DEVELOPMENT ON ESTIMATION METHOD OF OUTPUT OF PHOTOVOLTAIC POWER GENERATIONS FOR MICROGRIDS OPERATION

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ABSTRACT

Compared to the operation and control of the conventional electric power system, it is considered that the operation and control of microgrids are susceptible to the influence of load fluctuation and output fluctuation of renewable energy generations.
Considering the above influence, in order to operate, it is necessary to monitor the condition by installing sensors to measure voltage, current, and power flow in each part of the microgrids. However, since the power flow that passes through the sensors is the difference between the power flow due to the load and the power flow due to the power generations, even if this data is observed, it is not possible to estimate power flow due to only the power generations.
Therefore, in this research, from active and reactive power information of the sensors, active power / reactive power (A-R power) by load and A-R power by power generations are separated. As a result, we develop a method to estimate the amount of power generation at the time of measurement, and using sensor data in the actual distribution line, we verify the accuracy of the developed estimation method. The method is called vector decomposition method (VDM).
We verified the accuracy of the proposed method based on the sensor information collected in the actual distribution system. it was possible to show the effectiveness of the decomposition method.

INTRODUCTION

Compared to the operation and control of the conventional electric power system, it is considered that the operation and control of microgrids are susceptible to the influence of load fluctuation and output fluctuation of renewable energy generations.
Considering the above influence, in order to operate, it is necessary to monitor the condition by installing sensors to measure voltage, current, and power flow in each part of the microgrids. However, since the power flow that passes through the sensors is the difference between the power flow due to the load and the power flow due to the power generations, even if this data is observed, it is not possible to estimate power flow due to only the power generations.
Therefore, in this research, from active and reactive power information of the sensors, active power / reactive power (A-R power) by load and A-R power by power generations are separated. As a result, we develop a method to estimate the amount of power generation at the time of measurement, and using sensor data in the actual distribution line, we verify the accuracy of the developed estimation method. The method is called vector decomposition method (VDM).

SENSOR SYSTEM FOR DISTRIBUTION LINES IN JAPAN

Most distribution lines in Japan are overhead lines, and all necessary equipment is installed on the poles.
For this reason, the distribution line sensor is mainly built in the section switch and is installed on the poles (Fig.1).The data measured by the sensor is digitized at the slave station and sent to the business office of the electric power company via the communication line.
Communication lines are generally composed of metal wires, but in the case of utilizing the distribution line sensor for high function, it is necessary to constitute with an optical fiber.
Sensor systems measure both voltage and power flow at all times, and in addition to constant measurement, they are also measured at the time of accidents, and they are sometimes used to estimate the accident point and the cause of the accident.
In addition, 3 to 5 sensors are installed per distribution line in many cases. Generally, about 15 distribution lines are drawn out per substation. As a result, 45 to 75 sensors per substation are connected to the master station and data is collected at the business office.

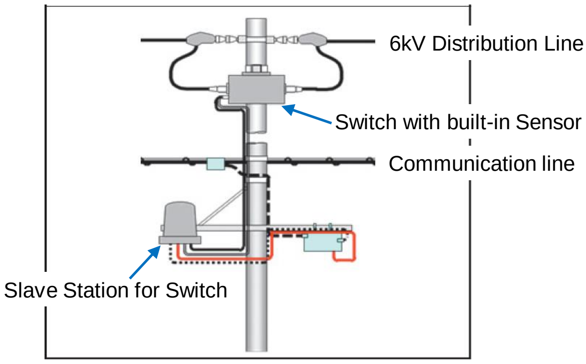

Fig.1 Sensor Installation Configuration

VECTOR DECOMPOSITION METHOD

Generally, when the power flow of the sensor is drawn on the A-R power plane, if the power factor of the load is constant, it is distributed in a straight line rising to the right. The intercept with the Q axis changes up and down depending on the input amount of the power factor improving capacitor. On the other hand, if PV is operated at a constant power factor, it is distributed in a straight line upward to the left, and the intercept is the origin (Fig.2).

From the data in Fig. 1, when the change amount at each measurement time is calculated and plotted on the plane of the change amount of the A-R power, the A-R power of the load and the PV are straight lines passing through the origin (Fig.3).

Here, the change amount of the A-R power at each measurement time is regarded as a vector, and it is decomposed in vector form into the change amount of the load and the change amount of the power generation output of PV using the relationship of Fig.3. By integrating this decomposition result for each duration time, the current PV power generation output is estimated (Fig.4).

