Hybrid Control System for Managing Voltage and Reactive Power in the JEJU Power System

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Abstract – This paper proposes a hybrid voltage controller based on a hierarchical control structure for implementation in the Jeju power system. The hybrid voltage controller utilizes the coordination of various reactive power devices such as generators, switched shunt devices and LTC to regulate the pilot voltage of an area or zone. The reactive power source can be classified into two groups based on action characteristics, namely continuous and discrete. The controller, which regulates the pilot bus voltage, reflects these characteristics in the coordination of the two types of reactive power source. However, the continuous type source like generators is a more important source than the discrete type for an emergency state such as a voltage collapse, thereby requiring a more reactive power reserve of the continuous type to be utilized in the coordination in order to regulate the pilot bus voltage. Results show that the hybrid controller, when compared to conventional methods, has a considerable improvement in performance when adopted to control the pilot bus voltage of the Jeju island system.

Keywords: voltage/reactive power control, hybrid control, hierarchical control, optimal control, pilot bus, sensitivity matrix, cost function

1. Introduction

It is becoming increasingly difficult to regulate the voltage of modern power systems owing to their increased size and complexity. Consequently, maintaining a desired voltage profile has become a more important issue from the voltage stability point of view. Recently, many countries have experienced several wide area black-outs caused by voltage instability due to an imbalance between the reactive power supply and demand. Hence, optimal voltage and reactive power control is a problem of great interest to all power system operators.

The Jeju power system is an island system connected to the mainland system by HVDC lines. The HVDC lines supply active power of approximately 150MW to Jeju from the mainland. The HVDC lines in Jeju, which is current-based and operates in frequency mode, absorb reactive power proportional to the active power flow thereby creating a critical situation to balance reactive power when a generator in Jeju shuts down. In the case Jeju, to supply 1 MW, the HVDC lines require about 0.7 MVar [1]. Fig. 2 shows the relation of active power and reactive power in the HVDC lines of the Jeju system, making the Jeju system more severe from a voltage point of view. Fig. 1 shows the structure of the Jeju power system with a two-circuit HVDC line from HEANAM to JEJU.

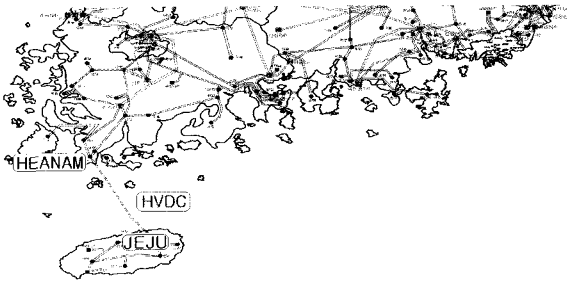

Fig. 1. The structure of Jeju Power System[1]

Various voltage control algorithms have been proposed in much of the recent research in this area [2]-[17]. The secondary voltage regulation (SVR) based on the hierarchical control system has been implemented in European countries for automatic voltage regulation [2]-[10]. The hierarchical system is organized in a three level structure: PVR (Primary Voltage Regulation), SVR and TVR (Tertiary Voltage Regulation). PVR controls the terminal voltage of the generator by AVR (Automatic Voltage Regulator) in the generation level. SVR, which is based on the pilot point concept, controls the pilot bus voltage by given generators in a control area of the transmission network divided into control regions by electrical distance. However, as modern systems become more meshed and heavily loaded, coupling exists between zones. In addition, it does not consider the important effect of other reactive power resources such as switched shunt capacitors/reactors, etc., and the coordination of the various reactive power sources in real-time. Another approach to control the voltage is an optimal power flow (OPF) managing the generators' real and reactive power outputs, transformer taps and shunt capacitors/reactors switching based on a mathematical algorithm

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Received : May 12, 2009; Accepted : July 24, 2009

[11] [12]. However, owing to the increase in complexity of modern power systems, the OPF is becoming more time consuming and in certain cases unsolvable. Thus, it is difficult to implement on-line feed-back control.

