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Review of the performance of fuzzy controller to improve sustainability in the mamdani's type of transient in SVC electric power systems

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***Abstract*—In this paper the structure of the model and practice of SVC (one of the small FACTS) we offer and we show that the fuzzy logic controller with use of the equipment has been used, since the FACTS of transient stability in power system data will be improved. Membership functions of fuzzy controlling this by a conventional PI control is controlling. Simulations made in two sections, one of which is the machine finally, the bass is connected and the other in a symmetrical line will be fed from both sides and the two regions, suggests that the system of transient is a perfect stability. In the model presented in the middle of two located in the SVC, and fluctuations in the local area of the transient between damping and in this way we will show that the fuzzy logic control of transient stability for an improvement in the power system will be.**

Keywords—Fuzzy logic; transient stability; FACTS; Damping; power system

I. INTRODUCTION

With the expansion of power systems need more electrical energy production and migration and due to reasons such as to minimize the reactance line and be reactive and transitional reduction of the toll line, increasing the high costs for the maintenance of the transitional power line, due to the rapid erosion of the mechanical parts, the deterioration of insulation oil, Slow to responses and quality improvement can make use of the increased compensation is houses [1]. However, the cost of compensating the disadvantages such as high maintenance with due to erosion. The rapid deterioration of insulation oil and mechanical parts, slow responses are [2].

But, in connection with the use of a remedy, one of the important parameters in power systems is of particular importance, sustainability is transient. Transient stability of power system in maintaining the ability of synchronization and when the system was not affected by turbulence are like short circuit prevention, loss of production, or the loss of a great load and... is high important[3].

Power system stability to the position and behavior of the synchronous machines after the occurrence of turbulence depends. Transient stability in relation to the present several methods provided that they can be used, including genetic, neural and fuzzy method to reference.

One of the other problems in power systems is a swing. Swing falls occur when the area in which the generator can be used for stimulation of the fluctuations of the stability damping power system (PSS) we used. The use of controller of FACTS like the SVC and STATCOM with PSS can improve power system stability of transient and prevention to reduce power system swings [4].

Our goal in this article is the use of a combination of the above methods to improve is the stability transient of the power system. To achieve this goal, we ad simulation system in two part. It should be noted that the capacity to be a transition can be improved by proper composition elements of passive and active is FACTS controllers [4].Of the FACTS controller can be used in a series of four categories of controller, the controller of a parallel series of combination control-and parallel-series combined controller in the Division.

II. HISTORY

The stability of the power system, one of the key topics in power systems is that during the past years has been a highly regarded engineer. In 1920 the stability of power system as the basic and fundamental criterion in power systems was raised, and on this basis was considered retrofitting requirements power systems [5, 6]. In 1924 the first results obtained from stabilization of power systems were presented in small scale [7]. Of course, it should be noted that the first field experiment related to the stability of a power system and in 1925 was on a power system with a simple syntax to perform receipts [8].In First, the issue of water power stability was raised to that of a long distance through the transmission lines feeding the urban centers of the time, and often tear their short because of medical errors that happen in the connection has been disabled [9]. Several methods, including line of artificial rubber and mechanical calculator and pictorial methods including equal levels of criteria and circular images, etc. Offered at this time. Study on the methods for simple systems and two machine and stability of steady-state and transient studied separately and transient stability of the slope and the angle of the curve peak are irrelevant-they can be. In a small scale model of the 1930the power system using AC resistance, reactors, capacitors adjustable load and network models, and in this way to display generators, voltage source with adjustable amplitude and angle, etc. [10] was used.

Theoretical point of view, the 1920s and 1930s can be the starting point of power system stabilization. Due to the study concerning power transmission during the long routes, provide stability and knowledge related to the possibility of improving the system stability using the faster elimination of medical errors, and system arrangement of continuous performance and voltage without the existence of the band was stagnant.

In the early 1920 sustainability were raised and persistent mode however was not recommended for dynamic stability of performance was ordinary, but as an additional margin for determining the working system was used approximately [7, 11].

Modeling system, fuzzy systems, knowledge-based systems, or the rules are. The heart of a fuzzy system is that knowledge base of rules (if-then) is made fuzzy. A fuzzy inference system of the four following main part is formed: 1) input values as being fuzzy turned to fuzzy values is 2) database of knowledge that Fuzzy membership functions and rules information in itself, the fact that a mechanism to overcome the engine 3) argument specifies the system and 4) The non-fuzzy connector output into a definitive system of fuzzy number and the real transformation.

