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TCSC Control for Transient Stability Increasing of Nonlinear Co-ordinated Generator Excitation on 230 kV Distribution System due to Outages in Hybrid Micro-Smart Grid

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Abstract

This paper presents the transient stability increasing of a robust nonlinear co-ordinated generator excitation using thyristor controlled series capacitor (TCSC) controller. A nonlinear feedback law for the generator is found, which linearises and decouples the power system model. Robust nonlinear control theory is then employed to design the nonlinear co-ordinated controller that consists of two controllers is the generator excitation and the TCSC controllers. The TCSC is located at the midpoint of the system. The hybrid micro smart grid considered comprises a synchronous diesel generator and an inverter distributed generation. The problem of power line outage identification has traditionally been formulated as a combinatorial optimization problem, to reduce the complexity while improving outage rate detection performance. The results of TCSC control are conducted by time domain simulations using MATLAB/Simulink software. Simulation results show that the proposed controller can ensure transient stability increasing on 230 kV power distribution systems in a critical fault clearing time, which may occur at the generator busbar terminal.

Keywords: Transient stability, TCSC controllers, fault clearing, smart grid and generator.

1. INTRODUCTION

A thyristor-controlled series capacitor (TCSC) is one of the flexible alternating current transmission systems (FACTS), is controllers which used as a series compensator in transmission lines. TCSC consists of a thyristor controlled reactor which is connected in parallel with a fixed series capacitor, and devices that is increasingly applied for various reasons by utilities in modern power systems with long transmission lines. TCSC can provide fast acting controls. The existing TCSC controllers use thyristor controlled reactors in parallel with capacitor segments of a series capacitor bank. A synchronous machine with a single TCSC example system in considered. A nonlinear feedback law for the generator excitation is found.

A new co-ordinated generated excitation and TCSC control in hybrid micro smart grid is proposed. The main protection of transmission line is provided by distance relays. The presence of TCSC in the fault loop may have some important effects on the impedance measured by the distance relays. The problem of the 230 kV power distribution systems of outage rate effects for lightning is identification has traditionally been formulated as a combinatorial stability optimization problem to reduce the complexity while improving outage rate detection performance. When outages over wide areas of occur on transmission lines, this paper of the proposed TCSC controller can ensure stability investigation of the hybrid smart grids with diesel generators and transient stability increasing on 230 kV power distribution systems in a critical fault clearing time, which may occur at the generator bus terminal. The results of TCSC control strategies are conducted by time domain simulations using MATLAB software. The assessment of the stability of a hybrid micro smart grid is conducted by examining the rotor angle stability.

2. THE STABILITY ANALYSIS

2.1 The Transient Stability Increasing of TCSC Controller

Power system stability analysis are increasingly called upon to operate 230 kV distribution transmission lines, to simplify the discussion [1], a simplified model for a generator and a TCSC system as shown is Fig. 1, is considered. The convenience of modeling can be written mechanical equations as follows:

$$\Delta\dot{\delta}(t)=\omega(t) \qquad (1)$$

and

$$\dot{\omega}(t)=-\frac{D}{2H}\omega(t)-\frac{\omega_0}{2H}\Delta P_e(t) \qquad (2)$$

where $\Delta\delta(t)=\delta(t)-\delta_0$; $\delta(t)$ is the power angle of the generator; δ_0 is the dynamic power angle of the generator at the operating point; $\omega(t)$ is the relative speed of the generator:

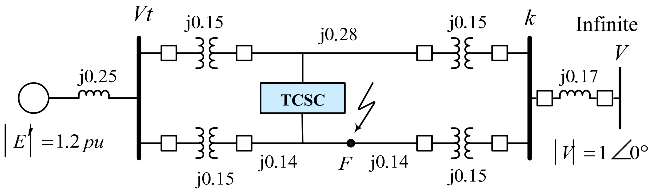

Figure 1. Single line diagram of the machine transmission line system with TCSC control

The generator dynamics equations of the machine as follows:

$$\dot{E}'_q(t)=(E_f(t)-E_q(t))\frac{1}{T'_{d0}} \qquad (3)$$

where $E'_q(t)$ is the transient EMF in the quadrature axis of the generator; $E_q(t)$ is the EMF in the quadrature axis of the generator; $E_f(t)$ is the equivalent EMF in the excitation coil; T'_{d0} is the direct axis transient open circuit time constant, and the generator machine terminal voltage equations.

