DEVELOPMENT OF COMPREHENSIVE ANALYSIS TOOL FOR DISTRIBUTION SYSTEM WITH DISTRIBUTED GENERATIONS AND CUSTOMER SYSTEM

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ABSTRACT

In recent years, distributed generations (DG) interconnected to power distribution system increase in order to cope with global environment problems in Japan. We are worried that it is difficult to control system voltage in power distribution system. We study about influence of DG to conventional operation and control of power distribution system and develop operation method by using control function of DG and distribution system. Moreover, we are worried that system voltage rise by capacitors of middle voltage customers to improve power factor (pf) and it is necessary to request capacity of capacitor become suitable and capacitors are open at light load. Under this circumstance, we cannot estimate this influence in detail because we don't have the analysis tool that can model voltage control by distribution system, power factor control by customer and voltage control function of DG. In this paper, we develop the analysis tool "CALDG" by using graphical user interface that can model voltage control by distribution system, pf control by customer and voltage control function of DGs.

INTRODUCTION

In recent years, distributed generations (DG) interconnected to power distribution system increase in order to cope with global environment problems in Japan. We are worried that it is difficult to control system voltage in power distribution system. We study about influence of DG to conventional operation and control of power distribution system and develop operation method by using control function of DG and distribution system. Moreover, we are worried that system voltage rise by capacitors of middle voltage customers to improve power factor (pf) and it is necessary to request capacity of capacitor become suitable and capacitors are open at light load. Under this circumstance, we cannot estimate this influence in detail because we don't have the analysis tool that can model voltage control by distribution system, power factor control by customer and voltage control function of DG. We develop the analysis tool "CALDG" by using graphical user interface that can model voltage control by distribution system, pf control by customer and voltage control function of DG. It is used by many electric power companies and electric power apparatus makers, and high evaluation has been obtained now.

COMPOSITION OF ANALYSIS TOOL

MV power distribution system

Fig.1 shows drawing window of MV power distribution system. We can draw MV power distribution system by using graphical user interface(GUI) on mesh (100*100), and set substation voltage control for distribution system, loads, generators (PV, WG, Co-gene etc.) and voltage control equipment (SVR[Step Voltage Regulator], SVC, STATCOM etc.).
The line impedance and distance of MV power distribution line can be set by GUI and line impedance database. The database is made based on the actual condition of use for each electric power company. There are two kinds of load. One is load which change in time and another is MV customer load with capacitors for improving pf (refer to Section 2.3 for details). The setting of load which changes in time is specified by csv files made by Microsoft Excel. There are two kinds of generator. One is generator which changes in time and another is PV system interconnected to LV line (refer to PV voltage control for details). The setting of generator which changes in time is specified by csv files. The settings of voltage control equipment are rating voltage, rating capacity, threshold value and timer value. All values are input by GUI.

LV power distribution system

Fig.2 shows setting window of LV power distribution system. We can set pole-mounted transformer, LV line (single phase, three lines) and 30 customers (load, PV etc.) in LV power distribution system.
The impedance of LV power distribution line and pole-mounted transformer can be set by GUI. The setting of LV load which changes in time is specified by csv files. The setting of generator (mainly photovoltaic) which changes in time is specified by csv files.

MV customer yard circuit

Fig.3 shows setting window of MV customer yard circuit. We can set MV/LV transformer, MV line, LV line, loads and capacitors with controller.
The impedance of MV/LV transformer, MV line and LV line can be set by GUI. The setting of MV and LV load which changes in time is specified by csv files. The

