Project Research — Development of a Supply/Demand Infrastructure for Next-generation Electric Power

Integrated Operation and Control Techniques for Supply and Demand in Autonomous Demand Area Power Systems

Background and Objective

The penetration of distributed power generation (DG), in particular, photovoltaic (PV) power generation, is expected to be accelerated to cope with global environmental problems, etc. To achieve the secure operation of a utility grid and to maintain appropriate power quality with a large penetration of DG, the development of integrated operation and control techniques for supply and demand, i.e., DGs and demand appliances at the customer side, is expected to be effective in addition to the improved operation and control of an electricity distribution system.

The objective of the project is to develop an integrated operation and control methodology for supply and demand in Autonomous Demand Area Power Systems (ADAPSs) to achieve the smooth introduction and utilization of DG through renewable energy.

Main results

1 Development of a Comprehensive Analysis Tool for Power Distribution Systems

In order to cope with issues actualized in recent years, such as voltage rise in distribution lines caused by the interconnection of PVs and capacitors for power factor improvements (SC) of middle-voltage (MV) customers, a comprehensive analysis tool for a distribution system that supports clarifying the phenomenon and planning measures of various issues in a distribution system was developed. The tool can create a system circuit model easily by using a graphical user interface (GUI) on a general-purpose PC, in addition to using control equipment on the system side, such as a automatic voltage regulator (SVR) and reactive power compensation equipment (SVC), and the voltage control function of DG and the SC connection/disconnection function of the customer side can be imitated. Moreover, the time variation of the current and voltage of MV and LV systems can also be clarified (Fig. 1) (R11025).

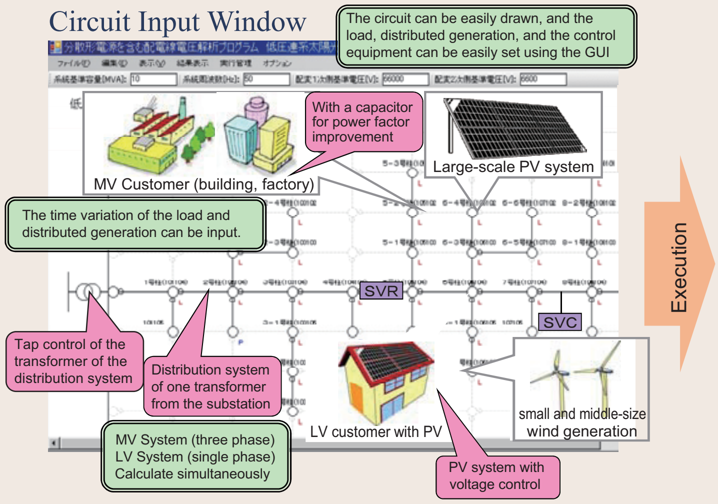
2 Evaluation of the Impact of the Large Penetration of Residential PV Systems with Three-phase Imbalances on the Voltage Management of Distribution Systems

For the cases in which large-capacity single-phase equipment such as PVs is largely connected, the impact on voltage imbalance between three phases was analyzed. The results show that voltage regulation by SVC controlling the three phases together becomes difficult. It is also clear that the number of customers, at which output power PV is restrained by a voltage control function, increases notably when the penetration rate exceeds 40% (Fig. 2) (R11026).

3 Development of an Operation Method for ADAPS for Utilizing the Surplus Power of an Entire Power System Due to PV Systems by Using a Heat Pump-type Water Heater and an Electric Energy Storage System

