Improving Transient Stability with Fuzzy Logic ControllerandDistributed Static Series Compensator

M.Rajeswari
Department of Electronics and Electrical Engineering
AITS, Rajampet, Andhra Pradesh, India

P.Bhaskara Prasad
Department of Electronics and Electrical Engineering
AITS, Rajampet, Andhra Pradesh, India

C.Ganesh
Department of Electronics and Electrical Engineering
AITS, Rajampet, Andhra Pradesh, India
ganesh.challa@gmail.com

Abstract--Most of the transmission lines use AC for long distance power transmission. However, such transmission systems are prone to stability problems which lead to the deterioration of transmission capability. Between synchronous generators, weekly damped swings is the main problem faced by large power systems. Transient stability plays an important role in power systems. Enhancing transient stability is the active area of research. Golshannavaz et al. enhanced the transient stability of power system using Distributed Static Series Compensator (DSSC). It includes function similar to SSSC (Static Synchronous Series Compensator) but with lower price and small size. The controller used in their experiments is Proportional Integral Controller which is not flexible and does not allow changes once input is given. To overcome this problem, in this paper we enhance the DSSC with Fuzzy Logic Controller which has a new set of rules. It does mean that we replace the PI controller with Fuzzy Logic Controller which provides optimum solution to the stability problems in power systems.

Index Terms –Power transmission systems, transient stability, PI controller, fuzzy logic controller

I. INTRODUCTION

In power systems that take care of long distance transmission of power care has to be taken to avoid disturbances. Stability is important in such power systems. The stability is based on various factors and different operating conditions. Transient stability is the frequently considered problem in power systems. This stability is achieved by constant maintenance of synchronism between generators when disturbance is encountered from server [1]. A recent development in power electronics is FACTS (Flexible Alternative Current Transmission System) that act as controllers in power systems. These controllers are popular in controlling conditions of a network rapidly. This feature of FACTS can help improving the transient stability of power systems [2], [3], [4], [5], [6], [7]. In spite of very good advantages of FACTS, it also suffers from some limitations. The limitations are as follows.

1. Costly due to more components and device complexity.
2. Has a problem known as “Single Point of Failure”
3. It may result in poor ROI in future as the devices are costly due to hype in the market.

Of late a new flavor of FACTS came into market. It is distributed in nature and named as “D-FACTS”. This is able to get rid of limitations of its predecessor. With all features of FACTS, the D-FACTS used novel mechanism for power flow control. It is more successful as it is distributed in nature and has fine grainedcontrol over the process. For utilizing single-phase inverter DSSC is the base and achieves power flow. DSSC has many capabilities. Many researchers focused on modeling and interrogating of this as it offers simulation model graphically. It also explores singe phase system with voltage source and one DSSC without the need for generators. For this reason further study of DSSC was required.

Golshannavaz et al. [8] studied DSSC further in order to integrate 1400 DSSCs and perform experiments on the transient stability of power systems. They also designed a supplementary controller for the purpose which has a control loop pertaining to DSSCs. Their simulation results revealed that the DSSCs have their impact on the enhancing transient stability of power systems. In this paper we replace the PI controller with Fuzzy Logic controller for more flexibility and also enhance the transient stability of power systems further. Our contribution in this paper is developing a fuzzy logic controller that is used with DSSC for enhancing transient stability of power systems further. The rest of the paper is structured as follows. Section II provides review of literature. Section III provides details of proposed system. Section IV presents experimental results while section V concludes the paper.

II. STABILITY ENHANCEMENT DSSC WITH FUZZY LOGIC CONTROLLER

Before elaborating the enhancement proposed by us, we briefly describe the DSSC and its underlying concepts. The concept of DSSC is based on the devices used in power systems such as FACTS. As a matter of fact FACTS is a model pertaining to SSSC in miniature features. More control and safety are possible with the distributed nature of DSSC. The general overview of the DSSC explored in power systems is as shown in figure 1.

