International Journal For Technological Research In Engineering
Volume 2, Issue 6, February-2015 ISSN (Online): 2347 - 4718

POWER SYSTEM STABILITY ENHANCEMENT BY USING SSSC FACTS DEVICE WITH FUZZY LOGIC CONTROLLER

Rahul Malviya[1], Pro. Sourabh Gupta[2]
[1]M.Tech Scholar, [2]Assistant Professor
NIIST, BHOPAL

ABSTRACT: In recent years, expansion of power system is not as par the need of power demand which has increased substantially [3]. As a consequence, existing transmission lines are heavily loaded and the stability of the system ecomes a power transfer-resisting factor. Flexible AC transmission systems (FACTS) controllers have been mainly designed to solve such type of power system steady state controlling problems [11]. In this paper the work is " an optimized fuzzy logic control based static synchronous series compensator(SSSC)" which is designed in place of a PI controlling technique and MATLAB based simulations are carried on a long transmission line by varying the load step by step and results are then compared with fuzzy and without fuzzy logic controller[1].The proposed fuzzy logic controller (FLC) improves power system transient stability and enhances the system damping [9]. Fuzzy logic controller works in accordance to system behavior as the input parameters of the Controller are carefully chosen such that to provide considerable damping for power system [2]. The range of the controller is determined based on simulation results of the fuzzification and defuzzification. [15]. Simulation results shows that this FLC controller with SSSC can improve stability margin of the system in the case of transient stability and provide considerable damping of power oscillations [4].

Key words: Transient Stability, Fuzzy Logic Controller (FLC), Static Synchronous Series Compensator (SSSC), damping.

I. INTRODUCTION

Transient stability analysis of the system is considered when the power system is confronted with large disturbances. Sudden changes in load, generation or transmission system configuration due to fault or switching are examples of large disturbances. Power system should retain its synchronism during and after all these kind of disturbances. Therefore transient stability is an important security criterion in power systems design. Different methods have been used for transient stability analysis in power systems. The utilities must need to operate their transmission system much effectively, increasing their utilization ratio. Reducing the effective reactance of lines by series compensation is a direct approach to increase transmission capability. However power transfer capability of long transmission line is limited by stability considerations. But the advent of fast acting FACTS devices allows for fast and vernier control of series compensation using thyristor control series capacitor (TCSC) and static synchronous series compensator (SSSC). SSSC is based on voltage source converter (VSC).schematic diagram is shown in fig (1).

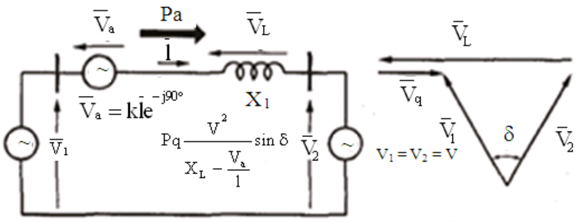


Fig. 1: Basic model of the series compensation with a voltage source

Flexible AC Transmission System (FACTS) devices are used to control power flow along transmission lines and improve power system stability. SSSC is one of the series FACTS devices that are mainly used for voltage regulation. It is also used to improve power system stability by injecting or absorbing reactive power. This function of SSSC needs some more supplementary input signals, several controllers have been used to perform this control strategy such as conventional PI controller. This paper work investigates the static synchronous series compensator (SSSC) Facts controller in terms of transient stability improvement and power system stability and performance. Here this paper is divided into six sections. In the first section a system model is described of long transmission line taken under consideration. In the second section PI controlling based SSSC model is elaborated in details. In the third section fuzzy logic controller with rule bases replaces the PI controller is described and also complete fuzzification with rule bases are discussed. In the fourth section results are compared between PI controlled SSSC and fuzzy based SSSC which are observed in the scope of matlab and readings are compared in Photoshop manager to review waveform comparison clearly. In the fifth section the work is concluded were it is proved that power system stability performance and damping is improved using fuzzy logic control.

Section I:

A 230 kV ,100 MVA source is taken for a long transmission line of 800 km. the line resistance per unit length is considered as [0.01273 0.3864] ohms/km [N*N matrix] or [R1 R0 R0m] in per unit, the line inductance per unit length is [0.9337e-3 4.1264e-3] H/km [N*N matrix] or [L1 L0 L0m] and the line capacitance per unit length is [12.74e-9 7.751e-9] F/km [N*N matrix] or [C1 C0 C0m] for each 200 km length. In this long transmission line parallel R-L-C load is connected which is introduced in different steps as no load, half load and full load. SSSC is introduced in series in the middle of the line as the most nominal place in the T model of installation strategy. The complete model is described in fig (2).