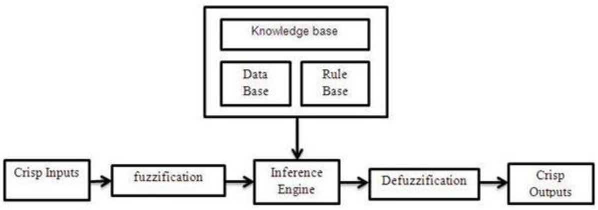

Fig. 1. *Block diagram of a fuzzy inference system*

The block diagram in Figure 1 as a fuzzy dot of mapping with fuzzy sets A' real value to a 'is in the U In fact, this is a part of the output is the same as the number of fuzzy membership function of the fuzzy degree of membership in the input or input the amount of the height of the point of entry in the form of this function is a number between zero and one, respectively.

Assumes two sets X and Y (x) two sets of reference and μA(x) and μB(y) membership function (y) are two categories. Then the following argument can be considered:

Derivation fuzzy-mamdani model

$$\mu_{A\to B}(x,y)=\mu_A(x)\cap\mu_B(y) \tag{1}$$

Larsson Model

$$\mu_{A\to B}(x,y)=\mu_A(x)\cdot\mu_B(y) \tag{2}$$

Derivation model 1

$$\mu_{A\to B}(x,y)=(\mu_A(x)\cap\mu_B(y)\cup(1-\mu_A)) \tag{3}$$

Derivation model 2

$$\mu_{A\to B}(x,y)=1\cap\left(\left(1-\mu_A\right)+\mu_B\right) \tag{4}$$

Non-fuzzy mapping as a day of the fuzzy set B ' and in (which is its engine output) to the actual point, respectively. Conceptual basis of choosing a non-fuzzy point in V that is the best way of fuzzy sets is B 'represents. Non-fuzzy is the most complex part of any fuzzy system is considered, and therefore many methods of non-fuzzy to have been the creation [11, 12].

A single machine the system connected to an infinite bus we would consider. Synchronous generators are connected to the power grid and times are subscribers can provide. The equations governing the rotor with consideration of the following expression changes the output speed of the car as you have:

$$\frac{d\delta_j}{dt}=\omega_j-\omega_o \tag{5}$$

$$\frac{d\omega_j}{dt}=\frac{1}{M}(p_{mj}+D\ \omega_j-P_{ej}) \tag{6}$$

The torque equation can be considered as follows:

$$\frac{dE'_{dj}}{dt}=\frac{1}{T'_{q0}}(-E_{dj}+(x'_{qj}-x_{qj})i_{qj}) \tag{7}$$

The equations for the simulation of the flow as a source of SVC controlled by voltage or sucptance variables are assumed to be fitted to the model as follows:

$$B_L(\sigma) = \frac{\sigma - \sin\sigma}{\pi x_L} \quad (8)$$

$$\left(I_{\min} \le I_{SVC} \le I_{\max}, V \ge V_{\min}\right)$$
$$V = V_{ref} - X_{sl}.I_{SVC} \quad (9)$$

The relationship between compensation active substance (B_L) and the angle h is a non-linear relationship to the main frequency is. CB substance capacitor that allows you to operate between the two regions and the self-capacitor. Rear side of saddle wire voltage stator with equations consider the output speed of the machine that changes as appropriate in a variable damping used volatility, can be expressed as follows:

$$V_q = -\frac{r_s}{L'_q}\left(\frac{-E'_d}{\omega} - \lambda_q\right) + \frac{d\lambda_q}{dt} + \omega_r\lambda_d \qquad V\,or\,pu \quad (10)$$

$$V_d = -\frac{r_s}{L'_d}\left(\frac{E'_q}{\omega} - \lambda_d\right) + \frac{d\lambda_d}{dt} - \omega_r\lambda_d \quad (11)$$