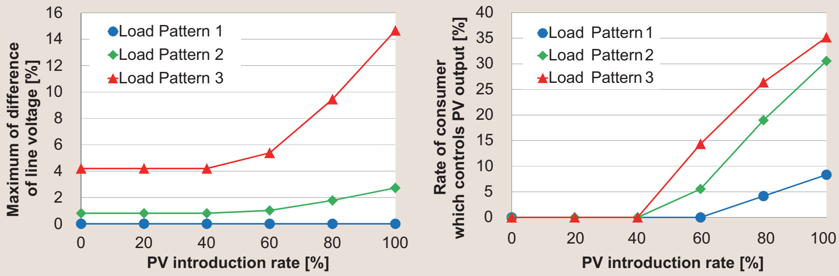
Suppressing PV generation is considered a measure for surplus power caused by the large penetration of PV systems and the shortage of storage capacity of an electric energy storage system. A determination method for the output power limit of a PV that minimizes the suppressed energy of the PV in an entire distribution system is thus proposed. The method applies the daytime operation of a heat pump-type water heater (HPWH) and maintains constant reverse power energy for each customer, by which the absorbed energy of the electric energy storage system is kept constant (Fig. 3, 4). Simulation results validate that the proposed method reduces the suppressed energy of PVs effectively (Fig. 5) (R11030).

Other reports: (R11035)



Calculation Results (Chart, Table)
- Line voltage, current, Power flow
- Output power of DG, power of Load
- Motion of control equipment
- Tap of transformer, SVR, SVC, SC
- Motion of PV control

Fig. 1: Circuit input window and calculation results data of the comprehensive analysis tool



(a) Maximum difference of line voltage

(b) Rate of the consumer that controls PV output

Load Pattern 1:
The PV connects with a three-phase balance in the entire feeder.

Load Pattern 2:
The PV connects with a three-phase imbalance at each section, maintaining three-phase balance in the entire feeder.

Load Pattern 3:
The PV connects with a three-phase imbalance in the entire feeder.

Fig. 2: State of three-phase imbalance versus the maximum difference of line voltage and the rate of the consumer controlling PV

Voltage unbalance and PV output power reduction increase according to the increase of the PV three-phase imbalanced connection rate.

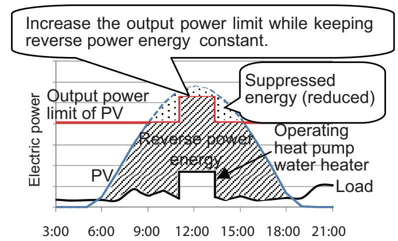


Fig. 3: Reduction of the suppressed energy of the PV by operating HPWHs

Next day's output power limit determination flow

① Set the PV output power limit without considering the daytime operation of the HPWHs and send this to customers.

② Collect the operation patterns of each customer scheduled based on the output power limit.

③ When the power consumption of the HPWH surpasses the suppressed power of the PV reducing reverse power energy, increase the output power limit to make the reduced reverse power energy to be zero.

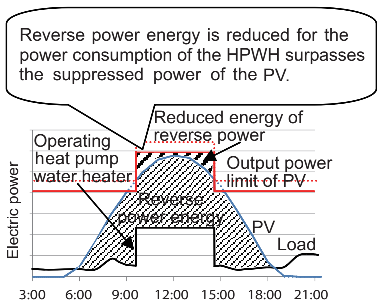
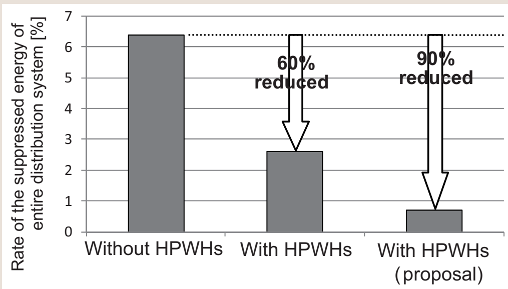


Fig. 4: Proposed determination method of PV output power limit for the next day



Simulation conditions
- Residential area (number of households: 1,284)
- Rated output power of the PV per a household: 3 kW
- PV output power limit: 75% (ratio to PV capacity)
- Heat pump water heater: Introduced into the household that has installed a PV.
- Season: Interim period (April–May)

– Rate of suppressed energy = (Suppressed energy)/(PV available power energy) × 100

Fig. 5: Reduction effect of the rate of the suppressed energy of the entire distribution system (average of suppressed days)

The suppressed energy of the PV is reduced effectively by introducing the proposed method and by operating HPWHs.