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Stability Improvement by Reducing Voltage Fluctuation using SVC in Penetration Wind Power System

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Stability Improvement by Reducing Voltage Fluctuation using SVC in Penetration Wind Power System

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Abstract. Currently, wind energy is a renewable energy that is growing because some of its advantages are connected to the grid system. This study is focus on presenting a probabilistic theory to design power system stability (PSS) and excitation of the FACTS system controller generator via Static Var Compensator (SVC) connected to wind turbines in Sidrap, region of South Sulawesi system. The purpose of the test system is on oscillation, profile voltage and influence stability of wind turbine penetration. An oscillating system requires system performance compensation from the side of the machine via PSS and transmission via SCV to increase the depth of the electro mechanical mode. So, the simulation results on 44 buses in the South Sulawesi system show the stability of the system and rapid voltage improvement and can reduce the oscillation that occurs. This system is tested using a time domain-based PSAT software simulation on the system.

1. Introduction

Modern power systems have come in the current era which has an impact on the limitation of variation and stress stability problems in the transmission network when operating. Historically, the South Sulawesi transmission system was more vulnerable to operating customer restrictions and uncertainty issues due to a network of reactive power requirements, deregulation of the electricity industry and the use of various renewable energy sources and different operations. At present the electric power system continues to evolve, load growth is always followed by transmission to connect power plants from new renewable energy such as wind turbines and PV. The load and growth are at the root of the load stability problem arising in accordance with the operating pattern so that the use of new technologies and controls is needed, to improve operation under oscillation conditions. Stability problems due to penetration of wind turbines have been carried out [1-3]. On the experience of steady state stability using Capital Analysis and stability, at [4, 5], and [6, 7]. Improper operating patterns can result in frequency stability, voltage stability and interred oscillation. However, currently the power stabilizer system (PSS) has been used to generate and control the voltage and frequency tuned using the metaheuristic method of neural network [8].

A lot of research has been successful on PSS presented in the literature [9]. On multi-machine systems, and the Coordinated SVC and AVR studies on voltage control on hybrid wind diesel systems have been carried out by [10, 11]. SVC using optimal load flow using SIMULINK has been done by [12]. Optimization using Eigenvalue analysis for transient stability of SVC has been carried out by [13]. In [14] has discussed the optimal sizing and location of SVC devices for improvement. Research has been conducted on the penetration of wind turbines [3] but the conventional SVC strategy still

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needs to be developed. The proposed method is implemented on the South Sulawesi 44 system bus using PSAT software, because the wind direction characteristics in South Sulawesi are classified into two, namely west wind and east wind and it will affect the output of wind turbine so stability can be disturbed. The Sulawesi system displays using the PSAT bus voltage profile before being penetrated when the wind turbine is before and after it is installed. A voltage controller on the Sulawesi system is a function to fluctuate with oscillation due to variations in wind turbine output.

2. Fundamental Theory

The basic purpose of PSS installation is to widen the stability limit by modulation of the excitation generator to provide attenuation to synchronous when oscillations occur due to changes in load. Analytically, PSS can function as a transfer obtained by PSS from wash-out and the lead lag shown in Figure 1. The lead-lag aims to provide a suitable phase lead to compensate for the phase of the excitation lag and the torque generator in the system.

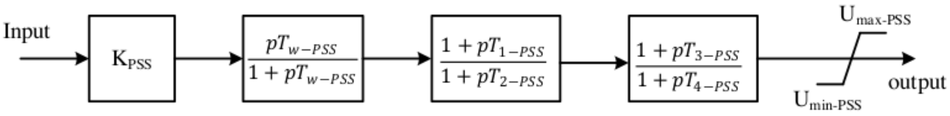

Figure 1. Typical controller with two lead lag stages

3. SVC Controller

Good damping to reduce the oscillation of the power system interconnected between the load and the filter. In addition to PSS, devices found on the transmission network side are FACTS devices to improve system stability. Static Var Compensator (SVC) is the most common FACTS device used in transmission networks. The main SVC application is maintaining a voltage bus bar at a predetermined value to supply the load. However, there has been a growing tendency to use SVC to help system stability when oscillations occur due to changes in load and the effect of penetration from wind turbines. An SVC equipped with a voltage regulator can provide synchronization torque but can be ignored by damping torque on a swinging system [15]. SVC can be operated in two different modes: voltage mode and VAR control mode. When SVC operates the voltage setting mode, implementing the following V-I characteristics is shown in Figure 2.