Electromagnetic torque equations: when stable speed maximum motor freight to the torque of the generator can supply the following relationships is fixed, comes from:

$$T_{em} = \frac{3}{2}\frac{P}{2}\left\{\frac{\lambda_d E'_d}{\omega_r L'_q} + \frac{\lambda_q E'_q}{\omega_r L'_d} - \left(\frac{1}{L'_d} - \frac{1}{L'_q}\right)\lambda_d\lambda_q\right\} \quad (12)$$

$$T_{em} = \frac{3}{2}\frac{P}{2}\left\{\frac{E'_q i_q + E'_d i_d}{\omega_r} - \left(L'_d - L'_q\right)i_d i_q\right\}$$
$$= \left\{\frac{E'_q i_q + E'_d i_d}{\omega_r/\omega_b} - \omega_b\left(L'_d - L'_q\right)i_d i_q\right\} \quad (13)$$

Equations to consider rotor machine output speed changes that can be used as a variable damping appropriate, the following relationships are obtained:

$$J\frac{d\omega_{mm}}{dt} = T_{em} + T_{mech} - T_{damp} \quad (14)$$

$$2H\frac{d\{(\omega_r - \omega_e)/\omega_b\}}{dt} T_{em(pu)} + T_{mech(pu)} - T_{damp(pu)} \quad (15)$$

$$\frac{d\delta_e}{dt} = \omega_r - \omega_e \quad , \qquad \omega_r = \frac{P}{2}\omega_{rm} \quad (16)$$

Transient in power systems cause nonlinear system is a system of equations is very heavy and the type of system, the system of equations is also different.

III. SIMUTALION RESULT

SMIB system is the first system studied. Robust design and optimization of fuzzy systems studied at various operating points are shown in Table 1.

TABLE I. HOW TO CHANGE THE SYSTEM OF DESIGNING THE CONTROLLER FOR A SINGLE MACHINE

Operating Point	Active Power	Reactive Power	Reactance	PF Type	H
1	0.8	0.4	0.3	Phase	3.25
2	0.5	0.1	0.3	Phase	3.25
3	1.0	0.5	0.3	Phase	3.25
4	0.8	0.4	0.6	Last Phase	3.25
5	0.5	0.1	0.6	Last Phase	3.25
6	1.0	0.5	0.6	Last Phase	3.25
7	0.8	0.0	0.6	--	3.25
8	1.0	0.2	0.6	Last Phase	3.25
9	0.5	0.2	0.6	Last Phase	3.25
10	1.0	0.2	0.3	Phase	0.81

Design the appropriate performance and optimal controller based on a lot of time to try and test the error takes place. Optimal choice of fuzzy rules from the other side for fuzzy membership functions and shape of the controller for this type of controller to improve the performance of the system is of particular importance.

The objective function is introduced for the design of four as the Figure of Demerit (FD), Time multiplied Absolute value of the Error (ITAE), Square Error (ISTSE) Integral Square Time of the Absolute Error (ISTAE) Integral Square Time of use it is.

$$FD = \sum_{i=1}^{N_p}(500\times OS)^2 + (800\times US)^2 + 0.01\times T_s^2 \quad (17)$$

$$ITAE = \sum_{i=1}^{N_p}\int_0^{t_{sim}} t(|\Delta\omega|).dt \quad (18)$$

$$ISTAE = \sum_{i=1}^{N_p}\int_0^{t_{sim}} t^2(|\Delta\omega|).dt \quad (19)$$

$$ISTSE = \sum_{i=1}^{N_p}\int_0^{t_{sim}} t^2.\Delta\omega^2.dt \quad (20)$$

In Figure 2, the output speed of the generator power system changes with the torque applied to the size of the error is 0.1 seconds in 1 time is shown.

Also, Figure 3, power system generator output velocity changes studied with error 1 time as torque 0.1 seconds and shows.

In tables 2 and 3 results of the comparison have been introduced between the function of test is displayed. Finally proposed how the convergence of the algorithm in Figure 4 in the proposed controller optimized design with the help of four introduced objective function is provided.

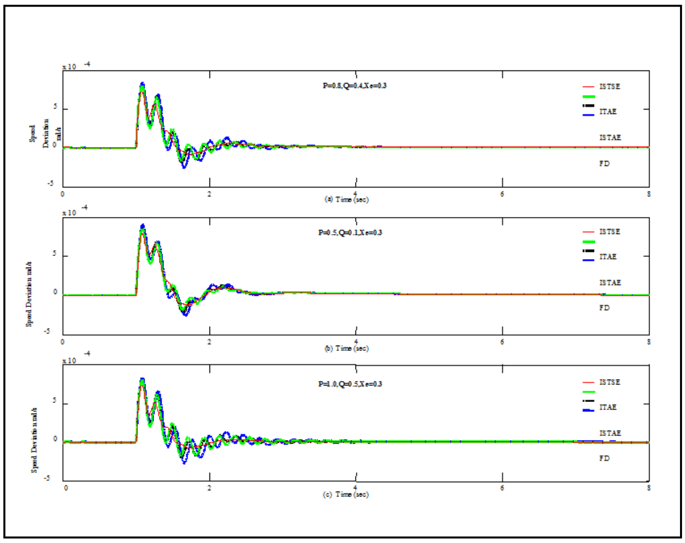

Fig. 2. *Changes in the systems studied by applying the error rate generator output torque during the first 0.1 seconds*

