The 32nd Electrical Engineering Conference (EECON32)

This certification is issued for

Dr. Javad Sadeh

For his presentation in the paper entitled
"Comparative Analysis on Impact of Series FACTS Controllers Applied Strategies on Subsynchronous Resonance"

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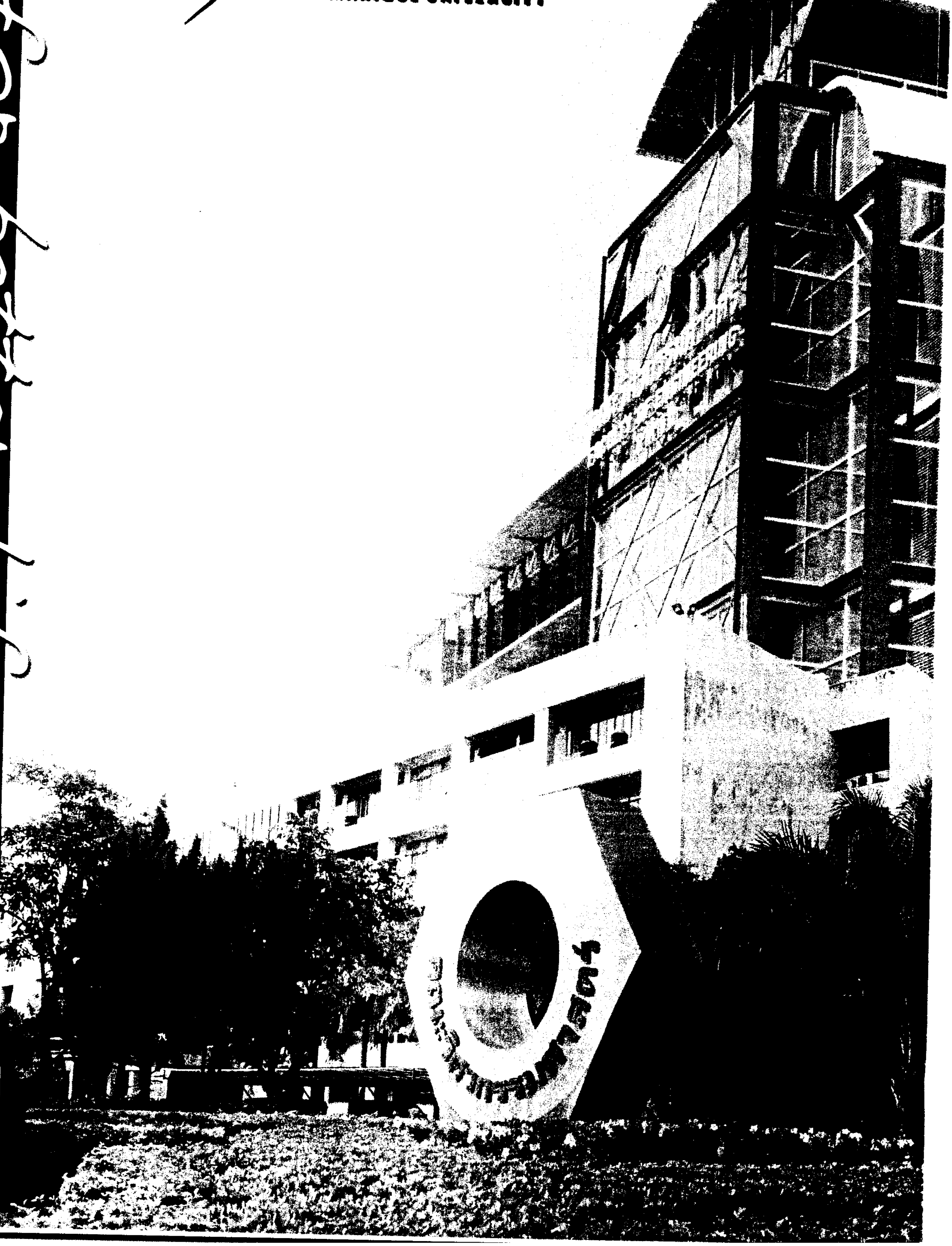

