THE INTRODUCTION OF VOLTAGE STABILIZATION SYSTEM ACCORDING TO THE INCREASED DERs IN KOREA

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ABSTRACT

Due to the increased DGs (Distributed Generations) in the distribution system, there are so many problems, such as instability of power quality, increase of safety risk by islanding, difficulty in coordinating protection and so on. Especially, the problem of voltage rise in distribution power line is the biggest concern in KOREA. This paper introduces that the Monitoring and Control System of DGs which is being constructed for the voltage control and also the verification case of the system in field test.

Index Terms – DGs (Distributed Generations), PFC (Power Factor Control), DERMS (Distributed Energy Resources Management System)

Ⅰ. INTRODUCTION

The penetration of DGs, such as photovoltaic systems, wind turbines, ESS (Electric Storage System) and fuel cells, in electric power grids has been growing continuously. Although DGs have positive effects in terms of system reliability and power loss, they sometimes cause voltage control problems in power grids by generating power without regard to grid conditions [1]. In particular, the voltage may rise near the connection point of DGs in the distribution power system. The magnitude of voltage variation depends on the output of DGs which is the reverse current. As a result, this violates the regulated voltage range (V_{limit}^{max} or V_{limit}^{min}) of the distribution power system when the output power of DGs is large. In order to resolve this serious problem caused by the DGs, the system which is monitoring and controlling the voltage of the connection of DGs is absolutely necessary. The variation of D/L voltage, which depends on distance from substation, is illustrated in Fig. 1 [2]-[4].

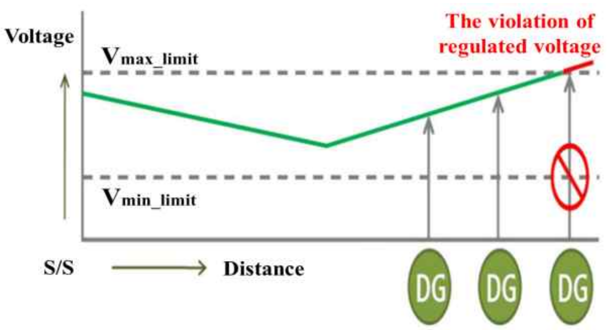

Fig. 1. The D/L voltage profile from S/S

Ⅱ. THE VOLTAGE STABILIZATION SYSTEM IN KOREA

A. THEORY

The voltage drop Δe across the line is approximated by the following equation [5] :

$$\boldsymbol{\Delta e = E_s - E_r = R \cdot P + X \cdot Q} \quad (1)$$

Where *R* and *X* is the line resistance and reactance, respectively, and *P* and *Q* is the active and reactive power exported from the DG toward power system. When the DG generates the active power toward power system, the voltage of PCC (Point of Common Coupling) rises. At this time, if the leading reactive power is inserted toward power system, the voltage of PCC further rises, but, if the lagging reactive power is inserted toward power system, the voltage of PCC falls. The voltage variation according to the active power and reactive power of DG is shown in Fig. 3. Therefore, it is power to control the voltage of PCC with PFC (Power Factor Control).
The equation (1) and Fig. 3 show that it is possible to control the voltage with PFC. Therefore, the PFC is applied to DERMS (Distributed Energy Resources Management System) of KOREA to control the voltage of DGs.