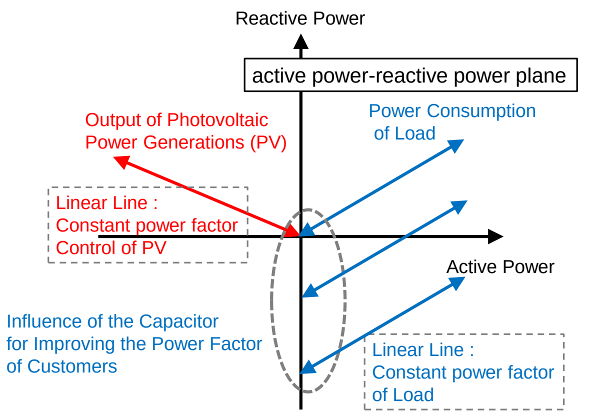

Fig.2 Active Power-Reactive Power Plane

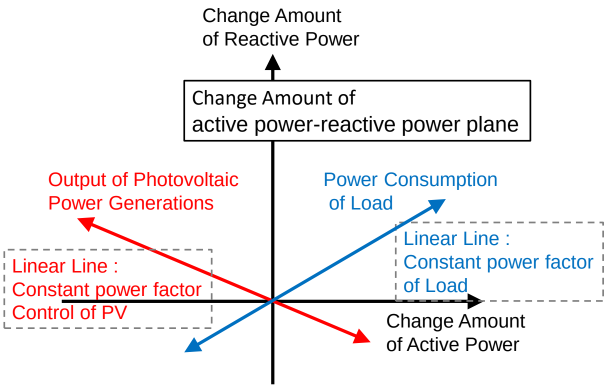

Fig.3 Change Amount of Active Power-Reactive Power Plane

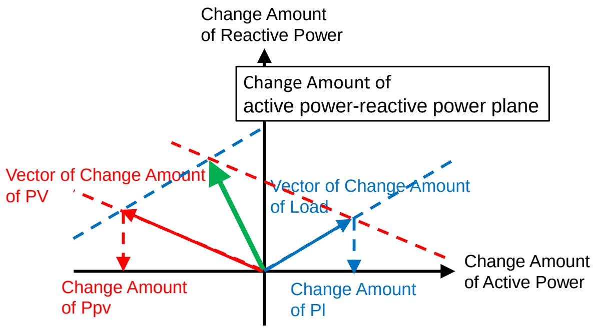

Fig.4 Concept of Vector Decomposition

The slope of the vector of the change amount of the load and the change amount of the power generation output of PV is assumed to be a constant value. We have also completed development of the method of finding this gradient. Based on the output curve of solar power generation on sunny days, it is possible to obtain the slope of each using the data of the past month or so. I would like to expect from the following papers.

VERIFICATION OF ACCURACY OF VDM IN ACTUAL DISTRIBUTION SYSTEM STYLES

We verified the accuracy of the proposed method based on the sensor information collected in the actual distribution system shown in Fig.5. In distribution power system in Japan, customers and PVs are interconnected to middle and low voltage classes line. This method can estimate regardless of voltage class.

Estimation results are shown in Fig.6 and Fig.7. The estimation accuracy was high in both cases of clear day and cloudy day.

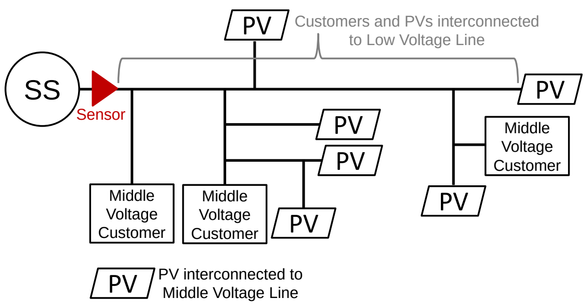

Fig.5 Actual Distribution System of Accuracy Verification

The output fluctuation on sunny days is slow and the output fluctuation on a cloudy day is steep. From the above results, it can be seen that VDM does not lower the estimation accuracy even if the output fluctuation is slow or steep. Strictly speaking, in fact, VDM tends to have higher estimation accuracy when the output fluctuation is steep. VDM treats the power generation output and load change amount at each measurement time as a vector and separates it, so the amount of change becomes larger when the output fluctuation is steep. This is because the accuracy of separation increases.

From the above results, it was possible to show the effectiveness of the estimation method.