PROCEEDINGS
VOL. 1

PW - Electrical Power System
PE - Power Electronics
CT - Control System and Instrument Technology
CP - Computer and Information Technology

EECON 32

การประชุมวิชาการทางวิศวกรรมไฟฟ้า ครั้งที่ ๓๒

๒๘-๓๐ ตุลาคม ๒๕๕๒ โรงแรมทวาราวดี รีสอร์ท จ.ปราจีนบุรี

32nd Electrical Engineering Conference

28-30 October 2009 Tawaravadee Resort Hotel, Prachinburi, Thailand

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จัดการประชุมโดย ภาควิชาวิศวกรรมไฟฟ้า
หลักสูตรวิทยาศาสตรมหาบัณฑิต สาขาวิชา
เทคโนโลยีการจัดการระบบสารสนเทศ
และภาควิชาวิศวกรรมชีวการแพทย์
คณะวิศวกรรมศาสตร์ มหาวิทยาลัยมหิดล

วันศุกร์ที่ 30 ตุลาคม 2552 เวลา 08:20 น.–10:20 น.

ห้อง Convention B

ประธานกลุ่มย่อย อ.ดร.พรระพีพัฒน์ ภาสบุตร

มหาวิทยาลัยธรรมศาสตร์

PW 074 เวลา 08:20 – 08:40 น.

ผลกระทบของการผลิตไฟฟ้าจากพลังงานลมต่อเสถียรภาพเชิงแรงดันของระบบส่งไฟฟ้าในภาคตะวันออกเฉียงเหนือของประเทศไทย

พิสิษฐ์พล จิรพงศานานุรักษ์ และ แนบบุญ หุนเจริญ

บทความนี้นำเสนอผลการวิเคราะห์เสถียรภาพเชิงแรงดันของระบบส่งไฟฟ้าในภาคตะวันออกเฉียงเหนือของประเทศไทย โดยพิจารณาถึงผลกระทบของการผลิตไฟฟ้าจากพลังงานลมที่จะติดตั้งในบริเวณอำเภอเขาค้อ จังหวัดเพชรบูรณ์ เปรียบเทียบสมรรถนะในกรณีที่ใช้เทคโนโลยีเครื่องกำเนิดไฟฟ้าเหนี่ยวนำแบบกรงกระรอก และแบบดูบลีเฟด ผลการทดสอบพบว่า ภายใต้การเพิ่มโหลดกำลังไฟฟ้าจริงอย่างต่อเนื่อง การผลิตไฟฟ้าจากพลังงานลมโดยใช้เครื่องกำเนิดไฟฟ้าเหนี่ยวนำแบบกรงกระรอกอาจทำให้เสถียรภาพเชิงแรงดันของระบบส่งไฟฟ้าแย่ลง ส่วนการใช้เครื่องกำเนิดไฟฟ้าเหนี่ยวนำแบบดูบลีเฟดไม่ส่งผลกระทบต่อเสถียรภาพเชิงแรงดันของระบบ

PW 075 เวลา 08:40 – 09:00 น.

COMPARATIVE ANALYSIS ON IMPACT OF SERIES FACTS CONTROLLERS APPLIED STRATEGIES ON SUBSYNCHRONOUS RESONANCE

Javad Sadeh and Iman Mohammad Hoseiny Naveh

The advent of series FACTS controllers, Thyristor Controlled Series Capacitor (TCSC) has made it possible not only for the fast control of power flow in a transmission line, but also for the mitigation of sub-synchronous resonance (SSR) in the presence of fixed series capacitors. This paper presents a detailed analysis of the impact of TCSC control methodology on sub-synchronous oscillations (SSO) problem of series capacitive compensated transmission systems. The second IEEE benchmark model for the analysis of SSR phenomena is adopted. The impact of control methodology is also evaluated on the torsional modes. As a result it was shown that this applied strategy is powerful method for SSR damping. So TCSC can also damp SSO as shown in simulations. The proposed method is applied to the IEEE Second Benchmark system for subsynchronous resonance studies and the results are verified based on comparison with digital computer simulation by MATLAB.