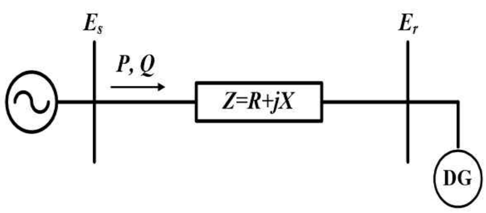

Fig. 2. The simple single-line diagram

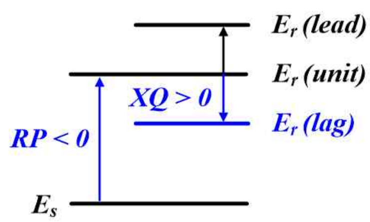

Fig. 3. The voltage variation according to P&Q from DG

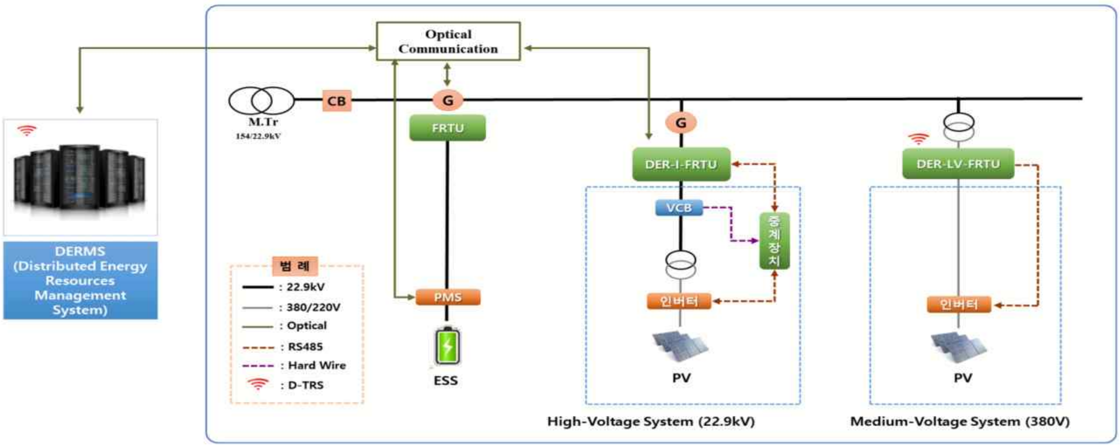

Fig. 4. The configuration of DERMS in KOREA

B. THE SYSTEM CONFIGURATION

In Korea, the DERMS is installed and operated in the distributed system. The configuration of DERMS, which is being constructed in KOREA, is shown in below Fig 4. DGs of the distributed power system include PV systems, wind turbines, ESS, and fuel cells. Especially, PV systems occupy most of the share. The configuration of DERMS consists of host system (Program Server, HMI, Log Server, FEP, etc.) and RTU (Remote Terminal Unit) which is installed in PCC of DGs. The RTUs, which control the reactive power of inverter, are divided into Medium-Voltage system and High-Voltage system.

Medium Voltage System (380V)

In Medium-Voltage system, devices (DER-LV-FRTU, Inverter, DG, etc.) are connected into the secondary of pole transformer. The detail configuration of Medium-Voltage system is illustrated in Fig. 5. The DER-LV-FRTU is measuring the three phase of voltage and current in real-time. As the output of DG increases, the DER-LV-FRTU controls the PFC (Lagging Reactive Power) of Inverter directly when the voltage of DG connection point violates the regulated value (V_{min}^{max}) and the FRTU send the alarm message to the host system. And also, the DERMS is monitoring the Power Quality (Sag, Swell, Interruption, etc.) of DGs. Therefore, this system can monitor the power quality as well as the voltage regulation function of the distributed power system according to the DGs. And DER-LV-FRTU can control maximum 3 DGs and 30 inverters simultaneously. The DER-LV-FRTU and inverter communicate the information every minute mutually and the information of communication are three phase voltages, three phase currents, active power, reactive power, power factor, and so on.

High Voltage System (22.9kV)

The detail configuration of High-Voltage system is illustrated in Fig. 6. In High-Voltage system, devices (DER-I-FRTU, DER-MID, Inverter, DG, etc.) are connected into switch gear. And DER-I-FRTU can control maximum 1 DGs and 10 inverters simultaneously In terms of functions, High-Voltage system is similar to the Medium-Voltage system except the install site and voltage level.

