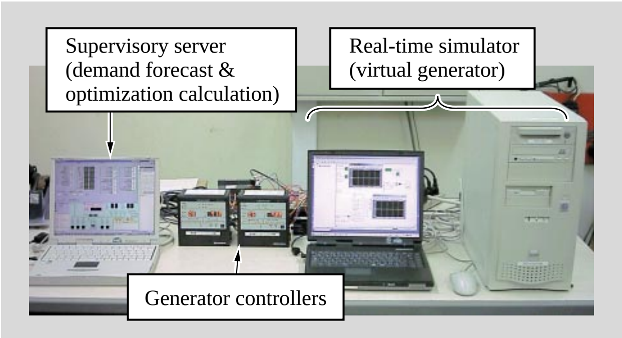

Fig. 5—Experimental Equipment of Optimal Operation System with Distributed Resources.
A real-time simulator imitates dynamos, a supervisory server forecasts demand and carries out the optimal operation, and a controller manages dynamo.

Demand-and-supply Adjustment System for Micro Grids

Research and development on micro grids has started for controlling the burden on the public power system by combining two or more alternative

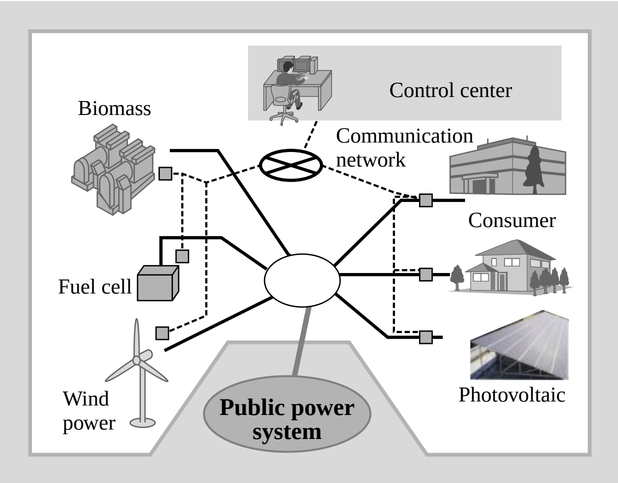

Fig. 6—Composition of Micro Grid.
The burden on a public power system is reduced, and alternative energy can be introduced by adjusting demand and supply within a grid using IT.

distributed resources and energy saving in a specific area and by adjusting the supply to the demand of an area. A demand-and-supply adjustment system for micro grids is being developed by combining the aforementioned optimal operation system and remote-control technology. An example of a micro grid is shown in Fig. 6. The system can minimize cost and reduce environmental burden.

CONCLUSIONS

A power quality analysis system with support function for maintaining power quality of power distribution systems was described. The functions included prior prediction of voltage changes by the influence of distributed resources, various loads, flicker, etc. They help to reduce unbalanced voltage.

In addition, the optimal operation technique of distributed resources using demand forecasting and optimization technologies and the control system for them were described.

ACKNOWLEDGMENTS

We would like to express our sincere gratitude to the members of The Tokyo Electric Power Co., Inc. for the expert guidance they provided in developing this power quality analysis system.

REFERENCES

(1) E. Muto et al. “Power Quality Analysis System (1):Basic Concept and Design,” Proceedings of the 12th Annual Conference of Power & Energy Society IEE of Japan, No.274 (2001).
(2) Y. Ohno et al., “Study on Optimal Operation of Distributed Resources Using the Predictive Control Based on Customer Data,” IEEJ National Convention, No.6-177 (2003) in Japanese.

ABOUT THE AUTHORS

Masahiro Watanabe
Joined Hitachi, Ltd. In 1991, and now works at the Energy and Environment Laboratory, the Advanced Research Laboratory. He is currently engaged in developing an analysis and control system for distribution systems. Mr. Watanabe is a member of The Institute of Electrical Engineers of Japan (IEEJ) and The Institute of Electrical and Electronics Engineers, Inc. (IEEE), and can be reached by e-mail at mwata@rd.hitachi.co.jp.

Yasunori Ono
Joined Hitachi, Ltd. in 1979, and now works at the T&D IT group at the T&D Systems Project, the Power & Industrial Systems R&D Laboratory. He is currently engaged in developing optimal operation systems for distributed resources. Mr. Ono is a member of IEEJ, and can be reached by e-mail at yasunori_oono@pis.hitachi.co.jp.

Tomoharu Nakamura
Joined Hitachi, Ltd. in 1978, and now works at the Power & Industrial Systems Division, the Power Systems. He is currently engaged in planning solutions for distribution systems. Mr. Nakamura is a member of IEEJ, and can be reached by e-mail at tomoharu_nakamura@pis.hitachi.co.jp.

Hidehiko Shimamura
Joined Hitachi, Ltd. In 1983, and now works at Kokubu Works, the Power Systems. He is currently engaged in developing a control system for distribution systems. Mr. Shimamura is a member of IEEJ, and can be reached by e-mail at hidehiko_shimamura@pis.hitachi.co.jp.