PW 076 เวลา 09:00 – 09:20 น.

Impact of Current-Transformer Saturation on An Overcurrent Relay

ภักดี สิทธิการ และ ชาญณรงค์ บาลมงคล

This article presents the impact of current-transformer saturation on an overcurrent relay. MATLAB/SIMULINK is used to simulate the saturation of current transformer. The simulation results are applied to an overcurrent relay via a relay tester in order to determine the tripping time of relay. It is found that the currenttransformer saturation results in a delay of tripping time.

PW 077 เวลา 09:20 – 09:40 น.

A Study of Coordinative Control for PSS's to Enhance Power Oscillation Damping in Multi-machine System

Chairerg Jakpattanajit and Naebboon Hoonchareon

In this paper coordination scheme is proposed to enhance the stability of power system network by tuning the parameters of coordinative control appropriately. Setting coordinative control input and weight parameters are used to reflect both the local and the inter area oscillation. Simulation results demonstrate that generator terminal voltages and powers oscillations are well damped when the coordinative control is used.

PW 078 เวลา 09:40 – 10:00 น.

The Analysis of the electric field value for finding the distance of high voltage cable XLPE type scale 12/20 (24) kV which has factor in the model of High Voltage Underground Cable Terminators XLPE

ศุภวุฒิ เนตรโพธิ์แก้ว

This research has present about the analyst of the electric field value in the High Voltage Underground Cable Terminators XLPE peel for using in the measurement of the partial discharge (PD). Find the distance value in the peel of High Voltage Underground Cable before configure the High Voltage Underground Cable Terminator XLPE which is the most difficult in finding the correct distance. It is today main problem in configure the model of High Voltage Underground Cable Terminators XLPE and measure the partial discharge value. In the configure of High Voltage Underground Cable Terminators XLPE, it is the difficult to know the electric field stress that occur at bronze coil will effect anything in the analysis and testing of partial discharge. In testing the High Voltage Underground Cable XLPE is the necessary to know the side of voltage and the distance of the High Voltage Underground Cable XLPE before create the model and High Voltage Underground Cable Terminator XLPE. So that the High Voltage Underground Cable XLPE peel 12/20 (24) kV for testing should have the far distance of the peel between bronze coil and outside which is the ground. This would protect the spark on the peel. This research has applied the COMSOL Multiphysics 33. Program and Matlab Program by using in calculate to find the distance of suitable Underground Cable. And it is a part of the study technical in analysis the electric field stress of the High Voltage Underground Cable XLPE which is the factor in creating the model for High Voltage Underground Cable Terminators XLPE

PW 079 เวลา 10:00 – 10:20 น.

Alleviation of Power Fluctuation in a Microgrid using SMES with Optimal Coil Size

Cuk Supriyadi Ali Nanda, Issarachai Ngamroo, Jonglak Pahasa

In a microgrid system with wind and photovoltaic power generations, the intermittent power from these sources may cause a large power fluctuation. If the power fluctuation cannot be maintained in the acceptable range, system stability may be deteriorated. To compensate for such power fluctuation, a superconducting magnetic energy storage (SMES) can be applied. This paper proposes a design method of SMES power controller with optimal coil size. The structure of a power controller is the first-order lead-lag compensator. The optimization problem of controller parameters is formulated based on an enhancement of system damping and a minimization of coil size and coil current. The genetic algorithm is applied to achieve control parameters. Simulation results confirm the control effect of the SMES with small energy capacity against various disturbances.

