Study Committee C4

Power system technical performance

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New Concept of Next-Generation Power System Reliability Control System based on RSDT (Real-time Smart Digital Twin)

Tomoki KAWAMURA, Yoshihiro KITAUCHI

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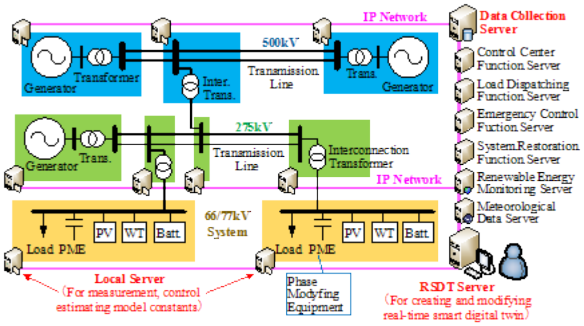
Introduction

- It is expected that grasping the power system condition will become more difficult due to the significant penetration of renewable energy sources.
- In order to realize the economical and reliable operation of power systems, it will be necessary to constantly monitor the condition of the system.
- By utilizing digital twins, there is a possibility that various problems associated with the large-scale introduction of renewable energy can be resolved.

Outline of proposed system

- The instantaneous value of each part of the power system and each component of the power equipment is collected on local servers.
- The local servers calculate the effective values from the instantaneous values and transfer them to the data collection server to grasp and monitor the current power equipment and system status.
- The specification information of the power equipment of this system and the measured values, etc. are described in a common information model (CIM)
- The communication protocol and the services of this system are based on IEC 61850
- When the state of a power system greatly changes due to a grid accident or the like, the model constants for the Power system Analysis Tools (CPAT) of the power system are checked and corrected by using the measured value at intervals of 0.01 seconds in order to maintain or improve the accuracy of the data.
- In this way, we can build a digital twin (RSDT) of the power system that can simulate past and present power system behavior in real time.



Concept of Next-Generation Power System Reliability Control System based on RSDT

Feature of proposed system

- A grasp of the state of each power equipment component from 500 kV to 66 kV, including renewable energy/load characteristics and improvement in the accuracy of model constants.
- High-precision power system status monitoring by state estimation methods based on real-time synchronization data.
- The realization of monitoring, operation, control, and restoration of an economical and reliable electric power system (including the construction of a support system that can confirm the effects and influences by the system operation immediately prior to operation).
- Sophistication of detection measures for power system faults.
- Early detection of power system status and abnormality/precursors to abnormality.
- Prediction of power system voltage and renewable energy outputs at the time of power system restoration, and support for power system operation at the same time.
- A real-time grasp of system constants and inertial constants that change constantly.
- Estimate the development of unforeseen events, consideration of measures, and construction of a support system.
- Construction, evaluation, and confirmation of a flexible operation method according to necessity, without being confined to the traditional forms of a load dispatching center.
- Construction of a flexible and efficient backup system for each server.
- Evaluation and confirmation of new operation methods on the computer.
- Automatic operation of the power system (automatic operation, control, and restoration).
- Education and training of system operation and cyber security exercises.

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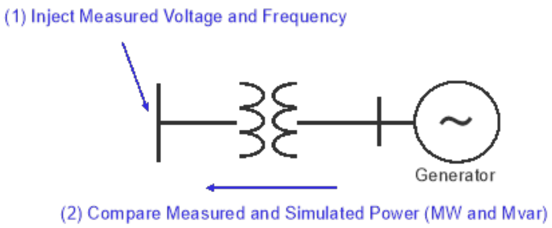
Elemental technology required in proposed system

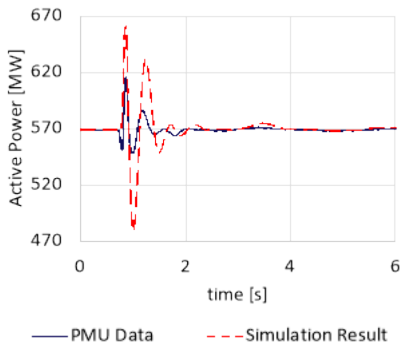
- To realize the system, it is necessary to study and verify various technologies in the future.
- There are three elements of the proposed system and the elemental technologies that are considered necessary to realize its functions: (1) data collection; (2) processing of the collected data, and; (3) utilization of the data for system operation.
- (1) In the proposed system, the use of devices such as a PMU (Phasor Measurement Unit) and a PDC (Phasor Data Concentrator), based on IEC 61850-90-5, is being considered for collecting data, but since it is necessary to handle a huge amount of information it is assumed that high performance will be required for device processing speed, the data transmission rate, storage capacity, etc.
- (2) The processing of the collected data and state estimation methods based on real-time time synchronization data will be important from the viewpoint of the sophistication of state estimation and measures against bad data.
- (3) As regards the collected and processed data for system operation, estimation/identification methods of model constants are used to construct a highly accurate Digital Twin (system model) of the power system.
- One promising method for estimating/identifying the model constants in the proposed system is PMU-based model verification.