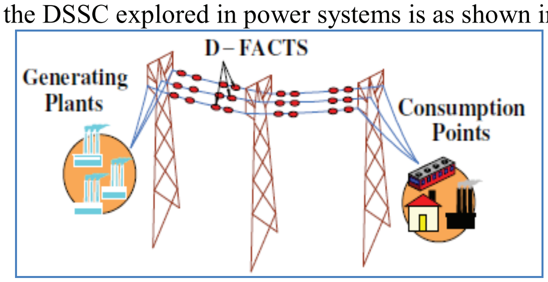

Fig. 1 –Schematic overview of DSSC (excerpt from [8])

As can be seen in figure 1, the D-FACTS devices which are improved variants of FACTS are employed in power lines in distributed fashion. The drawbacks of FACTS such as device complexity, single point failure, and poor ROI are overcome using D-FACTS devices. The number of DSSC modules employed on the power lines has their impact on the reduction of stability problems. As matter of fact, figure 1 does not show the minute details of DSSC while shows it at abstract level. Figure 2 shows the anatomy of a DSSC module.

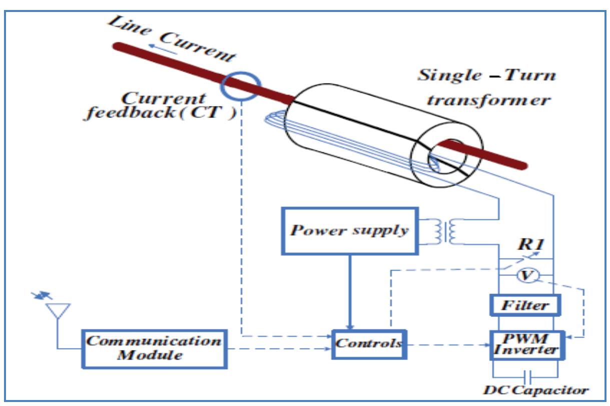

Fig. 2 –Minute details of DSSC module

As can be seen in figure 2, it is evident that the DSSC module has many components like Single-Turn transformer, communication module, filter, PWM inverter, power supply and controls. It has pre-defined communication capabilities as explored in [9]. Out of the components, STT is very crucial for the functionality of DSSC. It uses conductor in order to reduce the current being handled by the inverter and realize lower cost [10]. Such DSSC modules in series are connected to transition lines. They have capability of increasing transmittable power. They can also reverse polarity of the ac voltage that has been injected[11]. The main goal of DSSC is to control power flow problems in transmission lines. As a result of DSSC the power being transmitted over transmission lines can become a parametric function which can re represented as follows[12].

$$P_{12} = \frac{V_1 V_2}{X_L} \sin\delta - \frac{V_1 V_q}{X_L} \cos\left(\frac{\delta}{2}\right) \left[\frac{\sin\left(\frac{\delta}{2}\right)}{\sqrt{\left(\frac{V_1 + V_2}{2 V_2}\right)^2 - \frac{V_1}{V_2} \cos^2\left(\frac{\delta}{2}\right)}} \right]$$

Here, the bus voltage magnitudes are represented by V1 and V2. The series injected voltage magnitude is represented by V_q. The difference in voltage phase is represented as δ, and the line impedanceis represented by $X_{L.}$ The existing simulation model for transient stability with DSSC proposed in [17]is as presented in figure 3.

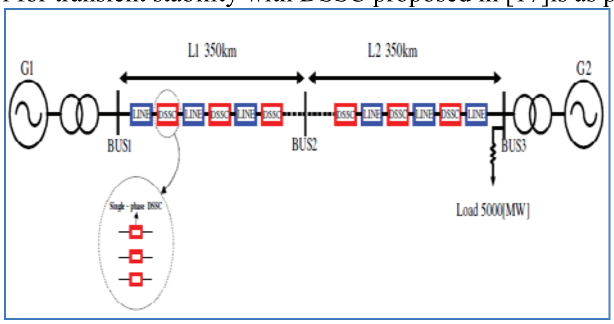

Fig. 3 –Simulation model of two machine power system for transient stability with DSSCs (excerpt from [8])

As can be seen in figure 2, it is evident that the DSSC modules are used as a series through the power transmissionlines. More technical details about this model can be found in [8].