PW 075

MPARATIVE ANALYSIS ON IMPACT OF SERIES FACTS CONTROLLERS APPLIED STRATEGIES ON SUBSYNCHRONOUS RESONANCE

Javad Sadeh[1] and Iman Mohammad Hoseiny Naveh[2]

[1] Department of Electrical Engineering, Ferdowsi University of Mashhad, Islamic Republic of Iran
[2] Islamic Azad University, Gonabad Branch,Islamic Republic of Iran

Sadeh@um.ac.ir and Mohammad.Hoseiny.Iman@gmail.com

advent of series FACTS controllers, Thyristor Series Capacitor (TCSC) has made it possible the fast control of power flow in a transmission also for the mitigation of sub-synchronous (SSR) in the presence of fixed series capacitors. presents a detailed analysis of the impact of ntrol methodology on sub-synchronous oscillations problem of series capacitive compensated systems. The second IEEE benchmark model alysis of SSR phenomena is adopted. The impact methodology is also evaluated on the torsional a result it was shown that this applied strategy is method for SSR damping. So TCSC can also O as shown in simulations. The proposed method is the IEEE Second Benchmark system for sub- nous resonance studies and the results are verified comparison with digital computer simulation by AB.

rds: Subsynchronous resonance, Subsynchronous ons, Torsional modes, TCSC.

roduction

Series capacitors compensation is a very economical to increase the power transfer capability of long sion lines. However, this technique may ntly increase the risk of sub-synchronous e (SSR) problems. SSR problems result from the between an electrical mode of the series ted network and a mechanical shaft mode mode) of a turbine-generator group, which may maging torsional torques.

e series FACTS devices most analyzed and applied ate sub-synchronous resonance is the Thyristor ed Series Capacitor (TCSC). Pilotto et al. [1] have TCSC operating with local current control mitigate SSR problem. Kakimoto and Phongphanphanee [2] have also demonstrated that TCSC can damp SSR if its firing angle is modulated with the rotor angle variation.

The main objective of this work is to present two TCSC applied strategy to mitigate SSR and to show their impact on SSO and torsional. For the analysis, the IEEE Second Benchmark system [3] was used. The electrical and mechanical systems were modeled in the MATLAB and the parameters used for simulation are also given in this reference [4].

2. Power System Model

The system under study is shown in Fig. 1. This is the IEEE Second benchmark model, with a fixed series capacitor connected to it. This system is adopted to explain and demonstrate applications of the proposed method for investigation of the single-machine torsional oscillations. The system includes a T-G unit which is connected through a radial series compensated line to an infinite bus.

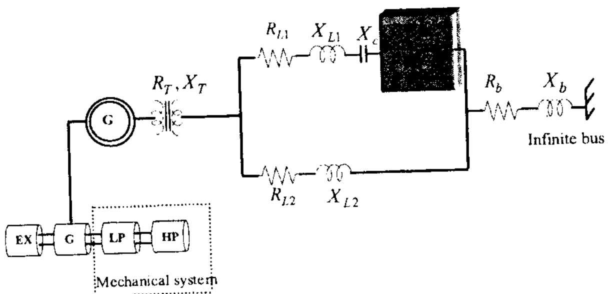

Fig. 1. Schematic diagram of the IEEE Second Benchmark System.

3. The Structure of TCSC

3.1 Modelling of TCSC

A TCSC consists of a capacitor in parallel with an inductor that is connected to a pair of opposite-poled thyistors. By using the firing angle of the thyristors, the inductor reactance is varied, which in turn, changes the effective impedance of the TCSC.

We can thus represent the TCSC as a variable impedance device. The TCSC is generally operated in the capacitive region, while inductive mode operation can be used during severe contingencies. The schematic of TCSC is shown in Fig. 2.

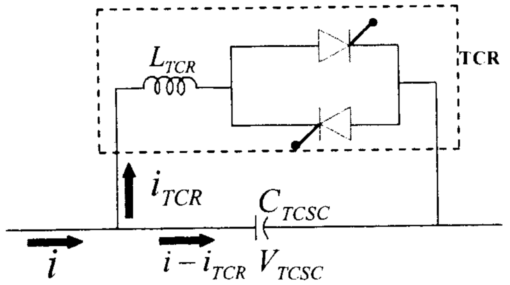

Fig. 2. Schematic representation of TCSC.