Ⅲ. THE RESULT OF FIELD TEST

A. THE OVERVIEW OF DEMOSTARTION

To verify the voltage regulation function of DERMS, the demonstration was conducted at the PCC of DGs. 2 DGs (198kW) and 2 inverters (200kW) are installed in the demonstration site. This demonstration site is the D/L where a number of DGs are connected and overvoltage occurs frequently. An overview of the demonstration site is shown in Table 1.

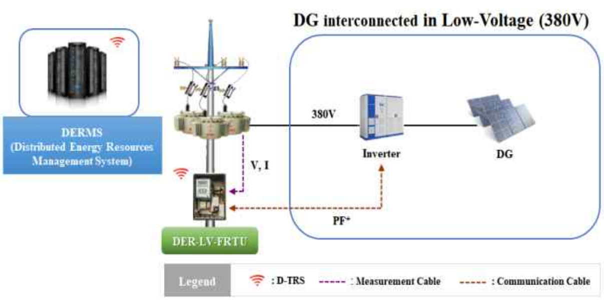

Fig. 5. The configuration of Medium-Voltage system

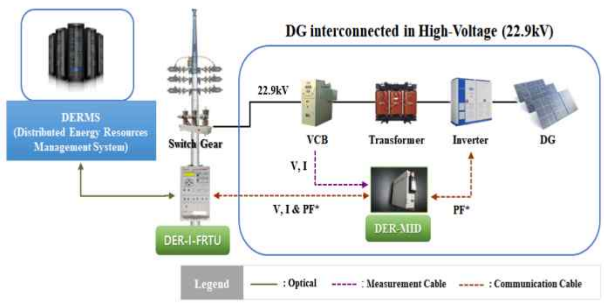

Fig. 6. The configuration of High-Voltage system

Table. 1. The information of demonstration site

Company	S/S	D/L	Capacity of PV	Capacity of Inverter
Soon-Ok PV	Jeong -Ju	Jeong -Eup	99kW	100kW x 1ea
Seong-Su PV			99kW	100kW x 1ea

There are three kinds of PFC algorithms, which are constant power factor control, constant voltage control, and voltage range control, applied to the RTU. Each algorithm and demonstration results are described below in detail.

B. MODE 1 (CONSTANT POWER FACTOR CONTROL)

Mode 1 is a function that the operator directly transmits the power factor (Set Point) to the inverter regardless of the current status of power system. The control range of power factor is from 0.9 (lagging) to 1.0 (unit). Generally, this operation mode is used when each DGs for the D/L are operated in the same PF.

The demonstration results(Active Power, Reactive Power, PF, PF_ref, and Voltage) for Mode 1 are shown in Fig. 7. The graph, which is stored in RTU, plots the points once a minute for 1 day (0~24h). The test was conducted for 1 hour from 14:00 to 15:00. To verity the Mode 1 function, the set point (lagging 0.9) of power factor is transmitted to the RTU remotely from host server. After that, the RTU transmits the PF command to the inverters of the DG (Fig. 7.2nd graph-PF_ref). The inverter generates the reactive power proportional to the current active power based on the received PF from RTU. At this time, the reactive power does not affect the active power because the active power and the reactive power can be controlled independently (Fig. 7.1st graph-Active & Reactive Power). Finally, the PCC Voltage drops from 0.962 to 0.951 (Fig. 7.3th graph-PCC Voltage).

C. MODE 2 (CONSTANT VOLTAGE CONTROL)

Mode 2 is a function that the operator transmits the desired voltage (Set Point) to RTU. Generally, this operation mode is used when each DGs for the D/L are operated in the same voltage.