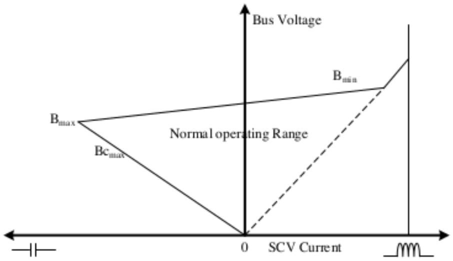

Figure 2. V-I characteristic of SVC

An additional damping controller is needed for extra attenuation when a voltage drop occurs due to additional load. SVC is more effective at controlling swinging power at higher power transfer rates; 150kV accuracy of SVC locations contributes greatly to compensation. A typical SVC configuration with inductors is controlled by thyristors and fixed capacitors, connected to the bus bar via step-down transformers, for BC and BL, each of which is an arrangement of capacitors and inductors. SVC behaviour can be represented by the following equation:

$$X_{SVC} = X_T - \frac{1}{B_C+B_L} = \frac{1}{Y_{SVC}} \tag{1}$$

$$\begin{bmatrix} V_R \\ V_j \end{bmatrix} = X_{SVC} \begin{bmatrix} -I_J \\ I_R \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} \Delta I_R \\ \Delta I_J \end{bmatrix} = \frac{1}{X_{SVC}} \left\{ \begin{bmatrix} \Delta V_J \\ \Delta V_R \end{bmatrix} - \frac{1}{(B_C+B_L)^2} \begin{bmatrix} I_R \\ I_J \end{bmatrix} \Delta B_L \right\} \tag{3}$$

ISVC are the amount of voltage and current in the SVC terminal.ΔVSVC and ΔBL is the controller output. Δ in Equations (1) and (2) for use in minor interference techniques. For equation (3) is obtained so that the SVC module with 4-pin in Figure 3. is installed in the system network. Thyristor controller connection system for SVC and the system in Figure 4 with the provisions of ΔV_{SVC} dan ΔI_{SVC} can be derived from V_R and V_J (real and imaginary power parts of SVC voltage) then to signal $\Delta V_{SVC} = \{(V_R / V_{SVC})\, \Delta V_R + (V_J / V_{SVC})\, \Delta V_J\}$ The signal

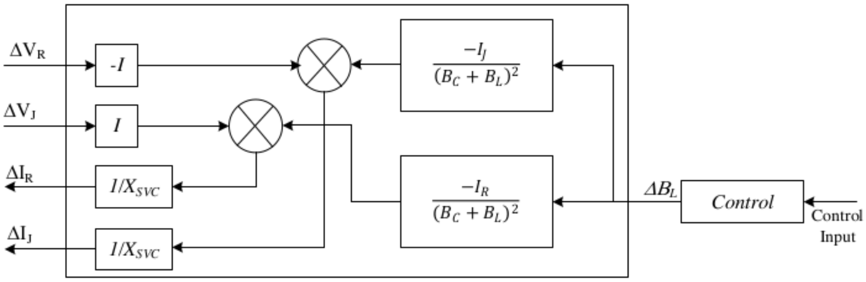

Figure 3. SVC Model with four pins

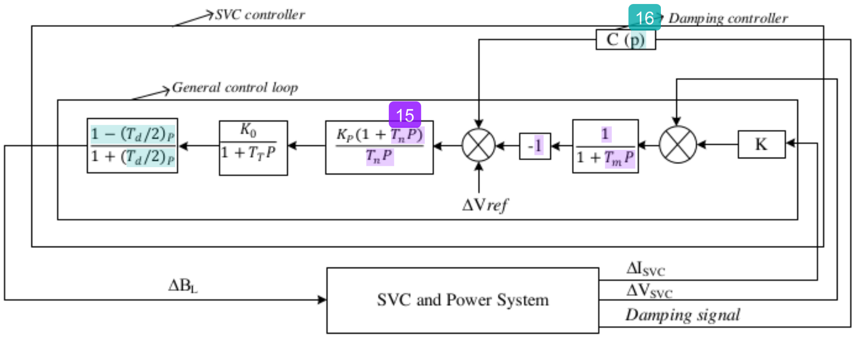

Figure 4. Signal and connection of SVC controller

To analyze the stability, a mathematical model of the differential algebraic equation (DAE) is needed. The set is used for Eigen value analysis in PSAT software. The form of DAE is

$$x = \dot{f}(x, y) \tag{4}$$

$$\mathbf{0} = \boldsymbol{g}(\boldsymbol{x}, \boldsymbol{y}) \tag{5}$$

In Equations (4) and (5) where x is a state variable and y is a vector of algebraic variables. The state matrix is calculated by Jacobean matrix. The state matrix is used to calculate Eigen values. There are two variables of positive Eigen value in a system using SVC shown in Figure 7, this shows the system is in stable condition. The objective function based on Eigen values is used to design SVC and PSS. Here, the scale function is used. complex pairs of Eigen values

$$\lambda = \boldsymbol{\sigma} + \boldsymbol{j\omega} \tag{6}$$

Note that σ is the real part of the Eigen value and jω is the imaginary part of the Eigen value, σ0 is the constant attenuation factor which is (-1). According to this objective function, relocate the oscillation mode from the right side to the left side image. so, the optimal value of the objective function is less than zero as shown in Figure. 5.