An approximate TCSC dynamic model is derived by representing the thyristor-controlled reactor (TCR) of the TCSC as an equivalent variable inductance [5,6]:

$$L_{TCSC} = \frac{\pi . L_{TCR}}{2(\pi - \alpha) + \sin 2\alpha} \tag{1}$$

Where L_{TCR} represents the fixed inductance of the TCR branch and α is the firing angle of the TCSC. By assumption $X_{TCR} = L_{TCR}.\omega$, the equal reactance of TCSC is given by:

$$X_L(\alpha) = \frac{\pi . X_{TCR}}{2(\pi - \alpha) + \sin 2\alpha} \tag{2}$$

As a result, TCSC can be used as a series compensator in transmission lines. In this case, the degree of compensation is defined by below equation:

$$K_{TCSC} = \frac{X_{TCSC}}{X_{L1}} = f(\alpha) \tag{3}$$

Where X_{L1} is total reactance of compensated transmission line in the IEEE Second benchmark model. In the other hand, degree of compensation changes as a function of α. This angle is produced in output of firing angle control system. Fig. 3 shows the manner of this process.

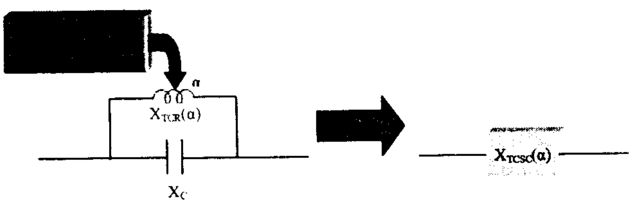

Fig. 3. Performance of TCSC as a variable reactance

3.2 Proposed Control Strategy

There are several methods for control of TCSC that they relevant to the purpose of designer [7]. Confidently, variation of current in transmission system is known as one of vital parameters. This parameter includes super synchronous and sub synchronous frequency components. In this paper, a proposed control strategy is presente... control of TCSC in IEEE Second benchmark model by... trait. Fig. 4 illustrates the block diagram of TCSC pro... control strategy. The desired line-current magnitude ... as a reference signal to the TCSC controller, which ... to maintain the actual line current at this value. ... controller is typically of the proportional-integral (PI... that $K_{P(TCSC)}$ and $K_{I(TCSC)}$ are evaluated as PI parameter... phase locked loop (PLL) executes based on [8-10].

Presented strategy is implemented on power ... study model for current setting $\Delta I_{(Set)}$=0.05 p.u with ... computer simulation by MATLAB and the obtained re... be shown in Fig.5. It can be fined clearly that prop... method is very appropriate to obtain the desired variatio... line current. The choice of $K_{P(TCSC)}$ and $K_{I(TCSC)}$, ... parameters is carried out by trial and error method.