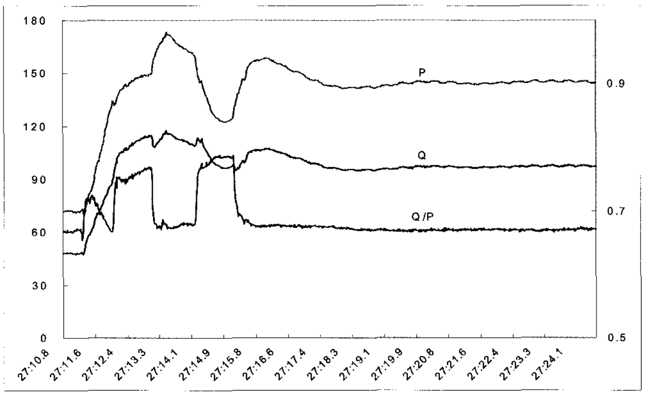

Fig. 2. The relation between PHVDC and QHVDC in the HVDC system [1]

The on-line voltage control is reported in [13]-[17]. In [13] and [14], a generation–based control to regulate the voltage profile using full SCADA information is proposed. It can only deal with a steady state power system because the SCADA information is updated every few minutes. When a system is in an emergency state such as a voltage drop, it cannot control the power system. In [15] and [16], a slow voltage controller using discrete type control devices such as ULTCs and switched shunt capacitors/reactors is presented. This scheme is also based on a steady-state power system. The controller acts on the SCADA measurements and selects discrete devices having the lowest cost to maintain the voltage profile. The algorithm in [16] has been implemented in the Bonneville Power Administration (BPA) system by National System Research Inc. (NSR) since August 2001. However, the generators, which are in a large number in the power system, are the key devices to regulate voltage profile especially in an emergency state. Thus the voltage controller needs to coordinate between the continuous type and a discrete one. In [17], a hybrid on-line slow voltage control scheme to closely monitor and control the steady state voltage for a large power system is proposed. Similarly, the controller can also not act in an emergency state because it uses the SCADA information as mentioned above.

This paper presents a hybrid control system using continuous type and discrete type for on-line and real-time voltage feedback control in the Jeju power system. The control system regulates a pilot bus voltage for the system while optimizing the reactive power reserve. The hybrid control system consists of two parts: the first is called the CVC (Continuous Voltage Controller) and controls the generators in order to maintain the voltage profile, and the second, the DVC (Discrete Voltage Controller), controls the discrete reactive sources to regulate the reactive power of generators. The regulated reactive power is calculated by optimal reactive power flow (ORPF). The CVC controls the generators by RPD (Reactive Power Dispatcher) by assigning a reactive power output to a generator, and stabilizes the power system by controlling the reactive power reserve. The last part of the paper presents the simulation results which show that the hybrid control system shows a considerable improvement in performance to regulate the desired voltage profile and reactive power reserve of the 2006 Jeju power system.

2. Control Scheme of Hybrid Control System

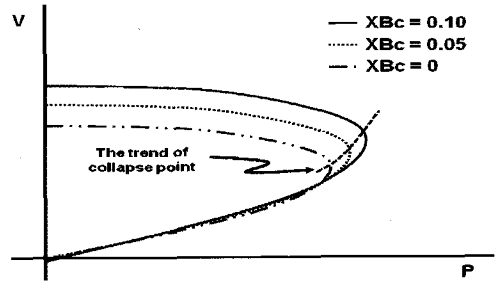

Fig. 3. PV curves for various compensation levels [19]

Shunt compensation using capacitor banks can increase the maximum transfer limit of real power [18] [19]. The power system becomes less stable when it is close to its collapse point. Fig. 3 illustrates a situation where more shunt compensation has to be added in order to keep the voltage within stable limits as the load power increases [19]. The figure also illustrates that the power system can collapse even in normal operating voltage levels due to over-compensation. It is necessary to consider generators as a major voltage control device for a more secure operation. A hybrid controller is proposed here to provide a solution for the voltage problem by coordinating continuous devices and discrete devices.