We can derive an energy function for the case of a synchronous generator connected to an induction generator. The system energy function is obtained and giving the energy function:

$$\dot{V} = V_{ss}+V_{si}+V_{ii} = V_{KE}+V_{PE}+V_F \qquad (4)$$

In stability studies it will be convenient to transfer the stable equilibrium points to the origin through the necessary transformations, and write the equations in state variable form. For the case of an induction generator connected to another induction generator, we can introduce state variables :

All the research work so far on power system stability analysis based on the direct method of Lyapunov has dealt only with system supplied from synchronous generator and synchronous .motor. The analysis of power systems are including induction machines is becoming mandatory from the viewpoint of the serious effect of these machines on the system stability. This paper proposes an energy function for a power system in which the supply is from synchronous motor and induction generators, with static loads connected at the terminals of the synchronous machine and at other system buses.

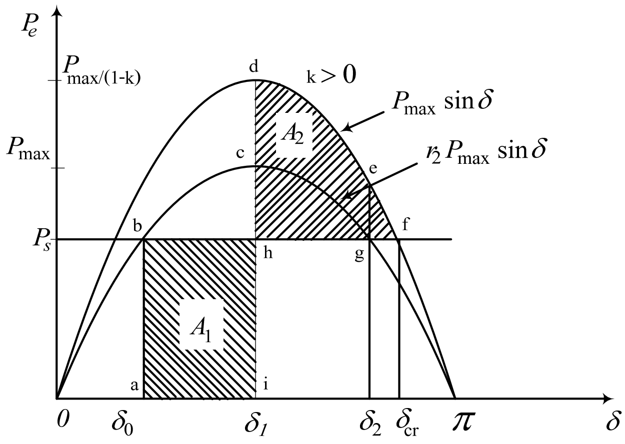

Figure 2. The equal-area criterion curve for transient stability

2.2 TCSC Control with Nonlinear Co-ordinated Controller

The TCSC control is varied such at $k>0$, the effective line reactance is reduced during the power and the power-angle $(P-\delta)$ curve is raised as shown in Fig.2. A TCSC dynamic model can be expressed as follows:

$$P_{ei} = E'_{di}I_{di}+E'_{qi}I_{qi}-\left(x'_{qi}-x'_{di}\right)I_{di}I_{qi} \qquad (5)$$

by

P_{ei} is the electrical power output ;[p.u.]

P_{mi} is the mechanical power output ;[p.u.]

M_i is the moment of inertia ;[p.u.]

D_i is the damping coefficient ;[p.u.]

where

$E'_i=E'_{di}+jE'_{qi}$ is voltage behind transient impedance [p.u.]

I_{di},I_{qi} is the stator current of d- and q- axis ;[p.u.]

x_{di},x_{qi} is the synchronous motor reactance of d- and q-axis ;[p.u.]

x'_{di}, x'_{qi} is the transient reactance of d- and q- axis ;[p.u.]

T'_{doi}, T'_{qoi} is the time constants in open circuit of d- and q-axis ;[s]

$$M_T = \sum_{i=1}^{n} M_i \tag{6}$$

$$\delta_o = \frac{1}{M_T} \sum_{i=1}^{n} M_i \delta_i \tag{7}$$

by

M_T is the total moment ;[p.u.]

δ_o is power angle of the centre of inertia;[rad]

δ_i is generator rotor angle ;[rad]

2.3 Power Distribution Line due to Outages in the Smart Grid of Flashover Effects

Lightning can be defined as a transients, lightning is a natural phenomenon of random character that can have a very adverse effect on power transmission lines and distribution networks. When outages occur on the high voltage transmission lines and induced voltages due to nearby lightning stroke is one of the main causes on 230 kV transmission line, Thus faults occur of power line outages will have a number of stroke on overhead ground wire. The maximum voltage from flashover effects in the lines, the interconnected micro smart grid is assumed to have reached a stable post-event state as shown in Fig.4.

2.4 Flashover Voltage for a Stroke to Tower

The required flashover voltages from conductor to tower top. A very brief iteration yields the tower top voltage. The vertical and the horizontal return stroke current starts from the top of the tower at t = 0 and V_{Top} required to produce flashover, at a given time. The following equations can be written for faults.

$$V_{Top} = \frac{V_{fo}}{1 - cf} \tag{8}$$

and

$$cf = \frac{z_{1a} + z_{2a}}{z_{11}} \tag{9}$$

where V_{fo} is flashover voltage a fault occurs, cf is coupling factor of conductor and z_{1a}, z_{2a}, z_{11} is tower surge impedance for a horizontal and a vertical return stroke.

