Introduction of Grid Control System for Power Distribution System

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1. Introduction

To maintain a reliable supply of electricity, measures are in place to mitigate voltage drops throughout distribution systems, including Load Ratio Control Transformers (LRTs)—transformers for power distribution installed at substations—and Step Voltage Regulators (SVRs) that compensate for voltage drops across distribution lines.

In recent years, however, distribution systems have been experiencing increased voltage fluctuations and reverse power flows over both short and long-period cycles as more PhotoVoltaics (PV) systems are connected to the power grid. Distribution systems are also being affected by complex voltage fluctuations on the transmission system side, making it difficult for current LRTs and SVRs to maintain the constantly fluctuating supply voltage of distribution system in the optimum range.

To address these challenges, Chubu Electric Power Grid Co., Inc. has been working on the development and installation of next-generation voltage regulators and distribution panel LR control units at distribution substations as on-site equipment. Mitsubishi Electric developed Grid Control System (GCS) as the voltage control system for controlling this on-site equipment(1). The method used to control voltage with GCS allows setting values to be updated in a timely manner to achieve more precise voltage control. This also provides a greater voltage control range at each SVR, which is anticipated to be effective in limiting the increase in the number of SVRs installed.

GCS is a system developed to help maintain the appropriate supply voltage of distribution systems, by not only determining the setting value for the following day for the on-site equipment based on linked data acquired from automated distribution systems and high-low voltage load curve control systems, but also enabling values to be set remotely in real-time if there are sudden fluctuations in voltage. This paper provides an outline of the GCS system.

2. Central Voltage Control by System

When voltage regulation was required in the past, the process involved using general-purpose spreadsheet software to manually calculate the setting values for LRTs and SVRs from the voltage profile of the setting value of the past year. Workers then visited sites once or twice a year to manually update the setting values based on the calculated data.

The introduction of this GCS means setting values can be calculated automatically by the system from voltage profiles and other data of the past seven days—setting values can be remotely updated automatically every day, instead of requiring workers to visit actual sites (Fig. 1).

This is the first time[*1] in Japan that central voltage control by a system has been applied(2) to all distribution lines, and has successfully achieved “visualization of system voltage” and “automatic calculation of setting values.”

*1 June 10, 2021 press release, Chubu Electric Power Grid Co., Inc.

3. GCS

3.1 Characteristics

The voltage control functions of GCS have the two following key characteristics.

(1) Batch processing: Function that automatically updates the setting value at a specific time every day

(2) Real-time processing: Function that constantly monitors the distribution system voltage, and automatically updates the setting value if deviation from the optimum voltage is detected

In general, batch processing (Fig. 2) creates the optimal setting values (standard voltage and dead zone width) beforehand and updates them daily. In the event that there are unexpected voltage fluctuations and there is deviation from the optimum voltage range, real-time processing (Fig. 3) is used for further updates.

In this way, GCS provides a 2-stage approach to maintaining optimum voltage with batch processing and real-time processing.

3.2 Functions

Functions fall into the main categories of system analysis, system calculations, equipment data management, and links with other systems, as described below.