Fig. 4 presents the structure of the hybrid control system proposed in this paper. The system has three operating parts: In the first part, called the SPC (Set Point Controller), the power system including the pilot points is monitored. The pilot points can be chosen in such a way that its voltage may represent the voltage variations in the power system [8]. In addition, the reference voltage of the pilot bus using optimal power flow (OPF) is calculated. The SPC can also calculate that the power system should have a reactive power reserve to make the power system stable. In the second part, the system tries to regulate the pilot bus voltage with the reference from the SPC by generator control. It is shown in the figure as “Run CVC”. The CVC produces the control signals of the generation reactive power level (Q%) by using the PI control. The generated signals are sent to the RPD by a communication system where the Q% is compared with the present reactive power and the reference of the generator terminal voltage being adjusted using I control. In each generator, an AVR (Automatic Voltage Regulator) controls the generator terminal voltage which would cause the generator’s reactive power reserve to change. This reactive power reserve of the controlled generators is monitored by the control system. In the third part, when the reactive power reserve does not meet the reference, the system will run the DVC to control the reactive power reserve as shown by “Run DVC” in the figure. The DVC using discrete type devices in the power system can control the reactive power reserve while the CVC is running. When the DVC sends an on/off signal to the substation where the discrete type control devices are installed, it will change the pilot bus voltage and cause a difference between the reference and the pilot bus. The difference will then control the generator reactive power by CVC. Finally, the hybrid control system regulates the voltage of the power system and adjusts the reactive power reserve of generators to a certain required reference. In addition, the DVC controller should not be operated if the CVC controller does not move to a steady state, which is the state when the output signal of the CVC is within a certain limit. This can avoid the hunting problem which can arise between the CVC and DVC. The algorithm details of the three steps are presented in the following sections.

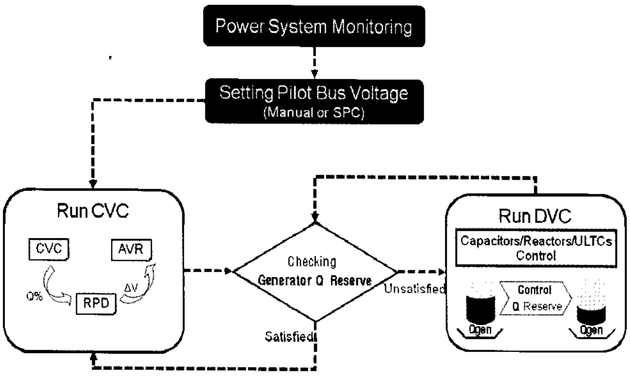

Fig. 4. Structure of Hybrid Control System

3. Network modeling

3.1 Linearized Equations of Power System

According to the generally accepted Stott’s simplifications, the linearized power system equations are described as follows:

$$[\Delta Q] = -[B][\Delta V] \qquad (1)$$

where

$\Delta Q = \left[\Delta Q_1, \Delta Q_2, \Delta Q_3, \cdots, \Delta Q_N\right]^T$, vector of reactive power changes;

$\Delta V = \left[\Delta V_1, \Delta V_2, \Delta V_3, \cdots, \Delta V_N\right]^T$, vector of bus voltage changes;

B, N by N matrix, symmetric matrix of the subsceptances of the power system in p.u.;

N is the total number of buses.

The matrix B represents the sensitivity of the injected reactive powers with respect to the voltages.

To distinguish the buses in the power system into the generation buses and the load buses, Equation (1) can be rewritten as follows:

$$\begin{bmatrix} \Delta Q_{GN} \\ \Delta Q_{LN} \end{bmatrix} = -\begin{bmatrix} B_{GGN} & B_{GLN} \\ B_{LGN} & B_{LLN} \end{bmatrix} \begin{bmatrix} \Delta V_{GN} \\ \Delta V_{LN} \end{bmatrix} \qquad (2)$$

where

GN is the number of generation buses;

LN is the number of load buses.

B_{GGN}, B_{GLN}, B_{LGN}, B_{LLN} which are the sub-matrices of B are defined as GN by GN, GN by LN, LN by GN, LN by LN respectively. From these equations, the sensitivity between voltages and injected reactive powers can be obtained. Substituting ΔV_{LN}, it is expressed as follows:

$$\Delta V_{LN} = -B_{LLN}^{-1} \cdot \Delta Q_{LN} - B_{LLN}^{-1} \cdot B_{LGN} \cdot \Delta V_{GN} \qquad (3)$$

If the generators’ voltages are considered to be constant ($\Delta V_{GN} = 0$), $-B_{LLN}^{-1}$ is the sensitivity matrix of the voltages of the load buses with respect to the injected reactive powers. The sensitivity matrix when defined as X_S, the equation can be rewritten as follows:

$$\Delta V_{LN} = X_S \cdot \Delta Q_{LN} \qquad (4)$$

In the sensitivity matrix, the diagonal terms signify how robust the bus is. A small value in the diagonal terms means that the bus is insensitive to a change in the injected reactive power. Therefore, the bus having the smallest value in the diagonal terms is the most robust in the power system. The off-diagonal terms represent the electrical distance between the buses.