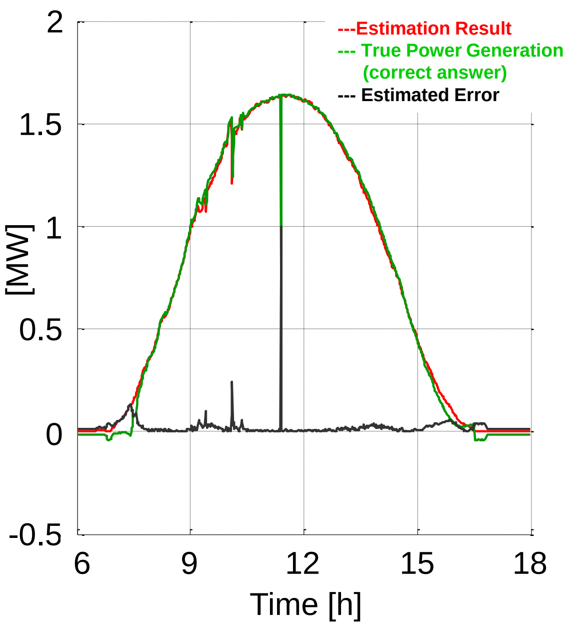

Fig.6 Estimated Result on Clear Day

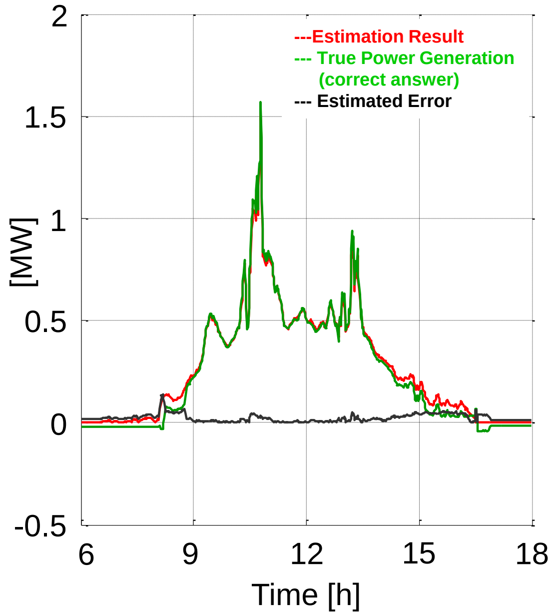

Fig.7 Estimated Result on Cloudy Day

INFLUENCE OF SENSOR MEASUREMENT INTERVAL ON ESTIMATION ACCURACY

Estimation accuracy when changing the interval of measurement time of the sensor was obtained, and the result is shown in Fig.8, Fig.9, Fig.10, Fig.11 and Table1. There is no significant change in the estimation accuracy from 1 minute interval to 10 minutes interval, but the estimation accuracy lowers if it exceeds 15 minutes interval.

In general, output fluctuation of photovoltaic power generation is faster than load fluctuation, in other words, fluctuation cycle is short. Therefore, the estimation accuracy depends on the speed (fluctuation cycle) of output fluctuation of photovoltaic power generation.

On the other hand, when calculating the cycle of output fluctuation of photovoltaic power generation, as shown in Fig.12, the fluctuation component is small until the 10-minute interval (600 seconds), but when the output fluctuation reaches the 15-minute interval (900 seconds) The component becomes large. From this fact, estimation accuracy is poor when the interval is longer than 15 minutes