(1) System analysis

System analysis performs system locking,

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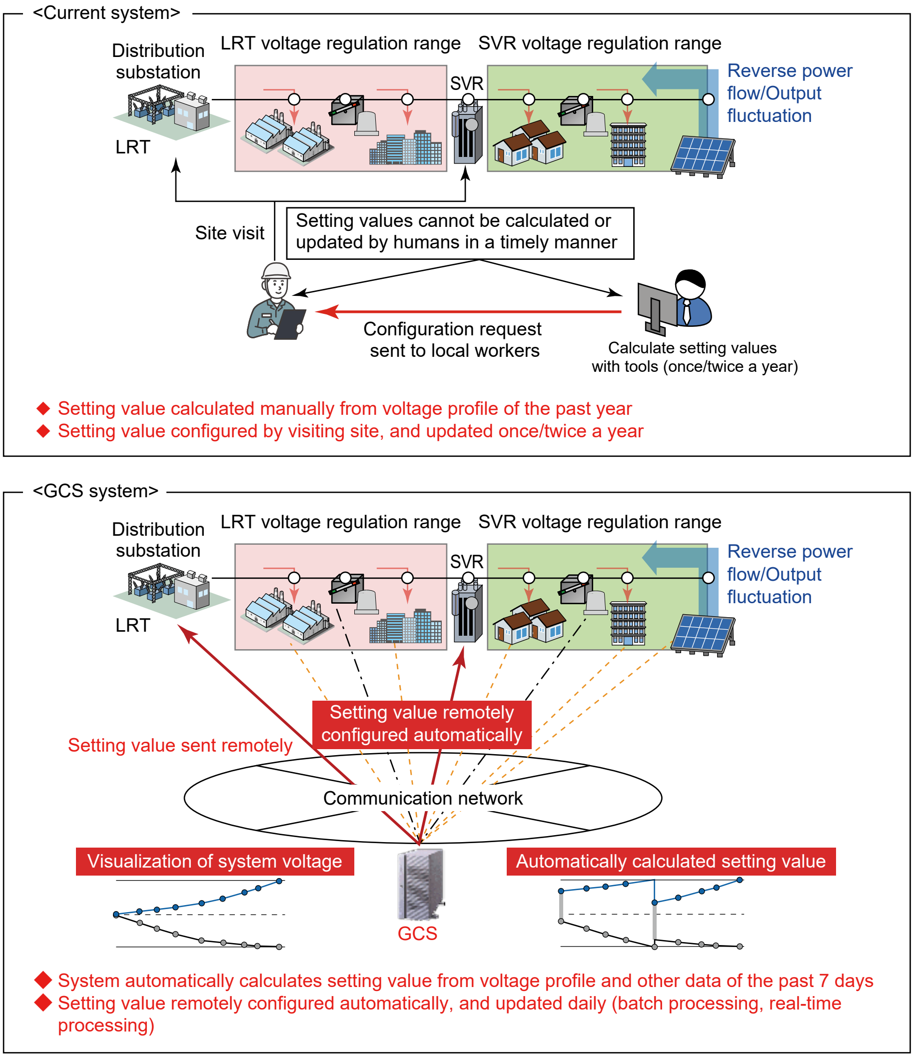