From Equation (2) and (3), we can obtain Equation (5).

$$\begin{aligned} \Delta Q_{GN} &= \left[-B_{GGN} + B_{GLN} B_{LLN}^{-1} B_{LGN}\right] \cdot \Delta V_{GN} \\ &+ \left[B_{GLN} B_{LLN}^{-1}\right] \cdot \Delta Q_{LN} \end{aligned} \qquad (5)$$

Using Equations (3) and (5), the equations of the voltage variations with respect to the injected reactive powers are as follows:

$$\begin{aligned} \Delta V_{LN} &= -C_{LGN} \cdot \Delta Q_{GN} - C_{LLN} \cdot \Delta Q_{LN} \\ \Delta V_{GN} &= -C_{GGN} \cdot \Delta Q_{GN} - [C_{LGN}]^T \cdot \Delta Q_{LN} \end{aligned} \qquad (6)$$

where,

$$C_{GGN} = [B_{GGN} - B_{GLN} B_{LLN}^{-1} B_{LGN}]^{-1}$$
$$C_{LGN} = -B_{LLN}^{-1} B_{LGN} \cdot C_{GGN}$$
$$C_{LLN} = B_{LLN}^{-1} - C_{LGN} \cdot B_{GLN} \cdot B_{LLN}^{-1}$$

C_{GGN}, C_{LGN}, C_{LLN} are defined as GN by GN, LN by GN, LN by LN respectively.

If the variations of the injected reactive power of load buses are considered constant ($\Delta Q_{LN} = 0$), C_{LGN} is the sensitivity matrix of the voltages of the load buses with respect to the injected reactive powers of the generator buses. The sub-matrix can be used to select the control generators.

3.2 Selection of pilot buses and control generators

Pilot buses should be selected so that the effect due to the voltage deviations for all the load buses, due to random variations in all loads, is minimal in a steady-state [6]. The pilot buses should comply with the following two requirements:

- The voltage at the pilot bus must reflect the voltage level in the entire control area.
- The pilot buses are strong in the reactive power point of view, i.e., have sufficient reactive power resources, so that the pilot buses should not be changed due to any disturbances.

In addition, in the sensitivity matrix expressed as C_{iGN}, the control generators are selected by the descending order of the coefficient. The large value means that the generator bus is closer to the pilot bus and these generators are more efficient to regulate the pilot bus voltage.

4. CVC (Continuous Voltage Controller) Algorithm

From the control point of view, the CVC results in a multi-level control problem. The control strategy in the CVC consists of two parts. The first part follows a proportional-integral (PI) structure.

$$\begin{aligned} \dot{e}_r(t) &= V_{P\_REF}(t) - V_P(t) \\ Q_G\%(t) &= K_{PC}\cdot \dot{e}_r(t) + \int K_{IC}\,\dot{e}_r(t)dt \end{aligned} \tag{7}$$

where,

$V_P(t)$ represents the voltage of pilot bus at time t

$V_{P\_REF}(t)$ is the voltage reference at time t derived from the tertiary controller or operator,

$Q_G\%(t)$ is the reactive power to be generated in each RPD (Reactive Power Dispatcher),

K_{PC}, K_{IC} are proportional and integral gain respectively in the CVC.

In this control, the reactive power levels should be generated in each RPD and sent to the RPD controller. The reactive power levels are calculated by PI control using the difference between the pilot bus voltage and reference value. K_{PC} and K_{IC} can be chosen using the sensitivity matrix of the pilot bus and the control generators. These coefficients must also consider the time constants in order to clearly establish the hierarchical characteristics. The control signals need to avoid a negative effect by overlapping with the other controls in the power system like AVRs. In this paper, the time constants are assumed so that AVR (ms) < RPD (5sec) < CVC (50sec). In addition, $Q_G\%(t)$ have a limit block corresponding to the generators' available capability.

The second part follows the integral (I) structure called RPD (Reactive Power Dispatcher).

$$\begin{aligned} \dot{e}_q(t) &= Q_{G\_REF}(t) - Q_G(t) \\ Q_{G\_REF}(t) &= Q_G\%(t)\cdot Q_{G\_MIN/MAX}(t) \\ \Delta V_G(t) &= \int K_{IR}\,\dot{e}_q(t)dt \end{aligned} \tag{8}$$

where,

$Q_G(t)$ represents the reactive power of each generator at time t,

$Q_{G\_REF}(t)$ is the reactive power reference at time t calculated from equation (7),

$Q_G\%(t)$ is the reactive power to be generated from CVC,

$Q_{G\_MIN/MAX}(t)$ is the reactive power upper and lower limit.