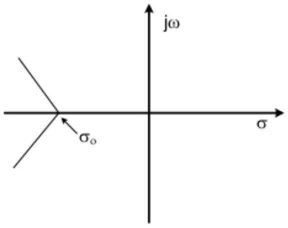

Figure 5. Objective function

4. Proposed Method

The testing of wind turbine penetration with SVC installation in the South Sulawesi network system is shown in Figure 6. The system consists of swing bus, fifteen bus generators, and 44 bus substations. This simulation uses the Matlab Toolbox to analyze and simulate electric power systems. Wind turbine used is 70MW installed on bus 2 in Sidrap.

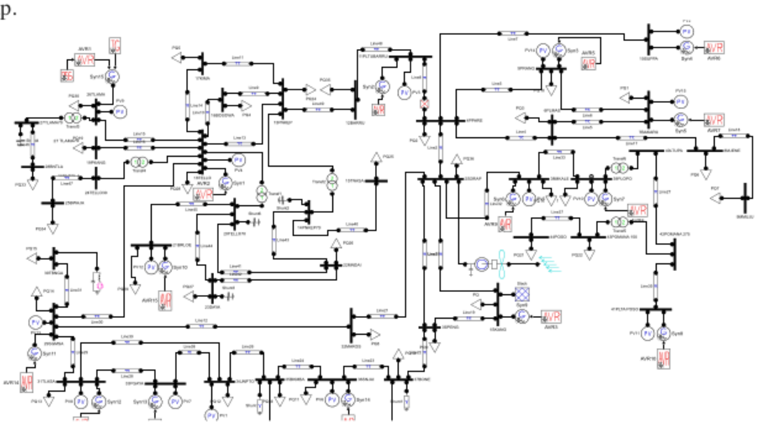

Figure 6. South Sulawesi 44-bus test system

5. Simulation and Results

Using PSAT software, the simulation was tested on the South Sulawesi 44 bus power system. This simulation aims to obtain the effect of the penetration of the wind Turbine on the bus 2 Sidrap on stability system using the SVSI indicator. Active and reactive power load fluctuations provide a different SVSI response due to the bus voltage deviation generated.

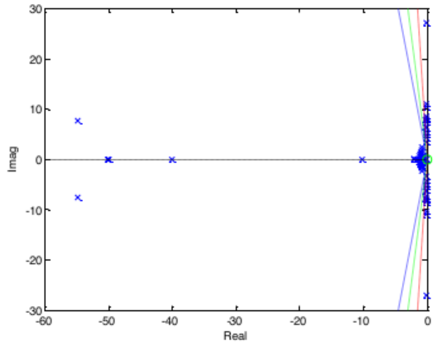

Figure 7. Eigen value analysis

Table 1. Eigen value analysis of system with SVC

	Without Wind, PSS and SVC	With Wind and PSS	with wind, PSS and SVC
Dinamic Order	111	117	119
Buses	44	44	44
Positive Eigen	0	0	0
Negative Eigen	110	116	117
Complex pairs	28	28	26
Zero Eigen	1	1	2