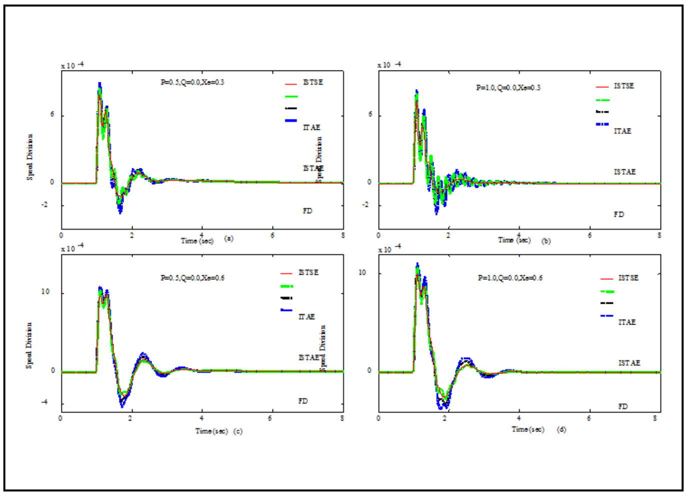

Fig. 3. *Changes in the systems studied by applying the error rate generator output torque during the first 0.1 seconds.*

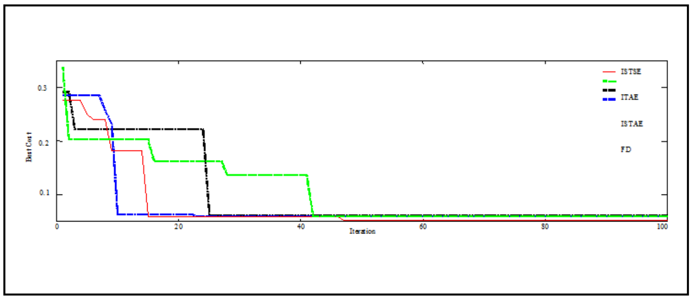

Fig. 4. *The convergence of the proposed control algorithm in optimal design using four objective functions presented.*

TABLE II. THE RESULTS OF SIMULATIONS CONDUCTED TO COMPARE THE OBJECTIVE FUNCTIONS ARE INTRODUCED TO HELP

Work Consideration	**ITAE**				**FD**			
	ITAE	FD	ISTSE	ISTAE	ITAE	FD	ISTSE	ISTAE
1	0.5316	0.6806	0.0170	1.3360	0.5951	1.0225	0.0212	1.3778
	0.8340	0.7651	0.0238	2.7279	0.8804	1.0837	0.0284	2.5517
	0.4396	0.7158	0.0157	0.8869	0.5173	1.0755	0.0200	0.6496
2	0.7704	1.2101	0.0455	1.4602	0.9943	1.8496	0.0636	1.8131
	1.0917	1.3683	0.0568	2.9185	1.3032	2.3175	0.0769	2.2961
	0.7632	1.3312	0.0486	1.3414	1.0353	1.9249	0.0697	0.3343
3	0.8340	0.7651	0.0238	2.7279	0.8804	1.0837	0.0284	2.5517
	0.4396	0.7158	0.0157	0.8869	0.5173	1.0755	0.0200	0.6496
	1.0917	1.3683	0.0568	2.9184	1.3032	2.3175	0.0769	2.2961
	0.7632	1.3312	0.0486	1.3414	1.0353	1.9319	0.0697	0.3343
4	0.5316	0.6806	0.0170	1.3360	0.5951	1.0275	0.0212	1.1777
	0.4396	0.7158	0.0157	0.8869	0.5173	1.0755	0.0200	0.6496
	0.7704	1.2101	0.0455	1.4602	0.9943	1.8496	0.0636	0.8131
	0.7632	1.3312	0.0486	1.3414	1.0353	1.9319	0.0697	0.3343
5	0.5398	3.2351	0.0253	1.2637	0.6291	4.2530	0.0315	1.3228
	0.8808	4.7434	0.0590	1.8689	1.0010	6.4666	0.0707	1.4529
	0.5395	3.2336	0.0254	1.2631	0.6297	4.2525	0.0316	1.3232
	0.5399	3.2351	0.0253	1.2636	0.6302	4.2507	0.0316	1.3241
6	0.4396	0.7158	0.0157	0.8869	0.5173	1.0755	0.0200	0.8496
	0.5316	0.6806	0.0170	1.3360	0.5951	1.0275	0.0212	1.1777
	0.7632	1.3312	0.0486	1.3414	1.0353	1.9249	0.0697	0.3343
	0.9423	1.2020	0.0503	2.2680	1.1474	2.0418	0.0688	1.6703