K_{IR} is the integral gain in RPD.

The RPD controllers produce a control signal to regulate the reactive power outputs on their own generator and send the signal to the AVR to change the reference voltage of the terminal at each generator. Using $Q_G\%(t)$ from the CVC controller, the reactive power that should be generated is calculated. The calculated reactive power is compared with the generating reactive power and the difference adjusts the reference voltage of the AVR by I control. K_{IR}, integral gain, is calculated taking into consideration the time constant of the RPD and the reactance of the step up transformer of each generator.

The main idea of the CVC is that the generators should deliver reactive power based on their own reactive power reserve in order to have a voltage stability margin. In steady-state, the reactive power in the controlled generators can be proportionally increased or decreased according to each generator's available capability, ensuring the power system's stability by distributing the reactive power reserve at each bus.

5. DVC (Discrete Voltage Controller) Algorithm

The objective of the DVC is to acquire the reactive power reserve of generators by regulating the pilot bus voltage by CVC. The generators should be maintained with the reactive power reserve from the voltage stability point of view.

The DVC algorithm selects the discrete control devices by integer programming. The formulation of integer programming is written as follows:

Objective function

$$Minimize : \sum_{i=1}^{m}\left[|s_i|\cdot C_{swi} + \sum_{j=1}^{g} w_j Pq\left(Q_{i,j}\right) + \sum_{k=1}^{n} Pv\left(V_{i,k}\right)\right]$$
$$s.t.: \sum_{i=1}^{m}\left[|s_i|\right] \le N_{sw} \qquad (9)$$
$$s_i \in -1, 0, +1$$

In the formulation, s_i represents the switching type: -1 for switching out, 0 for no switching, +1 for switching in. C_{swi} denotes the cost of the i_{th} control device under switching action type s_i, which can be reflected in the control strategy of system operators. $Pq\left(Q_{i,j}\right)$ and $Pv\left(V_{i,k}\right)$ are the penalty cost of the j_{th} generator reactive power and the k_{th} bus voltage under i_{th} control action, as shown in Figs. 5(a) and 5(b), respectively. $w_{i,j}$ represents the weight factor of the generator's reactive power with respect to the control device, which is calculated by the sensitivity matrix as mentioned in the previous section.

m, N_{sw}, g and n are the number of buses equipped with discrete control devices, the number of feasible control devices, the number of control generators, and the number of load buses, respectively. From the objective function (9), the DVC algorithm can select the optimal discrete control devices to minimize switching within the reactive power reserve and the voltage limits. The procedure for selecting discrete control devices is shown as follows (also see Fig. 6):

Step 1) Read the power system data from SCADA/EMS.

Step 2) Run the power flow calculation to check the reactive power reserve.