III. Fuzzy Logic Controller

In this paper we intend to replace PI controller with DSSC explored in [8]. The PI (Proportional Integral) controller is not flexible. The voltage output cannotbe controlled and inputs once given cannot be changed. Once the simulationstarts, the values cannot be changed in between. To overcome this drawback, in this paper we proposed a fuzzy logic controller which is very flexible in nature. This controller is governed by a set of rules. For simulations we built a fuzzy controller using Fuzzy tool box. The simulation output for transientstability enhancement using DSSC with fuzzy controller is as shown in figure 4.

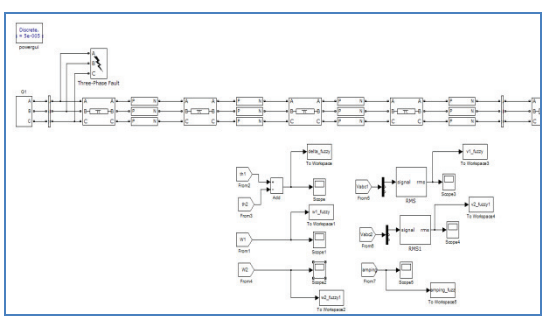

Fig. 4 –Simulation diagram for DSSC with fuzzy logic controller

As can be seen in figure 4, the Fuzzy Logic Controller brings about precision and significance in enhancing transient stability in power systems. Fuzzy logic provides convenient means to map inputs with output space. This will help in achieving flexibility. The results of the experiments with fuzzy logic controller with DSSC for efficient transient stability enhancement are shown in a series of graphs below.

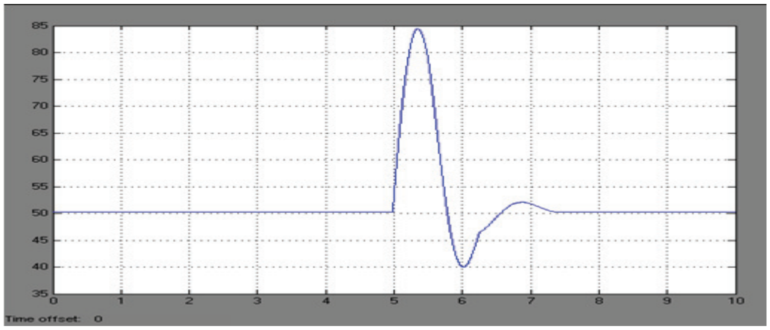

Fig. 5 –Time vs. Delta

As seen in figure 5, the horizontal axis represents time of simulation while the vertical axis represents the Delta measured in degrees. As the results reveal between 5 and 6 seconds the delta degree is very high. Again at 6^{th} second it is very least. Except this the delta is at 50 degrees consistently across the simulation.

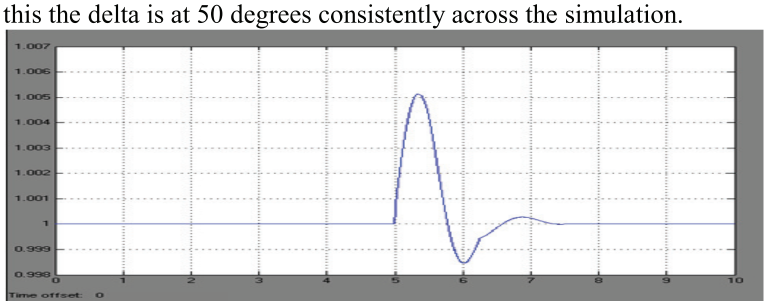

Fig. 6 – Time vs. speed

As seen in figure 6, the horizontal axis represents time of simulation while the vertical axis represents speed in per unit with which the DSSC with fuzzy logic controller operates. As the results reveal between 5 and 6 seconds the speed is very high. Again at 6^{th} second it is very least. Except this the speed is at 1per unit consistently across the simulation.