Therefore, this paper assumes steady-state operation of the system under the third case, the synchronous generators are assumed to take a larger part of the total load, the synchronous generator equations are written with the usual assumptions of constant mechanical power input constant excitation voltage, the phase angle of the voltage coincides with the rotor

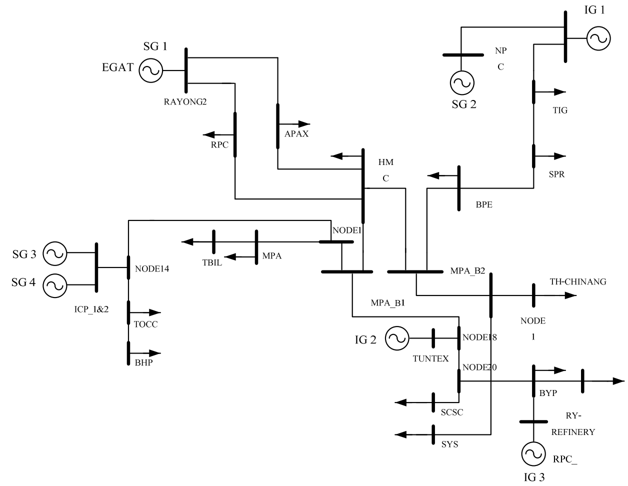

Figure 3. Single line of the 230 kV distribution networks test system with connected to the utility grid at bus 5

The tower top voltage is measured by a voltage probe with high resistance and low capacitance. The measured waveforms of the injection current and the tower top voltage. The step response of the tower is calculated using the as following equation [5].

$$V_{step}(t) = \Im^{-1}\left\{\frac{1}{s}\frac{\Im\{V_{Top}(t)\}}{\Im\{I_{Injection}(t)\}}\right\};\ s = \alpha + j\omega \tag{10}$$

and

$$V_{step} = \left(\frac{1}{Z_{in}} + \frac{1}{Z_L}\right)^{-1} . I_o \tag{11}$$

where $V_{Top}(t)$ is the tower top overvoltage, $I_{Injection}(t)$ is the injection current into the tower, $\Im$ is the Laplace transform operator, $\Im^{-1}$ is the inverse Laplace transform with operator, I_o is the return stroke current when a fault occurs of power line outages, z_{in} is the input impedance as viewed from the tower top and z_L is the surge impedance of the current injection power line connected smart grid [6].

3. SIMULATION RESULTS

The power system shown in Fig.1 is used for test purposes. The single-line diagram of 115 kV distribution transmission lines system for test from area of the Mabtaput Industrial Estate Authority of Rayong Substation to MEA in Thailand. In the simulations, the distribution system of 7 generating units is SG1-SG4 and IG1-IG3 to take part in the transient energy and 28 buses connected by 15 transmission lines loads. The total installed generating of the system is 397 MW. The transient energy function method is used to derive.

The fault conditions are cleared by opening of the respective circuit breakers after a period of time. Presented in Fig.4-6 are the variation of machines rotor angles relative to bus Rayong2 (take as reference bus) obtained from step-by-step simulation for some of the above faults. In Fig. 4 shown rotor angles for the aggregate induction machines obtained. If the machines were all synchronous generators, as then looking at Fig. 5 and Fig. 6 shown one would say that the former is for a stable case.

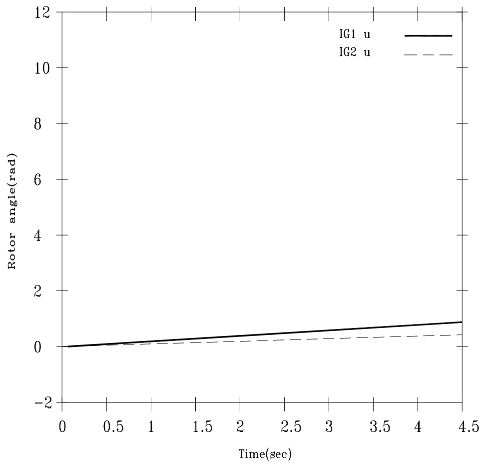

Figure 4. Responses of the terminal voltage with TCSC control of system in micro smart grid