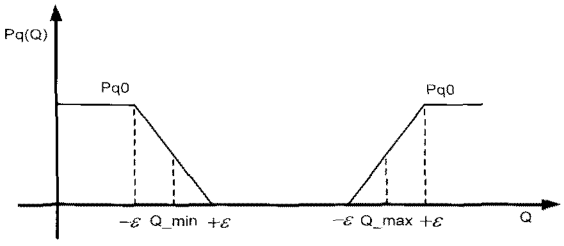

Fig. 5.(a) The reactive power penalty function

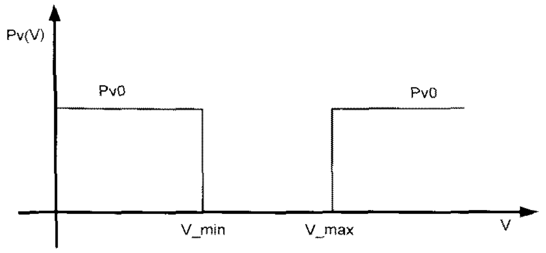

Fig. 5.(b) The voltage penalty function

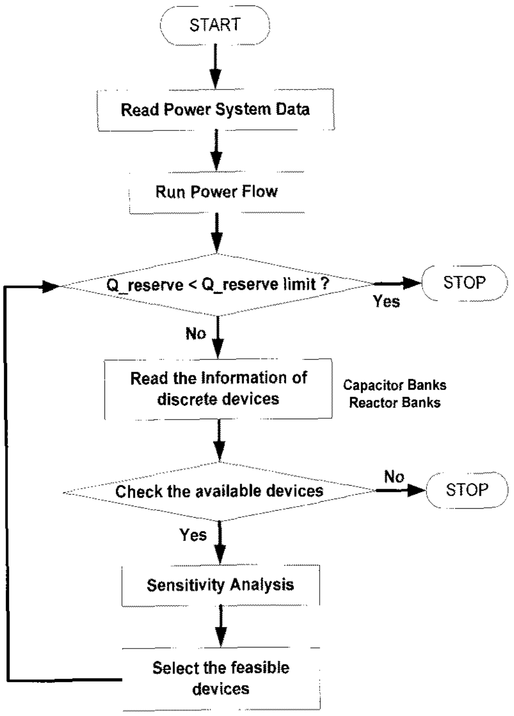

Fig. 6. Flow chart of DVC algorithm

Step 3) Compare the reactive power reserve, which is to be regulated in the system, with the reference reserve. If there is a violation of the reactive power reserve, proceed to the next step and if there is no violation, stop the algorithm.

Step 4) Read the information data of all discrete control devices.

Step 5) Check whether there are available discrete devices or not. If there are discrete devices, the controller will be moved to the next step, but if not, it will be stopped.

Step 6) Calculate the sensitivity with respect to the discrete devices and the reactive power of generators to determine the weight factor, $w_{i,j}$ as mentioned above.

Step 7) Select the feasible devices by integer programming and then return to step 3.

6. SPC (Set Point Controller) Algorithm

As mentioned in the CVC Algorithm section, the CVC can regulate the pilot bus voltage by controlling the generators. Therefore the CVC needs a target voltage of the pilot bus for regulation. The SPC is an algorithm to calculate the reference voltage of the pilot bus using Optimal Reactive Power Flow (ORPF). The ORPF is as follows:

- Objective Function

$$\min P_{loss} = \sum_{i=1}^{n}\left[V_i^2 G_{ij} + V_j^2 G_{ij} - 2V_iV_jG_{ij}\cos(\delta_i - \delta_j)\right] \qquad (10)$$

- Constraint Functions
  - ✓ System equations

$$P_{Gi} - P_{Li} = V_i \sum_j V_j V_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) \quad (11a)$$

$$Q_{Gi} - Q_{Li} = V_i \sum_j V_j V_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) \quad (11b)$$

✓ Load bus voltage constraint

$$V_{\min} \le V_L \le V_{\max} \quad (12)$$

✓ Generator bus voltage constraint

$$V_{\min} \le V_G \le V_{\max} \quad (13)$$

✓ Active and reactive power constraint

$$P_{G\min} \le P_G \le P_{G\max} \quad (14a)$$

$$Q_{G\min} \le Q_G \le Q_{G\max} \quad (14b)$$

where

P_{loss} loss of active power

V_i, V_j magnitude of bus voltage at from bus and to bus, respectively

G_{ij} line conductance

δ_i, δ_j angle of bus voltage at from bus and to bus, respectively

θ_{ij} angle of line impedance

n the number of buses

The SPC utilizes the optimization technique which applies the NIPM (Nonlinear Interior Point Method) to minimize the active power of transmission lines as Equation (10). Through the minimization of active power loss, the controller can control the power system economically in a normal state. In addition, managing the reactive power reserve of the generator by hybrid control of the CVC and DVC can make the power system stable in an abnormal state. Operational limits, which is the restriction of a bus voltage (0.95p.u ~ 1.05p.u) and a generator's active and reactive power can be specified as inequality constraints (12, 13, 14a and 14b) whereas the power flow equations (11a and 11b) are specified as equality constraints. To control the reactive power sources, the restriction of the active power of generators is only applied to the slack bus while the others are fixed.

7. Simulation Results for Jeju Power system

This section provides the results of the hybrid control system in the 2006 Jeju power system. The hybrid control system is implemented in the Real Time Digital Simulator (RTDS).

Fig. 7 shows Jeju power system in 2006. The power system has 460 MW loads in the summer peak. About 40% of the peak load is being supplied from the mainland system through the HVDC lines. Ten generators are located at the northern, western and southern part of Jeju Island, and most of the loads are concentrated in the northern and southern areas of Jeju and switched shunt capacitors and reactors are available for voltage control in substations. The transmission lines form a ring structure. The summary of the Jeju power system is reported in Table 1.