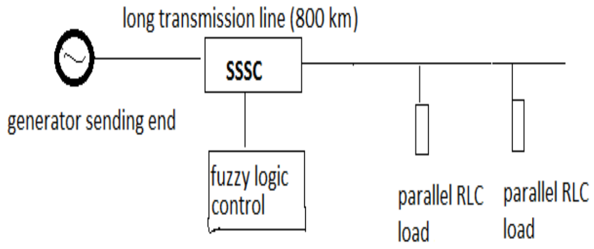


Fig.2- Block diagram of the Model

To achieve real and reactive power flow control, we need to inject series voltage of the appropriate magnitude and angle were the injected voltage can be split into two components which are in phase and in quadrature with the line current. The real power is controlled using the reactive voltage and the reactive power is controlled using the real voltage. The real and reactive power reference is obtained from the steady state load flow requirements. The real power reference can also be modulated to improve damping and transient stability.

Section II:

Controlling SSSC:

SSSC has the main objective to dynamically control the power flow over the transmission line. Earlier control schemes proposed were based on the line impedance control mode in this scheme the SSSC compensating voltage which is derived by multiplying the current amplitude with the desired compensating reactance X_{qref}. Since it is difficult to predict X_{qref} under varying network contingencies, the voltage control mode is considered in the proposed scheme. This controller is modified to operate the Static synchronous series copensator in the automatic power flow control mode. In the automatic power flow control mode, the main reference inputs to the controller are reference powers P and Q, which are to be maintained in the transmission line despite system changes. Using dq transformation the line voltage and the current are converted to corresponding d and q axis components. The power references are converted to current references using the Eq. 1 and 2. From the current references the sigma angle is calculated and then the firing pulses are generated.

$$I_{dref} = (P\times V_d + Q \times V_q) / (V^2_d + V^2_q) \ldots\ldots\ldots(1)$$

$$I_{dref} = (P\times V_q + Q \times V_d) / (V^2_d + V^2_q) \ldots\ldots\ldots(2)$$

SSSC dynamics:

The transfer function of SSSC based controller is:

$$U_{SSSC} = K_S \left(\frac{sT_W}{1+sT_W}\right)\left(\frac{1+sT_{1S}}{1+sT_{2S}}\right)\left(\frac{1+sT_{3S}}{1+sT_{4S}}\right) y,$$

Where, U_{SSSC} and y are the output and input signals of the SSSC-based controller respectively. During steady state conditions ΔV_q and V_{qref} are constant. During dynamic conditions the series injected voltage V_{q} is modulated to damp system oscillations. The effective V_{q} in dynamic conditions is given by:

$$Vq = Vqref + \Delta Vq.$$

Section III:

Fuzzy logic control:

Fuzzy control systems are based on rules . Fuzzy rules represent a control decision mechanism to adjust the effects of certain system stimuli through simulation. The aim of fuzzy controlling systems is to replace a skilled human operator with a fuzzy rule-based system. The fuzzy logic controller provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy. The fuzzy logic controller involves four main stages: fuzzification, rule base, inference mechanism and defuzzification (Sivanandam and Deepa, 2009).The structure of the fuzzy logic controller is shown in Fig. 3. The error and change in error are taken as the inputs to the fuzzifier. here the error is between the line voltage and the reference voltage (i.e Vq and Vqref) and the change in error is taken by subtracting two consecutive error values by providing a unit step delay and giving the second input to the fuzzifier as shown in the figure 3. Triangular membership functions are used for the inputs and the output. The universe of discourse for both the inputs is divided into seven partitions (NL – Negative Large, NM – Negative Medium, NS – Negative Small, Z– Zero, PS – Positive Small, PM – Positive Medium, PL – Positive Large). The output is the voltage and again the universe of discourse is divided into seven partitions. Fuzzy rules are if then rules were these are specified by max –min operator functions .the fuzzy rules taken here are of the form:

i) If error is large negative (LN), AND change in error is large negative (LN); THEN output (u) is large positive (LP).

ii) For N linguistic variables for each of error and change in error there are $N2$ possible combinations resulting into any of M values for the decision variable u. All the possible combinations of inputs, called states, and the resulting control are then arranged in a $NN2\times MM$ 'fuzzy relationship matrix' (FRM).

iii) The membership values for the condition part of each rule are calculated from the composition rule as Follows:

μ(Xi) = μ(e is LN, and Δe is LN) = min [μ (Δω is LN), μ ($\dot{\Delta\omega}$ is LN)]; where i=1, 2,…N2 Here, Xi is the i-th value of the N2 possible states (in-put-combinations) in the FRM.

iv) The membership values for the output characterized by the M linguistic variables are then obtained from the intersection of the N2 values of membership function μ(x) with the corresponding values of each of the decision variables in the FRM. For example, for the decision LN⊂M and for state Xi, we obtain, μu(Xi, LN) = min[μ(Xi, LN), μ(Xi)];

Where i=1, 2, N2 the final value of the stabilizer output 'LP' can be evaluated as the union of all the outputs given by the relationship

µu(LN)= max {µus (Xi, LN)} , for all Xi
The membership values for the other M-1 linguistic variables are generated in a similar manner.