Fig. 1 Central voltage control by system

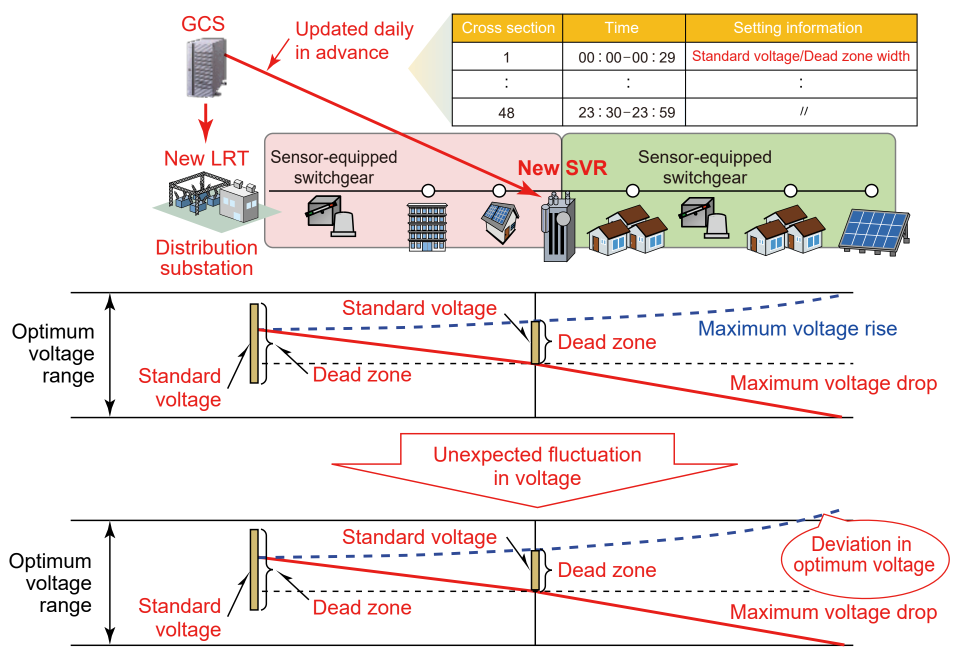

Fig. 2 Image of batch processing operation

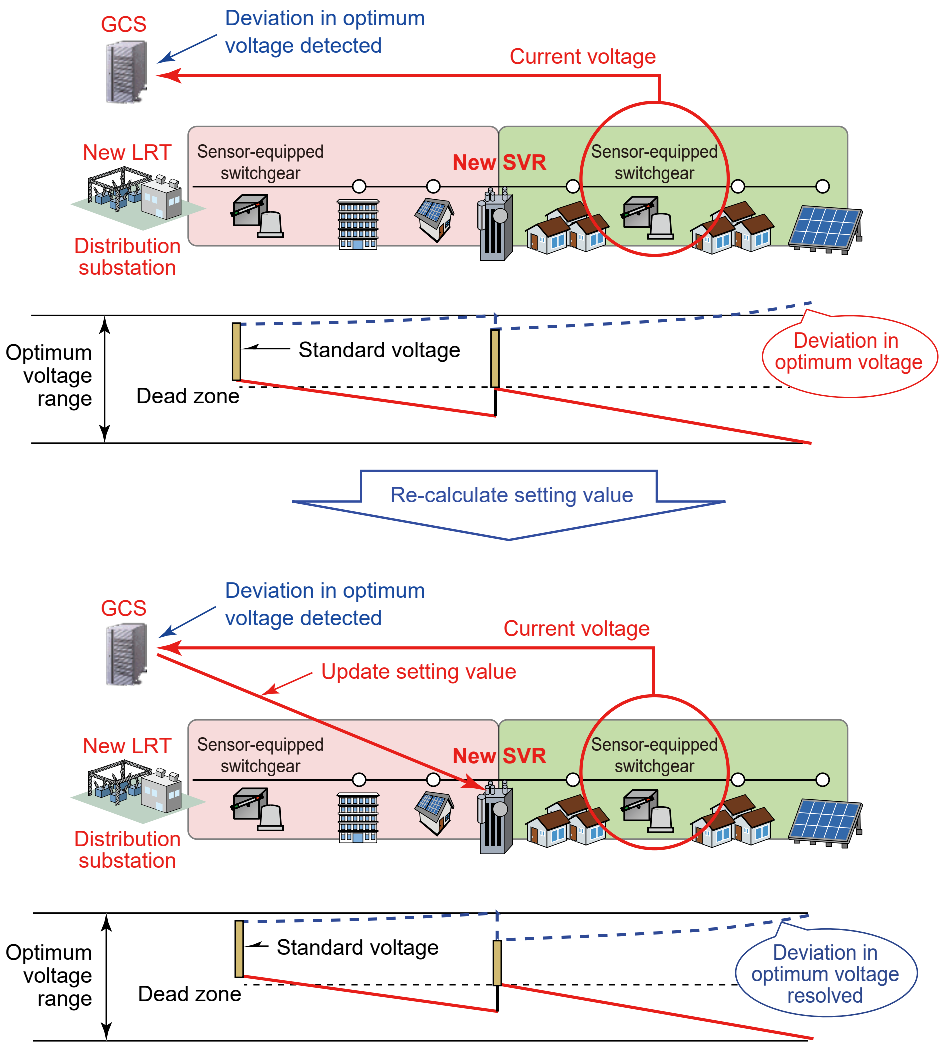

Fig. 3 Image of real-time processing operation

SuperVision (SV) analysis and TeleMeter (TM) analysis at 1-minute intervals. System locking acquires the current cross section of the SV (two-value data like on/off information of automatic switchgear) and TM (numerical information such as the current and voltage measured with on-site equipment) linked to the automated distribution system, and locks that as data for system analysis. With SV analysis, locked SV is assigned to the equipment data covered by GCS, while also acquiring details of the current system status. With TM analysis, locked TM is assigned to the equipment data covered by GCS, while also determining the validity of the TM value.