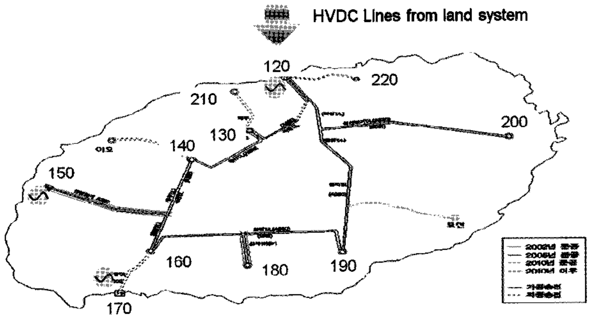

Fig. 7. Jeju power systems in 2006

Table 1. The summary of Jeju power system in 2006

Active power		Reactive power		the number of installed generators
Generations	Loads	Generations	Loads	
470.0	467.5	121.0	153.1	10

From the sensitivity matrix in section 3, the 120 bus was selected as the pilot bus and Jejutp# 2, 3 and Njejutp# 3, 4 as the control generators considering the sensitivity with 120 bus and capacity. Table 2 shows the diagonal terms from the sensitivity matrix. As mentioned in section 3.2, the diagonal terms signify how robust the bus is and the bus with the smallest coefficient in diagonal terms will be selected as a pilot bus in the system.

Table 2. Sensitivity matrix in Jeju Power System

#BUS	Diagonal term of sensitivity matrix
120	0.0133
130	0.0148
210	0.0174
160	0.0202
170	0.0202
140	0.0224
150	0.0295
220	0.0330
190	0.0336
180	0.0430
200	0.0635

Fig. 8 displays the control result of the pilot bus voltage. The control scenario to verify the pilot bus selection was that the pilot bus voltage was changed 1.027 to 1.02 at 300 sec and 1.02 to 1.03 at 600 sec. The result imparts that the other buses of the power system followed the pilot bus voltage.

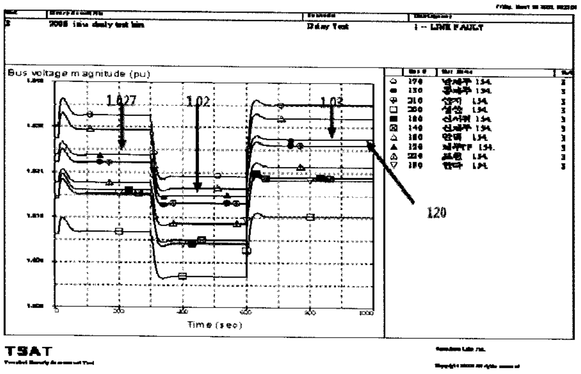

Fig. 8. The voltage of buses in Jeju Power System

Fig. 9 shows the control of the pilot bus voltage by changing the reference voltage in the hybrid control system. VP_REF:PV, VP:PV, QRESERVE_CVC:PV stand for the reference voltage, pilot bus voltage and reactive power reserve of generators respectively in Figs. 9-11. The graph verifies that the variation of pilot bus voltage with respect to the reference signal has a good performance. Another test is the load variation (Figs. 10 (a), (b)). Fig. 10(a) is without the hybrid control system and 10(b) is with the system. In the case of load variation without the control system, there is a considerable change in the bus voltage profile. However, in the case of load variation with the control system, the bus voltage is controlled within a boundary by controlling the generators.