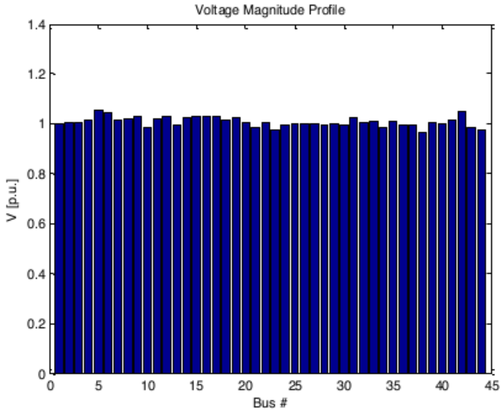

Figure 8. Voltage with wind, PSS and SVC

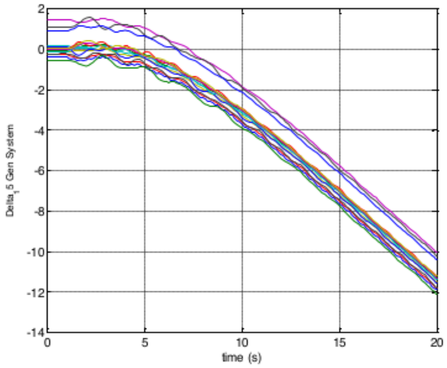

Figure 9. Delta 15 Gen system using wind, PSS and SVC

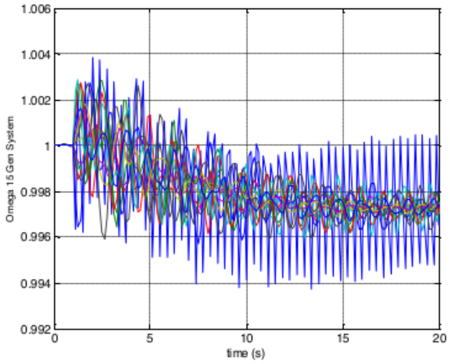

Figure 10. Omega 15 Gen system using wind, PSS dan SVC

Tabel 2. Test system parameter values

bus	Real power generation [pu] Without PSS, Wind and SVC	Reactive power generation [pu] Without PSS, Wind and SVC	Real power generation [pu] with PSS, Wind and SVC	Reactive power generation [pu] with PSS, wind, and SVC
Bus 1	1.2741	0.15092	2.2947	0.14243
Bus 2	-0.265	-0.103	-0.265	-0.103
Bus 3	-0.141	-0.034	-0.141	-0.034
Bus 4	-0.187	-0.047	-0.187	-0.047
Bus 5	0.099	-0.48739	0.099	-0.4501
Bus 6	-0.171	-0.041	-0.171	-0.041
Bus 7	0.013	0.86583	0.013	0.87468
Bus 8	-0.233	-0.037	-0.233	-0.037
Bus 9	-0.096	-0.048	-0.096	-0.048
Bus 10	0.311	-0.09708	0.311	-0.03173
Bus 11	0.604	-0.18632	0.604	-0.13574
Bus 12	-0.101	-0.024	-0.101	-0.024
Bus 13	-0.221	-0.08	-0.221	-0.08
Bus 14	0	0.13352	0	0.13335
Bus 15	-0.189	-0.0206	-0.189	-0.0206
Bus 16	0.331	-0.0154	0.331	-0.0154

Bus 17	-0.18	-0.058	-0.18	-0.058
Bus 18	-0.432	3.2572	-0.423	3.3367
Bus 19	-0.683	-0.177	-0.432	3.2572
Bus 20	0	0.21456	0	0.21441
Bus 21	0.062	-0.28016	0.062	-0.27682
Bus 22	-0.243	-0.026	-0.243	-0.026
Bus 23	-0.245	0.18617	-0.245	0.186
Bus 24	0	0	0	0
Bus 25	0	0	0	0
Bus 26	0.029	-0.7146	0.029	-0.7146
Bus 27	0	0.12435	0	0.12435
Bus 28	-0.265	-0.077	-0.265	-0.077
Bus 29	0.043	-1.1396	-0.457	-0.01295
Bus 30	-0.552	-0.167	-0.952	-0.999
Bus 31	0.584	0.45407	0.584	0.55431
Bus 32	-0.186	-0.005	-0.186	-0.005
Bus 33	1.961	-0.37138	1.961	-0.39327
Bus 34	0.451	-0.03284	0.451	-0.0265
Bus 35	-0.271	0.00095	-0.271	0.00107
Bus 36	0.031	0.0642	0.031	0.06249
Bus 37	-0.321	-0.01589	-0.321	-0.01605
Bus 38	-0.1108	0.25944	-0.1108	0.26881
Bus 39	-0.488	-0.02359	-0.1108	0.2359
Bus 40	0	0	0	0
Bus 41	195	0.25782	195	0.25782
Bus 42	0	0	0	0
Bus 43	-0.049	-0.005	-0.049	-0.005
Bus 44	-0.995	-0.018	-0.995	-0.018

6. Conclusion

In this paper, the problem of stability due to wind turbine penetration on the Sulawesi system on 44 buses is measured using SVSI. This study shows that wind turbine integration affects the value of voltage stability. Changes in load and the level of wind penetration installed on bus 2 in the sideway area determine the critical value of the load bus. The weakest voltage on bus 30 obtains with the active power value of -0.552 and the active power of -0.167, before setting up PSS wind and SVC. On the swing bus, the active power value from 1.2741 becomes 2.2947, while the reactive power from 0.15092 becomes 0.14243 when the power is increased but the reactive power decreases by 0.00849 pu.

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