(2) System calculation

System calculation comprises ΔV calculation processing, real-time processing, batch processing, and local setting value calculation processing.

ΔV calculation processing is a function where the current distribution data is assigned to the equipment data covered by GCS and calculates the ΔV per segment between switchgears (amount of voltage rise or amount of voltage drop), while also calculating and storing the maximum voltage rise value and maximum voltage drop value within the voltage regulation range.

Batch processing estimates future voltage distribution and determines the LRT and SVR setting values to ensure that the it does not deviate from the optimum voltage range, based on past measurement data linked from high-low voltage load curve control systems. This calculates the setting value for equipment requiring calculation that is currently part of the distribution line for which ΔV is being created.

Real-time processing monitors the voltage deviation estimated from the amount of maximum voltage rise and amount of maximum drop between the voltage monitoring location and the end of the current system at 1-minute intervals. If ongoing voltage deviation is detected for a certain period of time, the setting value is calibrated so that the amount of deviation is kept within the LRT and SVR setting range. This operates after system analysis is performed to monitor the deviation in the measured voltage, and if a deviation continues to be detected, a new setting value is calculated to calibrate the LRT and SVR with that setting value.

Local setting value calculation processing calculates the future voltage distribution and determines the LRT and SVR local setting values to ensure that it does not deviate from the optimum voltage range, based on the annual maximum load and power generation data linked from high-low voltage load curve control systems. This calculates the setting value for equipment requiring calculation that is part of standard systems in distribution line for which ΔV is being created. The purpose of the local setting value is that it is used if the setting value for on-site equipment cannot be remotely updated automatically from GCS for some reason.

(3) Links with other systems

Links with other systems are performed for coordinating data with other systems such as automated distribution systems or high-low voltage load curve control systems, in order to collect data required for system analysis and system calculation.

This creates and manages a database required for system analysis and system calculation functions, based on equipment data information of distribution systems linked from automated distribution systems. GCS also updates equipment data with the same timing that equipment data is updated by the automated distribution system.

3.3 Data coordination with other systems

Central voltage control by the system is achieved by coordinating data between multiple systems (Fig. 4).

Visualization of the grid current distribution is required in order to calculate the setting value. First, current information of sensor-equipped switchgear is acquired by the automated distribution system to acquire details of the general current distribution per segment. The metered value of smart meters is also acquired from the smart meter control management system to acquire details of the amount of power generated from PV and other sources. This information is added up and the high-low voltage load curve control system calculates the amount of electrical energy per high-voltage customer and transformer. The measurement value of distribution substations and the measurement value of distribution system sensor-equipped switchgear are then used to calculate the current distribution throughout the entire distribution system. Current distribution comprises data for each 30-minute segment (48 cross sections per day), and the calculated current distribution is sent from the high-low voltage load curve control system to GCS. Batch processing is used by GCS to calculate the optimum setting value based on the linked current distribution. The calculated setting value is then sent twice a day to voltage regulators via the Automated distribution system.

GCS is constantly linking data with the automated distribution system. It monitors the optimum voltage deviation and calculates the setting value based on the measurement information of on-site equipment linked from the automated distribution system, and creates a database based on equipment information of linked distribution systems.