TABLE III. RESULTS FOR COMPARISON BETWEEN DESIGNS

Work Consideration	ISTAE				ISTSE			
	ITAE	FD	ISTSE	ISTAE	ITAE	FD	ISTSE	ISTAE
1	0.5511	0.7500	0.0184	1.3774	0.5022	0.4727	0.0148	1.2787
	0.8655	0.9222	0.0262	2.7821	0.8381	0.5604	0.0233	2.7307
	0.4422	0.7871	0.0166	0.8902	0.3780	0.4632	0.0127	0.7544
2	0.8944	1.4693	0.0550	1.7404	0.7822	1.1228	0.0461	1.4352
	1.2133	1.7946	0.0681	3.1765	1.1247	1.3983	0.0588	2.9872
	0.9082	1.6457	0.0594	1.6638	0.7777	1.2101	0.0490	1.3848
3	0.8655	0.9222	0.0262	2.7821	0.7381	0.5604	0.0233	2.1307
	0.4422	0.7871	0.0166	0.8902	0.3780	0.4632	0.0127	0.7544
	1.2133	1.7946	0.0681	3.1765	1.1247	1.3983	0.0588	2.9872
	0.9082	1.6457	0.0594	1.6637	0.7777	1.2101	0.0490	1.3848
4	0.5511	0.7500	0.0184	1.3774	0.2021	0.4727	0.0148	1.0786
	0.4422	0.7871	0.0166	0.8902	0.3780	0.4632	0.0127	0.7544
	0.8944	1.4693	0.0550	1.7404	0.7822	1.1228	0.0461	1.4852
	0.9082	1.6457	0.0594	1.6638	0.7777	1.2101	0.0490	1.3848
5	0.5002	3.4209	0.0248	1.0858	0.4654	2.2101	0.0214	1.0921
	0.9870	5.4430	0.0679	2.0524	1.0741	5.8390	0.0805	2.2419
	0.5007	3.4322	0.0250	1.0866	0.4656	2.2116	0.0214	1.0924
	0.5011	3.4337	0.0249	1.0871	0.4662	2.2200	0.0215	1.0936
6	0.4422	0.7871	0.0166	0.8902	0.3780	0.4632	0.0127	0.7544
	0.5511	0.7500	0.0184	1.3774	0.5021	0.4727	0.0148	1.2786
	0.9082	1.6457	0.0594	1.6638	0.7777	1.2101	0.0490	1.3848
	1.5303	0.0604	2.5238	0.9661	0.9661	1.2237	0.0517	2.3194

IV. RESULT

In this article, our studies on one of the most important features of the improved transient stability or increase the FACTS, the transient stability of power system in maintaining the ability is synchronism when the system was not affected by turbulence are like short circuit prevention, loss of production, loss of a great load and Splitting. Such big fluctuations in turbulence that caused the rotor necessary for the voltage of power generators and other transitional shine will be system variables. The transient stability of system of non-linear characteristic of accepts. If the angle of deviation of the system within the machine come with cattle between the day of the synchronism system of the concrete will remain.

With different power systems simulation to develop this important topic that increased stability or improve the FACTS will be transient, we got. It should also be noted that in order to increase the stability of the power grid, non-fuzzy controller design as the controller is needed.

Transient stability increases when we have other result that does not also include increasing the stability of generators, voltage fluctuations and improved profile of damping and torque refers to the requirement that each study is more precise. In designing the proposed controller only has interest from a business point of view, but we've several used resistant working conditions being our work compared to other articles shows.

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