The demonstration results(Active Power, Reactive Power, PF, PF_ref, and Voltage) for Mode 2 are shown in Fig. 8. The graph, which is stored in RTU, plots the points once a minute for 1 day (0~24h). The test was conducted for 30 minutes from 16:00 to 16:30. To verity the Mode 2 function, the set point (0.95pu) of voltage is transmitted to the RTU remotely from host server. At this time, RTU calculates the power factor by comparing the current grid voltage with the voltage (Set Point). After that, the RTU transmits the PF command to the inverters of the DG (Fig. 8.2nd graph-PF_ref). The inverter generates the reactive power proportional to the current active power based on the received PF from RTU. Finally, the PCC Voltage drops from 0.961 to 0.953 (Fig. 8.3th graph-PCC Voltage).

Mode	Name	Control Signal (FRTU→Inverter)	Note
Mode 1	Constant Power Factor Control	PF*	PF* = 0.9 (lagging)

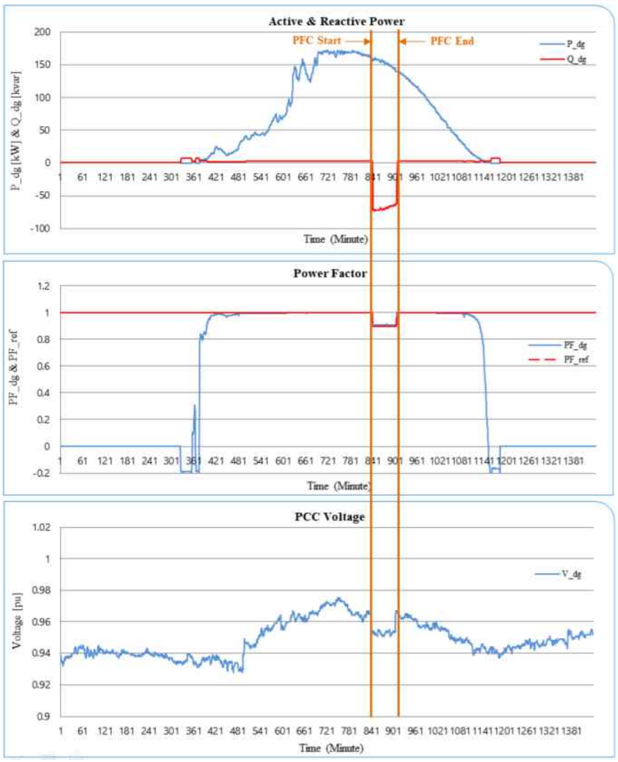

Fig. 7. The results of Mode1 demonstration

Mode	Name	Control Signal (FRTU→Inverter)	Note
Mode 2	Constant Voltage Control	PF*	V* = 0.95 (pu)

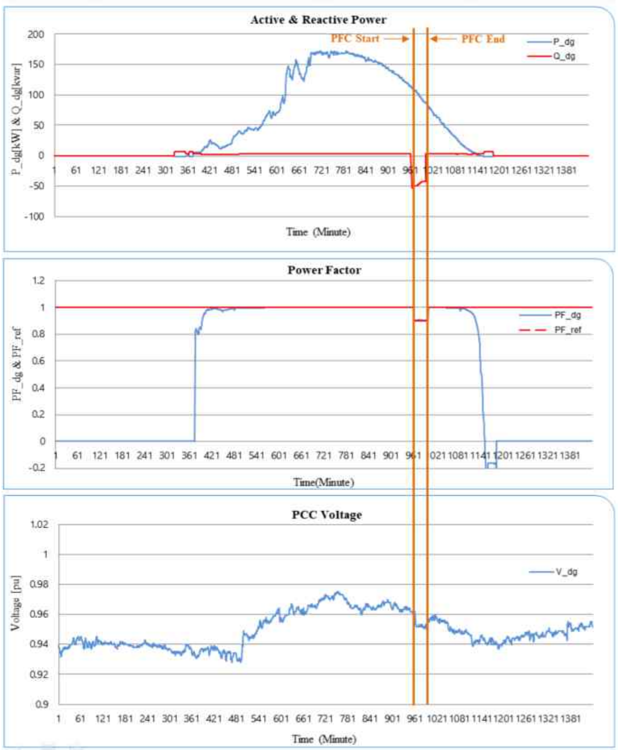

Fig. 8. The results of Mode 2 demonstration

Mode	Name	Control Signal (FRTU→Inverter)	Note
Mode 3	Voltage Range Control	PF*	V* = 1.02 (pu)