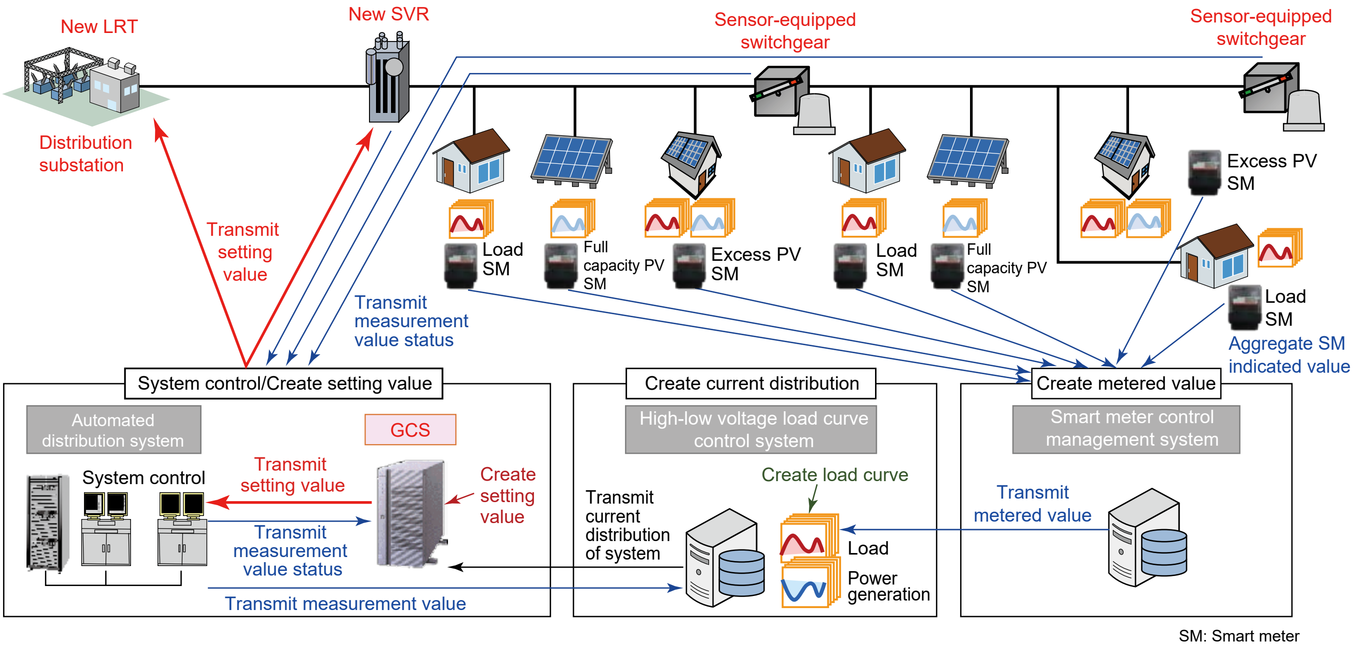

Fig. 4 Data coordination with other systems

3.4 Evaluation after starting system operation

In FY2021, results data stored within GCS was used for evaluation through actual data analysis in order to verify the effects of introducing GCS. The results data of 13 new SVRs that began operating with this system from June 2021 was the basis for the evaluation. A comparison of the number of tap operations before and after introducing the system indicated a reduction in the number of tap operations of all new SVRs covered by the evaluation. Analysis of data such as setting values updated with batch processing and real-time processing, measured voltage, occurrence of voltage deviations, and the results of real-time processing operations indicated that the optimum voltage is maintained by GCS using voltage control, with the expected effect being observed.

4. Conclusion

With the use of renewable energy sources like PV expected to increase further in the future, coupled with concerns about the impact that mass uptake of electric vehicles will have, the ability for distribution systems to maintain supply voltage within a suitable range is thought to become increasingly difficult. In addition to the detailed voltage control achieved with this GCS, systems to maintain and control optimum distribution voltage and power flow through the use of distributed energy resources (such as batteries and electric vehicles) connected to distribution systems will be required, and this is another field of development that is advancing. Mitsubishi Electric is working toward optimization of the entire system with the cooperative operation of centralized systems capable of large-scale control of distributed energy resources, and edge distributed terminals for smaller scale control[(3)]. Mitsubishi Electric will continue advancing technical development for further enhancement of system operation, with a view to increasing the introduction of distributed energy resources in the future.

References

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