The stability of a class of synchronous generator damping model

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Abstract. Electricity is indispensable to modern society and the most convenient energy, it can be easily transformed into other forms of energy, has been widely used in engineering, transportation and so on, this paper studied the generator model with damping machine, using the Lyapunov function method, we obtain sufficient conditions for the asymptotic stability of the model.

1. Introduction
The engineering technology and society cannot do without electricity, the power has become indispensable to modern society and the most convenient energy, it can be easily transformed into other forms of energy, is widely used in engineering technology, industry and agriculture, transportation and other industries.[1-4] The electricity is through the transformer and transmission to the user, then press the need to change into the required energy, power system is a complex system consisting of a large number of components, its planning and design, construction and operation, management is a large and complex project, in the face of such a huge and complex system, every aspect of it is related to the many electrical safety problems.[5-6] In today's society, has become an indispensable part of it bears the social progress or not, so its stability is very important. And the stability is that the power system continued to use Households in normal power supply state, the stability of the power system is a system of interference in a normal operation state, after a period of time can be restored to the original stable operation state or transition to steady state problems, the power system must satisfy the stability of generator synchronous operation.[7-8] The stability of the system if destroyed, the whole system will be severely affected, resulting in adverse consequences.[9-10]

The stability of the power system for the static stability and transient stability. According to the size of the static interference refers to the power system by a small disturbance in one operation mode, whether the ability to return to the running state of the original, commonly used approximation theory and method.[11-13] The transient stability is that the system is subjected to large disturbances, whether or not dysynchrony transition to the new steady state or the ability to return to the original state of stability, asymptotic stability analysis of the equilibrium position of nonlinear system to transient stability.[14] To quickly remove the fault, in order to ensure the normal power supply to.

2. Literature Survey
In reference to the relevant reference [1-5], In this paper, the oscillation criteria of two order nonlinear neutral delay differential equations with positive and negative coefficients are studied in reference[1]. The oscillation of two order delay differential equations is studied in reference [2], he oscillation criteria of two order differential equations with positive and negative coefficients are studied in
reference [3]. In the literature [4-14], some nonlinear systems and stability are studied. The stability and asymptotic behavior of these nonlinear systems are very important to the stability of power systems. On this basis, we study the stability of a class of important power systems.

3. Proposed Method

On the basis of [1-14], the governor does not consider the effects of a single model of synchronous generator damping machine:

\[
\begin{align*}
\frac{dx}{dt} &= c_1 y + c_2 x (x^2 + y^2) - c_3 x^2 y + c_4 y^2 \\
\frac{dy}{dt} &= -c_1 x + c_2 y (x^2 + y^2) + c_3 x^3 - c_4 xy
\end{align*}
\]  

(1)

The equation (1) is a nonlinear system, it is hard to find out a system (1) the expression of the solution, but we can not find out the expression of the solution, and by other methods to determine the stability of the solution, we use the method of Lyapunov second, which is the basic method of modern research on stability problem, the characteristic of the method is not having obtained equations, and by constructing a function with special properties, called Lyapunov function, combining the equations to discuss their own stability.

In order to explain the theoretical basis we have derived, we first give several existing conclusions as the theoretical basis under which we deduce, Before proving the result, it is necessary to introduce of some important conclusions, first consider the differential equation system:

\[
\frac{dx}{dt} = f(x)
\]  

(2)

Lemma 1\textsuperscript{[4]}. If there exist a positive definite function \( V(x) \) in the region \( Q_n \) along the derivative

\[
\frac{dV}{dt} \leq 0
\]

of differential equation (2), then the system is stable.

Lemma 2\textsuperscript{[4]}. If the area \( Q_n \) has the upper bound of the infinitesimal definite (negative definite) function \( V(x) \), the derivative \( \frac{dV}{dt} \) along the differential equation (2) is negative definite (positive definite), then the system (2) is asymptotically stable.