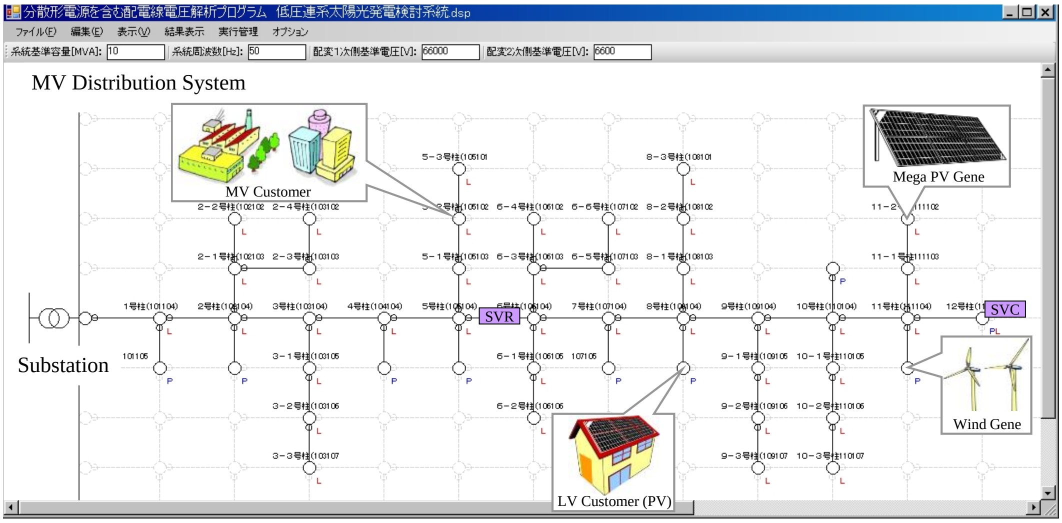


Fig.1 Drawing window of MV power distribution system

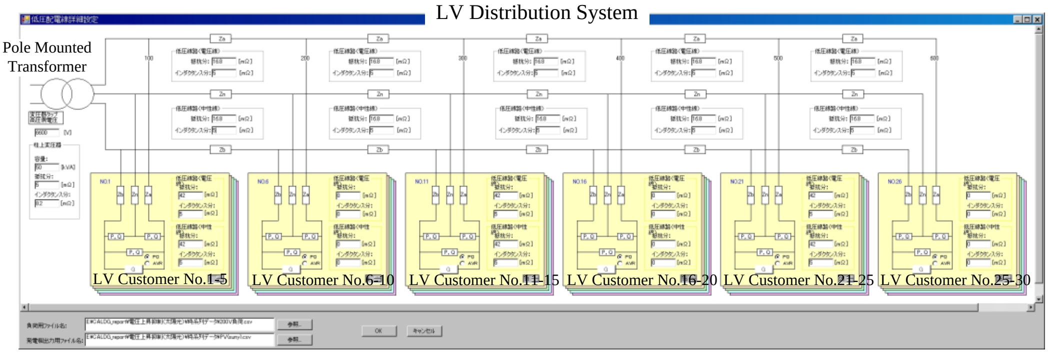


Fig.2 Setting window of LV power distribution system

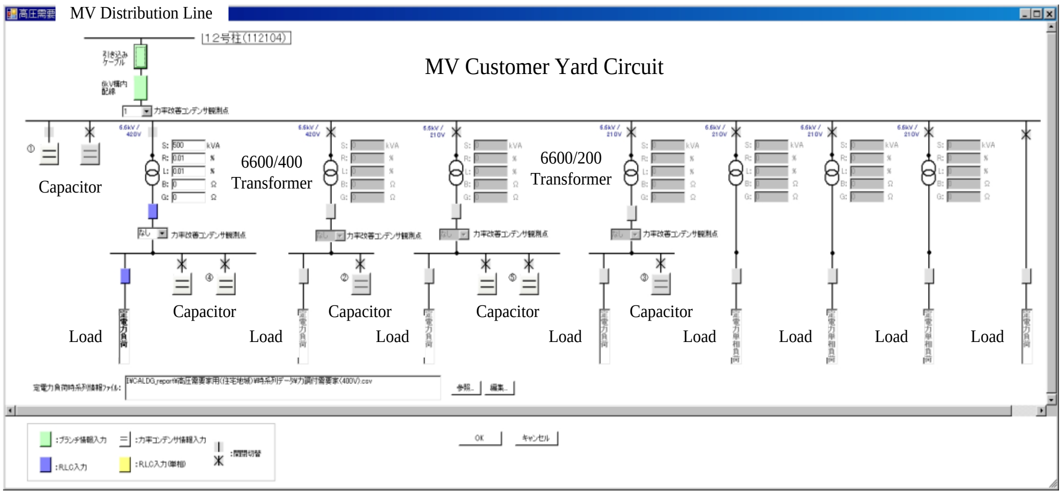


Fig.3 Setting window of MV customer yard circuit

settings of capacitors are capacity, reactor, loss and control method. There are four control method, always connecting capacitors, timer control, cyclic control and minimizing reactive power.

CONTROL FUNCTION

This chapter explains the main control functions built in the developed program. They are line drop compensator with substation transformer, cyclic control with capacitor for improving pf and PV voltage control.

Line drop compensator

Fig.4 shows relation between transformer current and target of secondary voltage of transformer in substation for distribution system. The target voltage is constant minimum voltage under minimum load current, and constant maximum voltage over maximum load current. In between minimum load current and maximum load current, transformer current and secondary voltage is proportional relations. The tap of transformer is changed according to the target voltage.