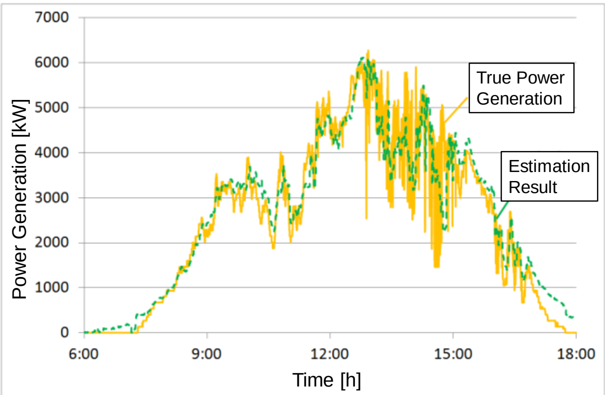

Fig.8 Estimated Result with measurement interval of 1 minute

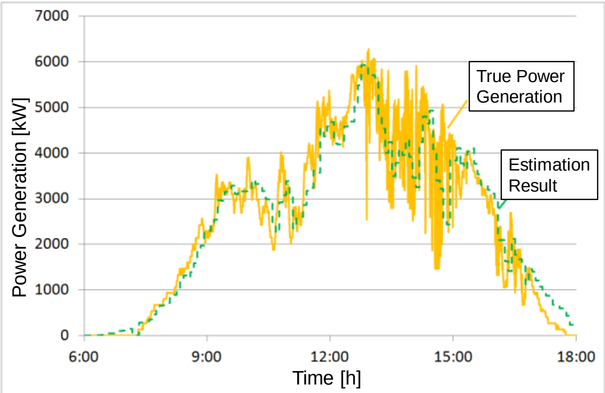

Fig.9 Estimated Result with measurement interval of 5 minutes

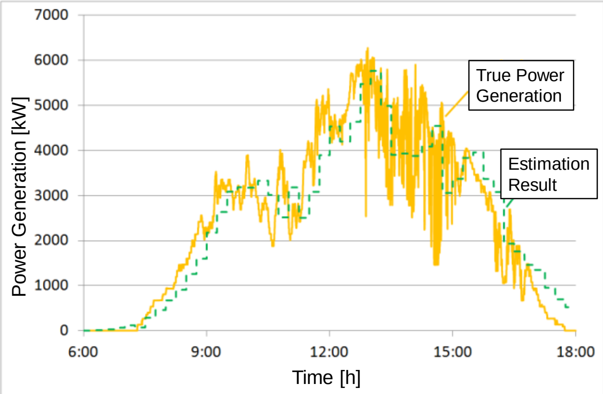

Fig.10 Estimated Result with measurement interval of 15 minutes

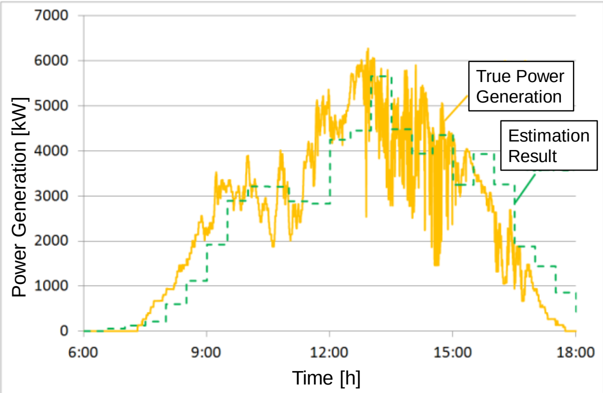

Fig.11 Estimated Result with measurement interval of 30 minutes

Table1 Mean error of each measurement interval

interval [min]	1	5	10	15	30
Mean error [%]	6	7	7	8	11

Average error per month

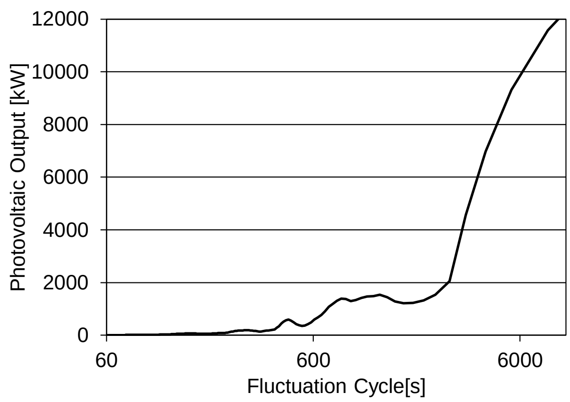

Fig.12 Components of each Fluctuation Cycle of Photovoltaic Power Generation Output

In recent years, distribution companies in Japan have gradually increased the number of switches equipped with sensor functions. However, in many sensor systems, the measurement interval is 15 to 30 minutes, so application of this estimation method is difficult. These sensor systems are installed to roughly grasp the tidal current and demand of distribution lines and are not used for the operation of distribution lines. In order to utilize it for operation of sophisticated distribution lines like this estimation method, it is necessary to enhance the function of the sensor system.

CONCLUSION

We develop a method (VDM) to estimate the amount of power generation at the time of measurement, and using sensor data in the actual distribution line, we verify the accuracy of the developed estimation method.
We verified the accuracy of the proposed method based on the sensor information collected in the actual distribution system. As a result of the accuracy verification of the method, it was confirmed that the average estimation error per month was 10% or less. It was possible to show the effectiveness of the decomposition method.
Finally, although it is a digression, we can estimate the output of photovoltaic power generation by attaching several sunshine meters to the distribution line. However, in sunny countries like Japan, even though solar radiation is hit, in the situation where snow is accumulating in the solar module, the amount of electricity generated can not be estimated with a solar irradiation meter.

REFERENCES

[1] Y.Nakayama, S.Uemura: "Development of photovoltaic power generation output estimation method using distribution system sensor information - Accuracy improvement of vector decomposition method -", *CRIEPI Report*, R16301 (2017) [in Japanese]

[2] J.Sakaguchi, S.Uemura "Development of Estimation Method of Photovoltaic Generation Output Using Power Flow Information of Section Sensor in Distribution System", *CRIEPI Report*, R14012 (2015) [in Japanese]