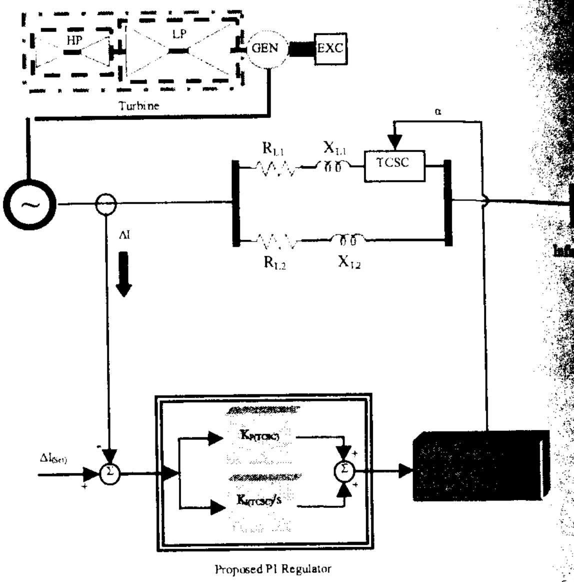

Fig. 4. Block diagram of TCSC proposed control strategy

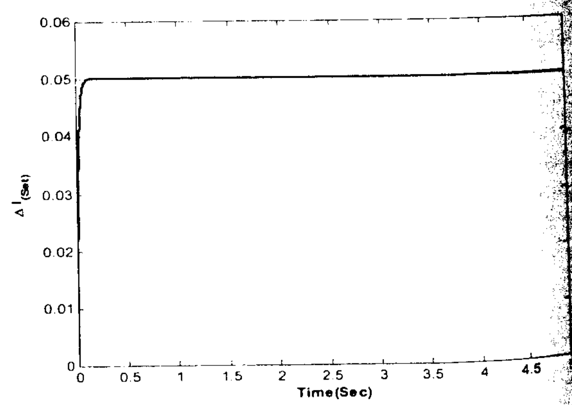

Fig. 5. setting variation of line current on the desired magnitude (ΔI_{Set}=0.05) by proposed control strategy

3.3 Impact of TCSC Proposed Methodology on the Torsional Modes

In this case, we consider the single machine infinite bus (SMIB) power system without tacking the series

...controller into account. The study is carried out ...vily loaded synchronous generator of P_G=0.9 p.u, ...41 p.u and V_t=1.138 p.u. Figure. 6shows the variation ... parts of the eigenvalues of A_{Sys} with the ...nsation factor $\mu_C=X_C/X_{L1}$.

...be observed that the first torsional mode is the most ...ble modes at μ_C=81.62%. The unstable range of ...on of torsional modes has been illustrated in Fig. 6.

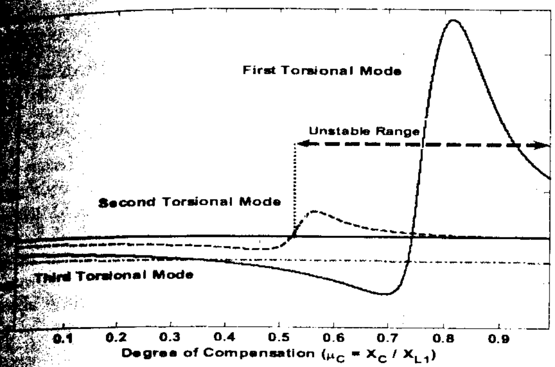

Fig. 6.Variation of real part of eigenvalues as a function of μ_C

As mentioned, impact of presented strategy has ...alyzed on the first and second torsional mode. In the other ...nd, the state matrix of system (A_{Sys}) is updated by ...easurement of K_{TCSC} from proposed method. K_{TCSC} ...fluenced by Variation of firing angle from Eq. (3).

...g. 7 illustrates variation of the first torsional mode when ...is methodology is carried out on power system study model with TCSC. It can be observed that the first torsional mode is suitably stable and this process continues with increase of K_{TCSC}. As a similar way, there is a suitable stability in the curve of variation of the second torsional mode on Fig. 8.