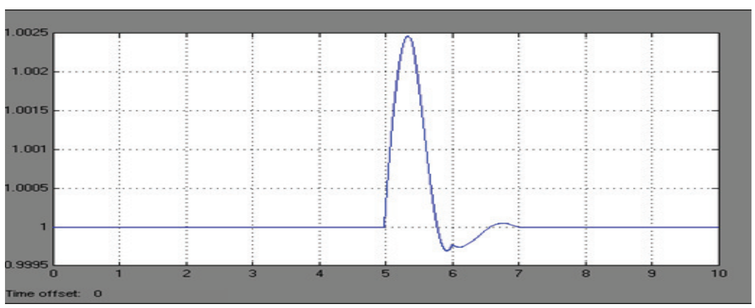

Fig. 7 – Time vs. speed (second simulation)

As seen in figure 7, the horizontal axis represents time of simulation while the vertical axis represents speed in per unit with which the DSSC with fuzzy logic controller operates. As the results reveal between 5 and 6 seconds the speed is very high. Between the time 6 and 7 the speed increased gradually till it reaches 1. Again at 6^{th} second it is very least. Except this the speed is at 1 per unit consistently across the simulation.

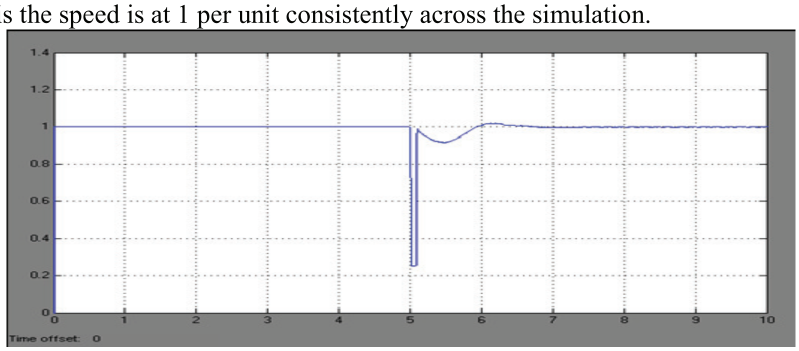

Fig. 8 – Time vs. voltage

As seen in figure 8, the horizontal axis represents time of simulation while the vertical axis represents voltage in per unit with which the DSSC with fuzzy logic controller operates. As the results reveal,at time 5 the voltage hits lowest. Between the time 5 and 6 the voltage increased gradually till it reaches 1. Except this the speed is at 1 per unit consistently across the simulation.

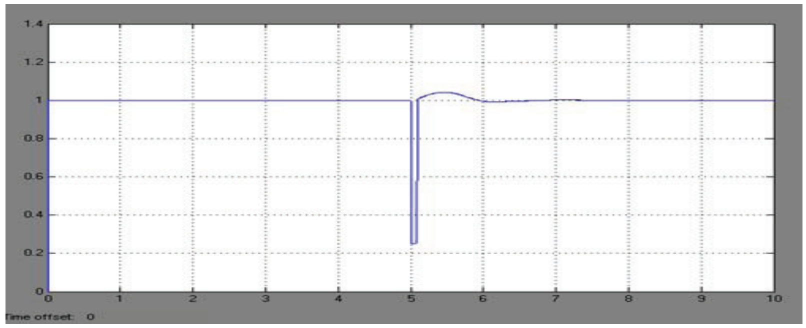

Fig. 9 – Time vs. voltage (second simulation)

As seen in figure 9, the horizontal axis represents time of simulation while the vertical axis represents voltage in per unit with which the DSSC with fuzzy logic controller operates. As the results reveal, at time 5 the voltage hits lowest. Between the time 5 and 6 the voltage increased gradually till it reaches beyond 1. Except this the speed is at 1 per unit consistently across the simulation.