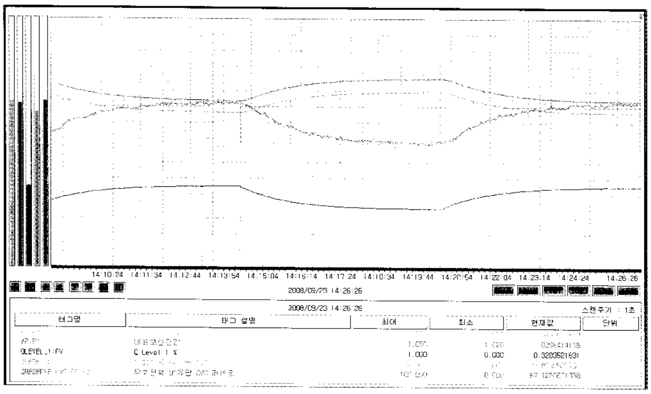

Fig. 9. Voltage control of pilot bus

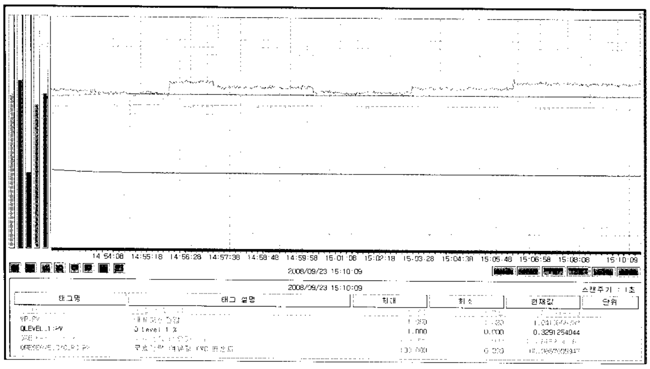

Fig. 10.(a) Voltage profile without hybrid control system in load change

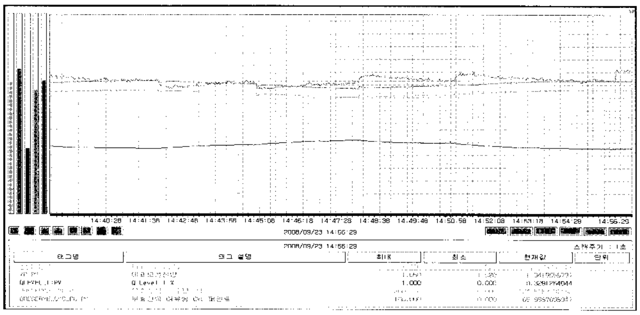

Fig. 10.(b) Voltage profile with hybrid control system in load change

Fig. 11 shows the results of the hybrid control with the CVC and DVC. When the load was increased, the voltage of the pilot bus decreased, thus creating a difference between the bus voltage and the reference. To regulate the voltage, the CVC was executed, causing the pilot bus voltage to follow the reference voltage a few minutes later. Then, the reactive power reserve of the generators was checked for the set boundary by the control system. Since the condition wasn't met, the system executed the DVC to meet the reactive power reserve, after verification of the steady state operation of the CVC. From the DVC, the switched shunt capacitor was injected to the power system leading to an increase in the voltage of the pilot bus. The CVC then adjusted the pilot bus voltage close to the reference. Finally, the control system met the reactive power reserve and the pilot bus voltage. The reactive power reserve was acquired by the control system and the voltage stability from a dynamic point of view was enhanced to overcome an abnormal state.

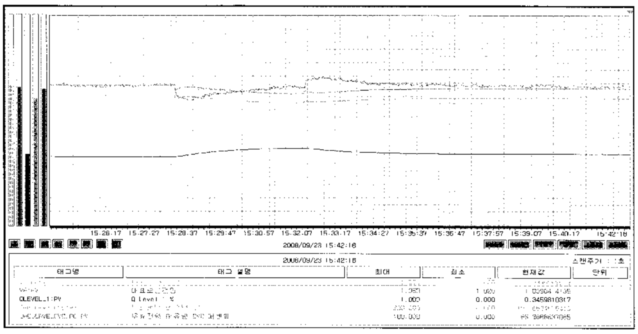

Fig. 11. Reactive power generation with hybrid control system in load change

8. Conclusion

A hybrid control system for managing the voltage and reactive power by coordinating continuous and discrete devices is being described. The main objective of the control system is to regulate the voltage profiles of the power system and the reserve of reactive power for an emergency state. To achieve the control goal, the control system regulates the voltage of the pilot bus using a CVC, which is a feed-back loop control based on the generators. It also adjusts the switched shunt capacitors by using integer programming to control the reactive power reserve which is the margin to prevent voltage collapse in an emergency state. The reference voltage of the pilot bus and the reactive power reserve can be calculated using optimal reactive power flow to minimize the loss of the power system. This control system enables an economical and stable power system operation from the voltage stability point of view. The test results on the Jeju power system clearly show that the control scheme is feasible, and can be more realistic because the Real Time Digital Simulator is being implemented on the Jeju power system.

Acknowledgements

This work was the outcome of a Manpower Development Program for Energy & Resources supported by the Ministry of Knowledge and Economy (MKE) and the Electric Power Infrastructure Center supported in part by the Korea Electric Power Corporation (KEPCO) under MKE.

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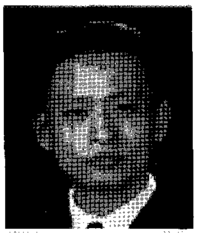

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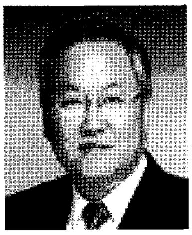

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