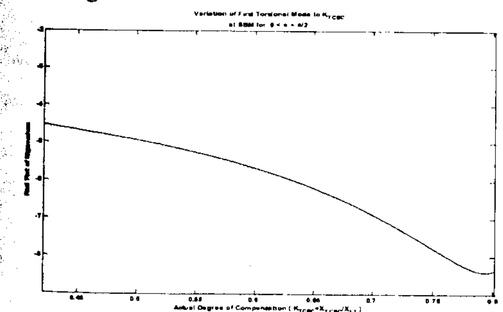

Fig. 7.Variation of the first torsional mode using proposed control methodology

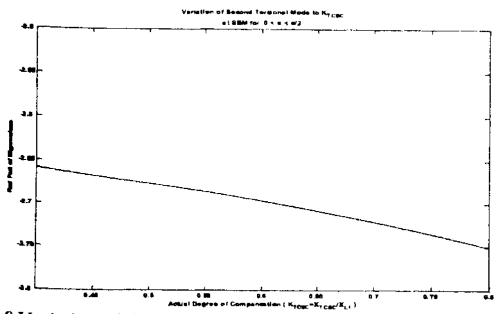

Fig. 8.Variation of the second torsional mode using proposed control methodology

3.4 Impact of TCSC proposed methodology on SSO

As mentioned earlier, the system considered here is the IEEE second benchmark model. In this stage, two state from this model is studied. For the first one, the power system study model is simulated when transmission line is compensated by fixed series capacitor. The degree of compensation is chosen 81.62% in this case. In the second one, the system is carried out when transmission line is compensated by TCSC with similar degree of compensation (%K_{TCSC}=81.62%). These states are simulated together in order to obtain more accurate comparison.

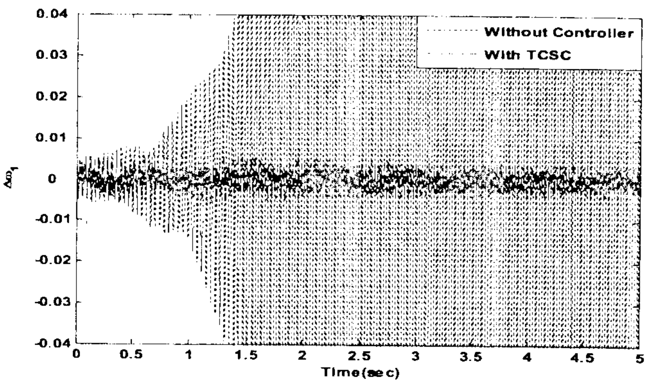

Fig. 9.variation of angular velocity of the rotating mechanical system of the T-G set for states-1, 2: Dotted (without controller), Dot-dashed (with TCSC)

Fig. 9 shows variation of angular velocity of the rotating mechanical system of the T-G set for state-1 and 2. It can be noted that, with case-1, SSO are un-damped and the system tends to the instability.

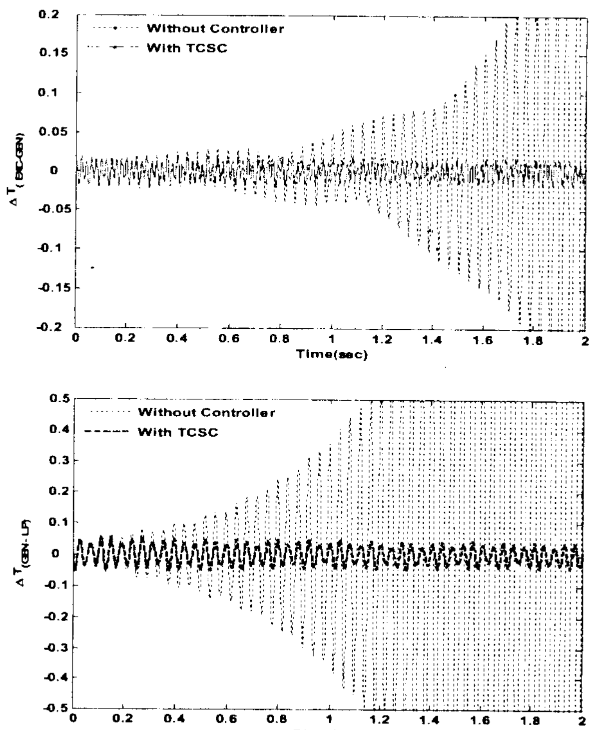

Fig. 10.variation of torque of the rotating mechanical system of the T-G set for states-1, 2: Dotted (without controller), Dot-dashed (with TCSC).