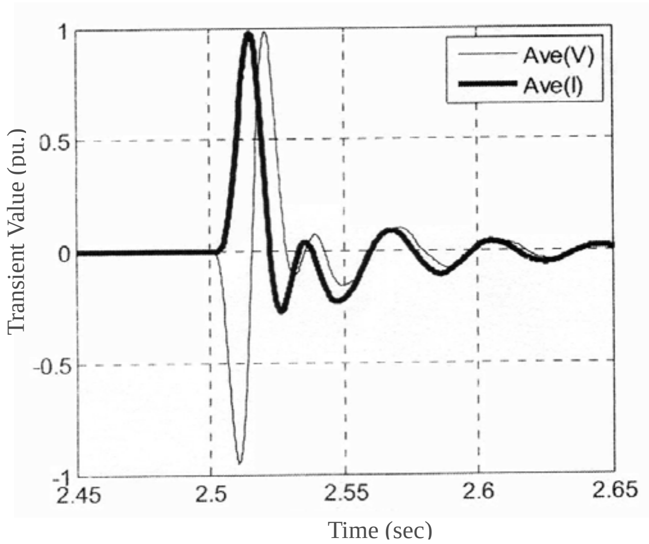

Figure 5. Result of comparison averages of voltage and current with transient stability increasing of TCSC control

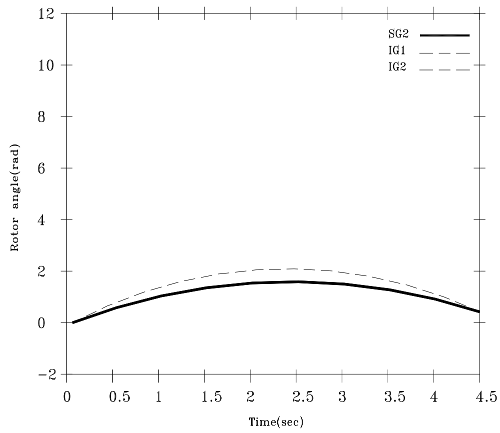

Figure 6. Result of loss of section with loads is TIG and SPR.

Table 1. Result of the critical fault clearing times due to outage with control strategy of system

Control strategy	Load composition	
	35 % IM 65 % RLC	40 % IM 50 % RLC
1. Gen.excit for droop control	1.0 sec	1.30 sec
2. TCSC controller for transient control	1.029 sec	1.50 sec

Table 2. Result of the dynamic power angles δ_{min} and δ_{max} of the generator during the swing curves of system for various values of k

Value of k	δ_{min} (degrees)	δ_{max} (degrees)
0.2	36.25	85.10
0.4	42.31	93.56
0.6	49.07	102.34
0.8	50.62	107.20

Table 3. Result of the critical clearing power angle value with the relation of the swing curves

δ_{cr} (degrees)	$\cos \delta_{cr}$	$\cos \delta_{cr}$ +0.7804
40	0.7660	1.5464
50	0.6428	1.4232
60	0.50	1.2804
70	0.342	1.1224
80	0.1736	0.954

This paper proves that the rotor angle for the induction motor machine can also an important role in the analysis of transient stability of power systems. The simulation results from the obtained energy-like functions are found to will be in close agreement with results from step-by-step integration shown in Table I, showing that with improved studies and stability analysis of system, including induction machine. These results may be extended to the general case study of power systems supplying induction motor loads.

The proposed co-ordinated TCSC controller consisted of two controllers, a robust nonlinear generator excitation with droop control and a single TCSC controller for transient control. The hybrid micro smart grid operating as an island connot sustain faults for long duration and the critical fault clearing times are defined as the time for which a micro smart grid can sustain a fault without losing its stability. the diesel generator frequency power droop gain have the most profound impact of the hybrid micro smart grid for stability.

4. CONCLUSIONS

The transient stability increasing of power system with control strategy can be broadly classified into voltage stability and frequency stability. Voltage stability refers to the ability of the system to maintain steady voltages at all the buses after being subjected to a disturbance, a short-circuit fault occurs of power line outages initiated at time. The fault current may increase as much as extreme overvoltages are induced across for TCSC. A power system with a single TCSC located at the midpoint of the transmission lines has been considered in this paper. A new robust nonlinear co-ordinated generator excitation and TCSC controller has been proposed to enhance the transient stability of 230 kV power distribution system in a critical fault clearing time of the hybrid micro smart grid for various system with the type of interconnections. An energy-like function for a power system supplied by synchronous and induction generators has been developed.

This paper proves that the rotor angle for the induction motor machine can also an important role in the analysis of transient stability of power systems. The simulation results from the obtained energy-like functions are found to will be in close agreement with results from step-by-step integration shown in Table I, showing that with improved studies and stability analysis of system, including induction machine. These results may be extended to the general case study of power systems supplying induction motor loads.

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