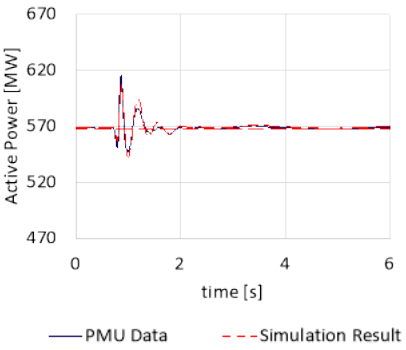
PMU-based Model Verification

Example of estimation/identification methods of model constants

- An example of model constants validation results from PMU-based model verification using test data of synchronous generators.
- From the result, it can be confirmed that the PMU data and the simulation results are more matched after calibration of the model constants.



(a)Before Model Constants Calibration



(b)After Model Constants Calibration

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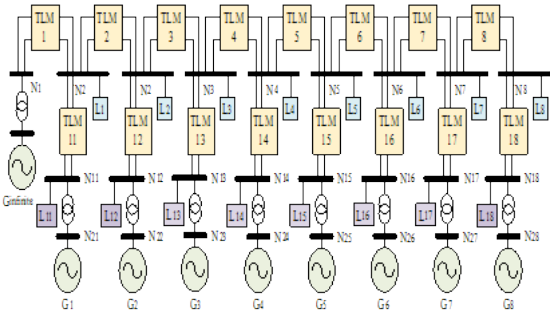
Demonstration equipment of proposed system

- We are developing an RSDT demonstration facility to verify the feasibility of the next-generation power system reliability control system and to tackle research issues toward its realization.
- The RSDT demonstration facility consists of two elements, an analog simulator and a communication system.

(1) RSDT Demonstration Analog Simulator

- It is an analog simulator with a rated voltage of 8V, consisting of 8 generators, 8 demand area system models that can simulate distributed power sources, 8 simple load models, and 17 bus lines.
- Infinite Bus Model (Ginfinite): 1 unit
- Power Station Model (G1 to G8): 8 units
- Bus model (N1-N8, N11-N18): 16 units
- Demand area system model (L1 to L8): 8 units
- Simple load model (L11 to L18): 8 units
- Fault point model: 1 unit
- Transmission line model (TLM1-8, TLM11-18): 18 sets
- Voltage/ current amplifier: 2 units
- Model management system: 1 set



Configuration diagram of the RSDT demonstration analog simulator

(2) RSDT Demonstration Communication System

- In this system, analog data from the generators, various loads, and instantaneous voltage/current of the bus of the RSDT demonstration analog simulator are collected by merging units (MUs), converted into digital data, and transmitted to intelligent electronic devices (IEDs).
- Based on the data from the MUs, IEDs calculate the effective values of the generators, various loads, and various amounts of each bus in 0.01 second increments and transmit them to the data collection server via a communication network.
- The components of the RSDT demonstration analog simulator are shown below.

(a) MU: Merging Unit

- A device that converts analog signals into digital signals and transmits data such as current and voltage to the IED.
- About 100 units in all the RSDT demonstration equipment

(b) IED (Intelligent Electronic Device)

- A device that realizes protection and monitoring control functions
- About 16 units in all the RSDT demonstration equipment

(c) Operation support system

- A device responsible for case management, system diagram creation, monitoring control by communication with the IED, etc.

(d) Communication network

- Communication network for interconnecting the above devices

Conclusion

- Discussed the new concept of a next-generation power system reliability control system based on RSDT.
- In the future, we plan to use the RSDT demonstration equipment to conduct research and development on the feasibility of a communication network for collecting and transmitting data every 0.01 seconds, as well as state estimation methods.