Fig. 10 shows variations of torque of the rotating mechanical system of the T-G set for state-1 and 2. It can be noted that, with case-1, SSO are un-damped and the system tends to the instability. These figures illustrate the capability of the proposed TCSC methodology in order to mitigate SSO.

4. Conclusion

The main objective of this work is to present two TCSC applied strategy to mitigate SSR and to show their impact on SSO and torsional. For the analysis, the IEEE Second Benchmark system was used. The proposed methodology is based on evaluation of desired variation of line current parameter. This purpose is carried out by accurate setting of a PI regulator. Impact of TCSC control methodology was studied on the torsional modes and SSO for the power system study model.

The simulation results of IEEE-SBM carried out on 2states (without controller, with TCSC). Variation of angular velocity and torque of the rotating mechanical system of the T-G set for all cases was studied.

Analysis reveals that the proposed technique gives good results and suitable impact on torsional modes. By this method, first and second torsional modes are stable accurately. The peak deviations of SSO and inadvertent interchange are reduced by using this method. It can be concluded that using TCSC applied strategy have similar results and mitigates destroyer SSO.

References

[1] Pilotto, L. A. S., Bianco, A., Long, F. W. and Edris, A. A., "Impact of TCSC Control Methodologies on Subsynchronous Oscillations", IEEE Transactions on Power Delivery, Vol. 18, No.1, 2003, pp 243-252.

[2] Kakimoto, N and Phongphanphanee, A ; "Subsynchronous Resonance Damping Control of Thyristor-Controlled Series Capacitor", IEEE Transactions on Power Delivery, Vol. 18, Issue 3, July 2003, pp. 1051 – 1059.

[3] IEEE Subsynchronous Resonance Working Group of the Power System Engineering Committee, "Second Benchmark Model for Computer Simulation of Subsynchronous Resonance", *IEEE Transactions on Power Apparatus and Systems*, vol.104, pp.1057-1066, May 1985.

[4] Harb AM, Widyan MS. Modern nonlinear theory as applied to SSR of the IEEE second benchmark model. In: IEEE Bologna Power Tech 2003 Conference, Bologna-Italy, June 2003.

[5] Kundur P., Power System Control and Stability, McGraw-HILL, Inc., New York, 1993.

[6] S. Helbing and G. Karady, "Investigations of an advanced form of Series Compensation", IEEE Trans. Power Delivery, Vol. 9, April1994, pp. 939-947.

[7] R.M. Mathur and R.K. Varma, *Thyristor-based FACTS Controllers for Electrical Transmission Systems*, pp.315-335, New York: Wiley; 2002.

[8] M.E. Hawary, *Control System Engineering*. Canada: Reston; 1996.

[9] D. Jovcic, "Control of High Voltage DC and Flexible AC Transmission Systems". Ph.D. Thesis, University of Auckalnd, New Zealand, 1999.

[10] D. Jovcic and G.N. Pillai, "Discrete System Model of a Six Pulse SVC". *Transmission and Distribution Conference and Exhibition, IEEE PES*, pp.318-323, Sep 2003.

About the authors

Javad Sadeh was born in Mashhad, IRAN in 1968. He received the B.Sc. and M.Sc. in electrical engineering from Ferdowsi University of Mashhad in 1990 and 1994 respectively and the PhD degree from Sharif University of Technology, Tehran Iran with the collaboration of the electrical engineering laboratory of the National Polytechnic Institute of Grenoble (INPG), France in 2000. Since then he served as an assistant professor at the Ferdowsi University of Mashhad. His research interests are Power System Protection, Electromagnetic Transients in Power System and Restructuring.

Iman Mohammad Hoseiny Naveh was born in Mashhad, Iran in 1981. He received the B.Sc. degree in the power engineering from Islamic Azad University of Iran, Gonabad branch, Iran in 2004. Now he is continuing his researches on M.Sc. degree in Control Engineering of Islamic Azad University, Gonabad branch, Iran. His research interests are Subsynchronous resonance, Power System Control,Dynamics and Operation, Optimal Control and FACTS devices.