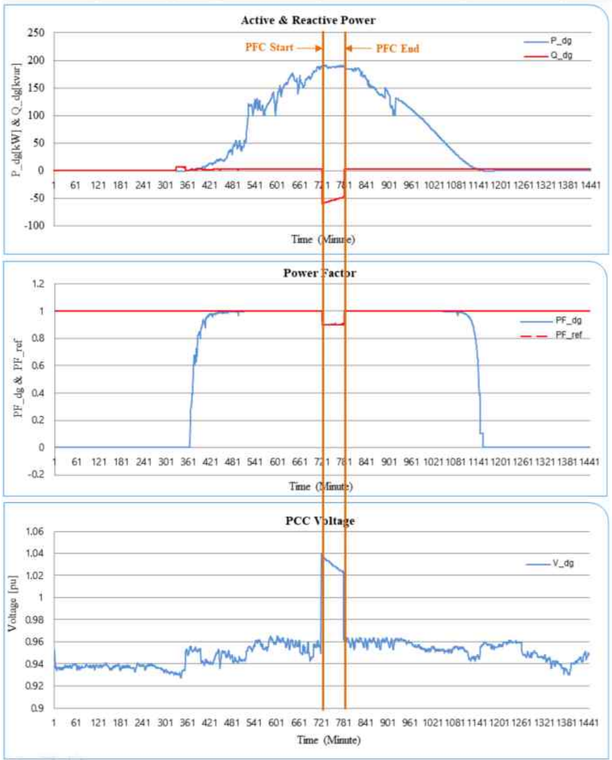

Fig. 9. The results of Mode 3 demonstration

D. MODE 3 (VOLTAGE RANGE CONTROL)

Mode 3 is a function that the operator transmits the desired range of voltage (Set Point) to RTU. Generally, this operation mode is used when each DGs for the D/L are operated within the voltage range (V_{limit}^{max} or V_{limit}^{min}). When the grid voltage is within the specified voltage range (Set Point), PFC is not performed (PF : Unit)
The demonstration results(Active Power, Reactive Power, PF, PF_ref, and Voltage) for Mode 3 are shown in Fig. 9. The graph, which is stored in RTU, plots the points once a minute for 1 day (0~24h). The test was conducted for 1 hour from 12:00 to 13:00. To verity the Mode 3 function, the set point (V_{limit}^{max} : 0.975 pu & V_{limit}^{min} : 1.02 pu) of voltage is transmitted to the RTU remotely from host server. The set point of voltage range is according to the Korea guideline, "KEPCO Standard for Interconnecting Distributed Resources with Electric Power Systems" At this time, RTU calculates the power factor by com-paring the current grid voltage with the voltage (Set Point). After that, the RTU transmits the PF command to the inverters of the DG (Fig. 9.2nd graph-PF_ref). The inverter generates the reactive power proportional to the current active power based on the received PF from RTU. Finally, the PCC Voltage drops from 1.04 to 1.02 (Fig. 9.3th graph-PCC Voltage). Since the grid voltage can not be arbitrarily adjusted at this test, the PT ratio of RTU was corrected and the test was conducted.

Ⅳ. CONLCUTION

In this paper, DERMS was introduced to resolve the voltage problem in the distributed power system due to the increase of DGs in Korea. And also, it is described the DERMS, the strategy of voltage stabilization. The performance of PFCs, which are Mode1 (Constant Power Factor Control), Mode2 (Constant Voltage Control), and Mode3 (Voltage Range Control), are verified in field demonstration. This system can manage the DGs efficiently and also is expected to contribute to the expansion for DGs in the future.

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