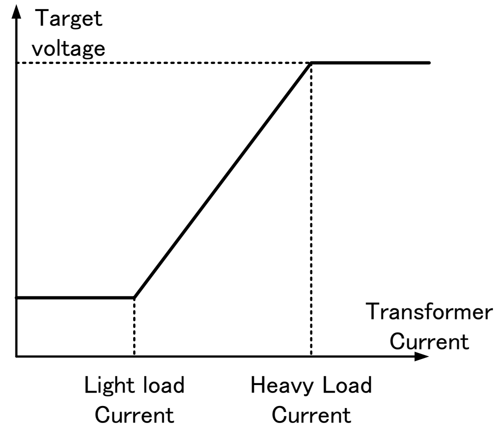
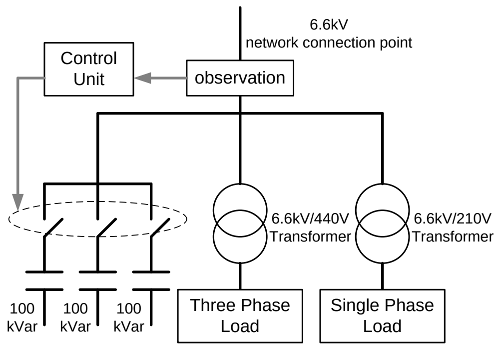


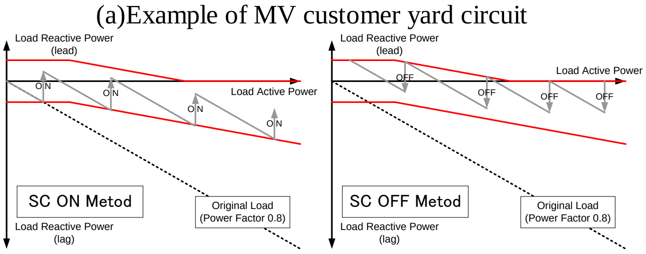
Fig.4 Method of line drop compensator

Cyclic control with capacitors

The Power factor control method by 6.6kV customers is shown in Fig.5. Original Load is lag (example PF=0.8) and the power factor is improved by switching capacitor (SC). SC is controlled between two red lines of target power factor (example PF=0.98). In fact, capacitors are connected or unconnected like gray arrows by observing the power factor at connecting point. Moreover, all SCs are unconnected if the load active power is very low. In Japan, there are few consumers which introduced such power factor control systems, and almost customers have always connected capacitors or adopted timer control.



(a)Example of MV customer yard circuit



(b)Control method of cyclic control

Fig.5 Method of capacitor control

PV voltage control

Fig.6 shows voltage control using active power and reactive power by standard PV power conditioning subsystem (PCS) in Japan. The PCS voltage controller control A-B-C-D in order. A is conditions generating normally, B is conditions increasing reactive power, C is conditions keeping PCS capacity by decreasing active power and increasing reactive power, D is keeping pf by decreasing active power and reactive power. In fact, control speed differs for every maker. Moreover, there are makers who omit reactive power control.

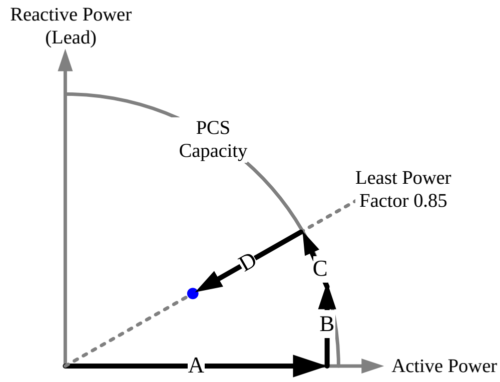


Fig.6 PV voltage control in Japan

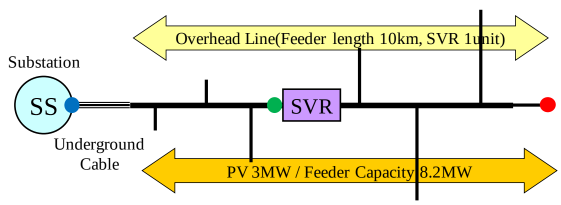
CALCULATION RESULTS

This chapter shows the main analysis results by the developed program. These results are SVR control, capacitor control and PV voltage control.

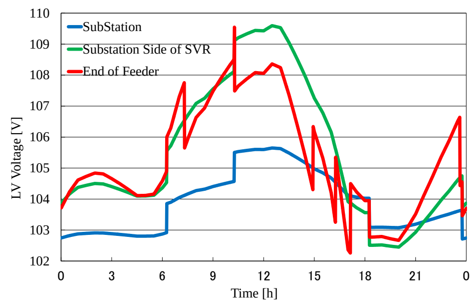
All analysis results were mostly in agreement with the experimental value or the instantaneous analysis result, and it checked that analysis accuracy is enough to calculate the voltage in power distribution system.