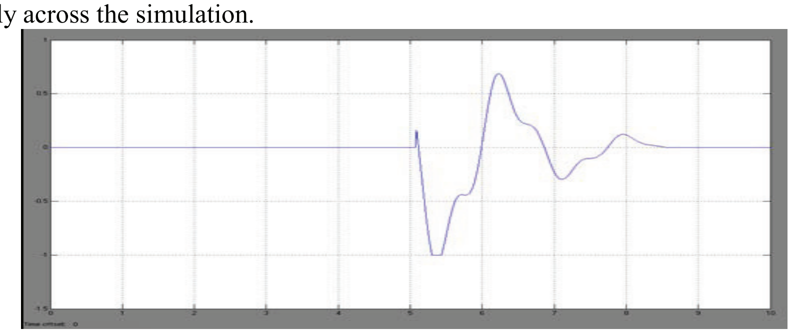

Fig. 10 – Illustrates damping fuzzy

As seen in figure 10, the results reveal details of damping fuzzy with which the DSSC with fuzzy logic controller operates. As the results reveal, between time 5 and 6 the damping factor hits lowest. Again it gradually increases between the time 5 and 6 the damping factor increased gradually till it reaches beyond 0.5 up. Between time 6 and 8 also there are fluctuations in damping factor reading.Except this the speed is at 0 consistently across the simulation.

IV. CONCLUSION

In this paper we studied the stability problems in power systems. The availability of devices such as D-FACTS is has simplified the deployment process and also the cost involved in FACTS, its predecessor. These are the distributed devices that work in tandem with DSSC for enhancingtransient stability of power systems. In order to improve the transient stability margin of the power system POD controller is sued along with DSSCs. A series of DSSCs deployed on transmission lines could enhance transient stability in [8]. In this paper we enhance that system further by replacing PI controller with Fuzzy Logic controller which is more flexible and gets more margins in transient stability enhancement. Out simulation results revealed that the proposed controller along with distributed DSSCs can enhance transient stability in power systems.

REFERENCES

[1] P. Kundur, Power system stability and control, Prentice-Hall,N. Y, U. S. A, 1994.
[2] R. Majumder, B. C. Pal, C. Dufour and P. Korba, “Design andrealtime implementation of robust FACTS controller fordamping inter-area oscillation,” IEEE Trans. Power Syst, vol.21, no. 2, pp.809–816, 2006.
[3] L.J., Cai and I., Erlich. “Simultaneous coordinated tuning ofPSS and FACTS damping controllers in large powersystems”, IEEE Trans. Power Syst, vol. 20, No. 1, pp. 294-300, 2005.
[4] M. S. El-Moursi, A. M. Sharaf, and K. El-Arroudi, “Optimalcontrol schemes for SSSC for dynamic series compensation,”Elect. Power Syst. Res., vol. 78, no. 4, pp. 646–656, 2008.

[5] J. G. Singh, S. N. Singh, and S. C. Srivastava, “Enhancementof power system security through optimal placement of TCSCand UPFC,” in Proc. IEEE PES General Meeting, pp. 1–6,Jun, 2007.

[6] A.H.M.A Rahim and M.F. Kandlawala, “Robust STATCOMvoltage controller design using loop shaping technique,”Electric Power System Research, 68, 2004, pp.61-74.

[7] M. Bongiorno, J. Svensson, and L. Angquist, “On control ofstatic synchronous series compensator for SSR mitigation,”IEEE Trans. Power Electron., vol. 23, no. 2, pp. 735–743,Mar. 2008.

[8] S.Golshannavaz, M.Mokhtari, M.Khalilian, and D.Nazarpour, Transient Stability Enhancement in Power System with DistributedStatic Series Compensator (DSSC).

[9] Deepak Divan, “Distributed Intelligent Power Networks-ANew Concept for Improving T&D System Utilization andPerformance,” IEEE Transmission and DistributionConference, New Orleans, Louisiana, 2005.

[10] D. M. Divan, W. Brumsickle and R. Schneider, “DistributedFloating Series Active Impedance for Power TransmissionSystems,” U.S. Patent Application # 10/679.966.

[11] L. Gyugyi, C.D. Schauder and K.K. Sen, “Static SynchronousSeries Compensator: a Solid-State Approach to the SeriesCompensation of Transmission Lines,” IEEE Trans. PowerDelivery, vol. 12, No. 1, Jan. 1997, pp.406-417.

[12] P. Fajri, D. Nazarpour and S. Afsharnia, “A PSCAD/EMTDCModel for Distributed Static Series Compensator (DSSC),”Electrical Engineering, ICEE 2008. Second InternationalConference on Publication, March 2008.