We using energy function constructed \( V \) function. Constructing Lyapunov function as follow:

\[
V(x, y) = x^2 + y^2
\]  

(3)

\( V(x, y) \) is positive definite function. Consider the derivative \( \frac{dV}{dt} \) of system (3), we have

\[
\frac{dV}{dt} = 2x \frac{dx}{dt} + 2y \frac{dy}{dt}
\]

\[
= 2x[c_1 y + c_2 x (x^2 + y^2) - c_3 x^2 y + c_4 y^2] + 2y[-c_1 x + c_2 y (x^2 + y^2) + c_3 x^3 - c_4 xy]
\]

\[
= 2c_1 xy + 2c_2 x^2 y^2 + 2c_3 x^3 y - 2c_3 x^2 y + 2c_4 xy^4
\]

\[
- 2c_1 xy + 2c_2 x^2 y^2 + 2c_3 y^4 + 2c_3 x^3 y - 2c_3 xy^2
\]

\[
= 2c_2 x^2 y^2 + 4c_2 x^2 y^2 + 2c_3 y^4
\]

\[
= 2c_2 (x^2 + y^2)^2
\]

4. Conclusion

We according to lemma 1 and lemma 2, we can get it from the above discussion:

If \( c_2 > 0 \), that is \( \frac{dV}{dt} > 0 \), The zero solution of the system (1) is unstable.
If $c_2 = 0$, that is $\frac{dV}{dt} = 0$, The system (1) is stable.

If $c_2 < 0$, that is $\frac{dV}{dt} < 0$, The zero solution of the system (1) is asymptotically stable.

In this paper, because of the particularity of the power system stability, transient stability, due to different disturbances lead to different steady states, and more than one equilibrium point, it is not possible to be globally stable. In this paper, for this reason, to prove its asymptotic stability by using the Lyapunov function method, the stability of the power system is presented in the guiding role of theory.

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References
[1] E.Thandapani, V.Muthulakshmi, J.R.Graef. “Oscillation criteria for second order nonlinear neutral delay differential equations with positive and negative coefficients”, Int.J.Pure and Appl Math., vol 70, No.2, February 2011, PP-261-274.
[2] A.Weng, J.Sun. “Oscillation of second order delay differential equations”, Appl.Math.Comput, vol 198, No.3, March 2008, PP-930-935.
[3] J.Manojlovic, Y.Shoukaku, T.Tanigawa, N.Yoshida. “Oscillation criteria for second order differential equations with positive and negative coefficients”, Appl.Math.Comput, vol 81, No.5, May 2006, PP-853-863.
[4] Mei Fengxiang, Wu Huibin, Differential Analysis of Mechanical Methods, Beijing: Science Press, 2012.
[5] Liu Jun, Luo Hongying Luo, Liu Xi. “Oscillation criteria for half-linear function differential equations with damping”, Thermal Scienc, vol.18, No.5, October 2014, PP-1537-1542.
[6] Liu Jun,Dai Zhengde,Mu Gui, Liu Xi. “New abundant exact solutions for Kundu equation”, Acta Mathematicae Applicatae Sinica, vol.38, No.3, June 2015, PP-729-734.
[7] Liu Jun, Mu Gui, Dai Zhengde, Luo Hongying.” Spatiotemporal deformation of multi-soliton to (2+1)-dimensional KdV equation. Nonlinear dynamics”, vol.83, No.3, January 2016, PP-355-360.
[8] Zeng Yunhui, Luo Liping, Yu Yuanhong."Oscillation for Emdewn-Fowler differential equations of neutral type", Acta Mathematica Scientia, vol.35, No.4, April 2015, PP-803-814.
[9] Zhang Zhiyu, Wang Xiaoxia.″Oscillation of third-order half linear neutral differeential equations with distributed delay″, Acta Mathematicae Applicatae Sinica, vol.38, No.3, March 2015, PP-450-459..
[10] Lin Quanwen, Yu.Yuanhong. "Oscillatory and asymptotic properies for third order half-linear delay differential equations".J.Sys.Sci.& Math.Scis. vol.35, No.2, February 2015, PP-233-244.
[11] Z.L.Han, T.X.Li, S.R.Sun and W.S.Chen, “Oscillation of second order quasilinear neutral delay differential equations”,J.Appl.Math.Comput. vol.40, No.2, February 2012, PP-143-.152.
[12] H.D.Liu, F.W.Meng and P.C.Liu, “Oscillation and asymptotic analysis on a new generalized Emden-Fowler equation”,Appl.Math.Comput. vol.219, No.10, October 2012, PP-2739-.2748
[13] L.Erbe, T.S.Hassan, A.Peterson. “Oscillations of second order neutral delay differential equation”, Adv.Dynam.Syst.Appl., vol 24, No.3, March 2008, PP-53-.71
[14] C.G.Philos. “Oscillations theorems for linear differential equations of second order”, Arch.Math., vol 51, No.3, March 1989, PP-482-.492.