SVR control

Fig.7(a) shows power distribution model for calculation. The feeder length is 10km, and the feeder capacity is 8.2MW. PV systems are interconnected to the feeder equally, and the total capacity is 3MW. SVR is set at the middle point of the feeder. Fig.7(b) shows system voltage curve (of blue, green, red point) with SVR. These voltages can be controlled by the substation voltage control for the distribution system and the SVR control. But these voltages cannot be control under upper limit (107V at low voltage system [100V]) by conventional voltage control method.



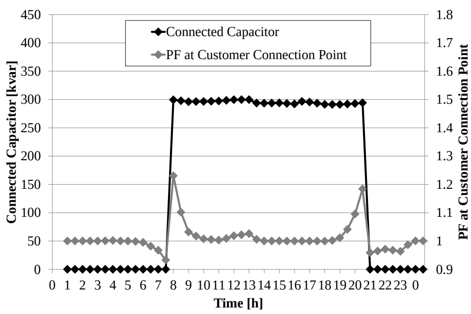
(a)Power distribution model for calculation



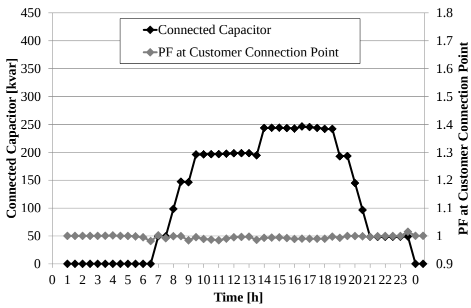
(b) Time variation of voltage in power distribution system
Fig.7 Calculation results of SVR control

Capacitor control

Fig.8(a) shows system voltage curve (black line) and pf (gray line) at customer connection point in the case of timer control. Fig.8(b) shows system voltage curve and pf in the case of cyclic control. The cyclic control is best, and maintains pf to 1 all day. But the cyclic control system is expensive and cannot be adopted as a result.



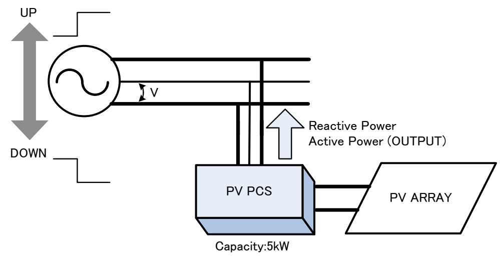
(a)Timer control



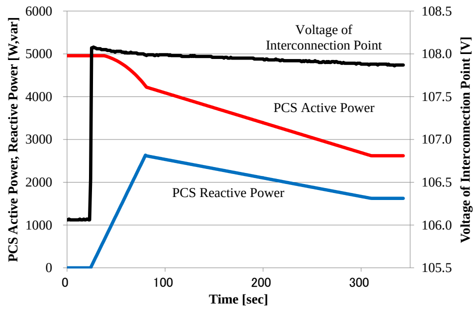
(b)Cyclic control
Fig.8 Calculation results of capacitor control

PV voltage control

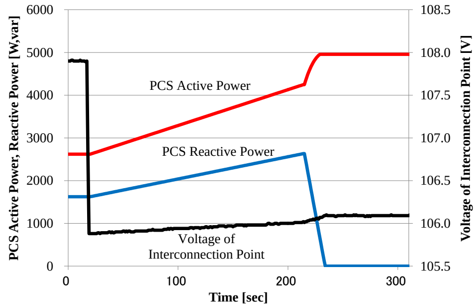
Fig.9(a) shows LV power distribution model for calculation. Fig9(b) shows PCS active power and reactive power in the case of rising system voltage. PCS output is controlled according to PV voltage control method (Fig6 A-B-C-D). Fig9(c) shows PCS active power and reactive power in the case of falling system voltage. PCS output is controlled according to PV voltage control method (Fig6 D-C-B-A). The system voltage is analysed by setup not changing so that the control of PCS becomes easy.



(a) LV power distribution model for calculation



(b)Calculation results in case of rising system voltage



(c) Calculation results in case of rising system voltage
Fig.9 Calculation results of PV voltage control

CONCLUSIONS

In conclusion, we can calculate comprehensively system voltage in power distribution system including substation voltage control, distribution line control (SVR,SVC, STATCOM etc.), load control (pf control by capacitors) and distributed power generation system control (PV, WG, Co-gene etc.) by using developed calculation program called “CALDG”.

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