v) The fuzzy outputs µu(LN), µu(LP), etc. are then defuzzified to obtain crisp u. The popular methods of defuzzification are the centroid and the weighted average methods. Using the centroid method, the output of the FLC is then written as

$$u = \frac{\sum_{i=1}^{M} \mu_u(A_i) * A_i}{\sum_{i=1}^{M} \mu_u(A_i)}$$

$$u = \frac{\sum_{i=1}^{M} (\mu_u(A_i) * threshold\ value\ of\ A_i)}{\sum_{i=1}^{M} \mu_u(A_i)} \qquad (18)$$

vi) A set of decision rules relating the inputs to the output are stored in the memory in the form of a 'decision table'. The rules are of the

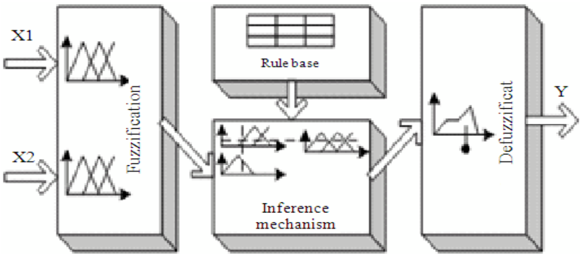
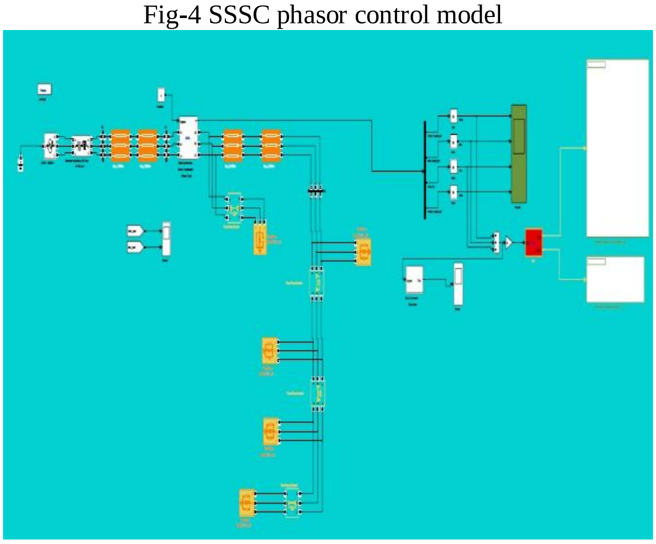


Fig-3: Strcture of Fuzzy Logic Controller

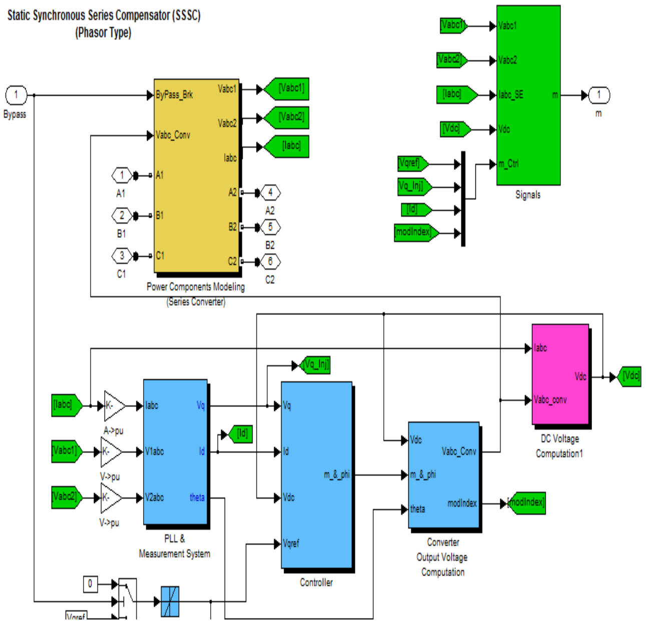
	NL	NM	NS	Z	PS	PM	PL
NS	PS	PL	PL	PS	NM	NS	NM
NM	PM	PL	PL	PM	Z	Z	Z
NL	PL	PL	PL	PL	Z	Z	Z
Z	PS	PM	PL	Z	NS	NM	NL
PS	PS	PS	NM	NS	NS	NL	NL
PM	Z	Z	Z	NM	NM	NL	NL
PL	Z	Z	Z	NL	NL	NL	NL

The decision rules established for fuzzy controller are given above:

Fig-4 SSSC phasor control model



Static Synchronous series Compensator (phasor type)



II. DESCRIPTION

Injected voltage Vq and Vq_ref is measured in the SSSC phasor control and the current Id and Vq_conv is moduled by the PI control. Here the higher order terms containing error and change in error are neglected in PI control .in our proposed controller with fuzzy logic the error and change in error terms are fed as input as shown in the replacement of fuzzy logic controller. The bus voltage needed is controlled by following equation which are locally available which can easily calculate our real voltage Ep(pq) :

$$V_{(b)} = \sqrt{\{ (V_{D(b)})^{2} + (V_{Q(b)})^{2} \}}$$

$$V_{(b)} = \sqrt{\{ (V_{R(a)} + e_{R(pq)})^{2} + (V_{p(a)} + e_{P)pq)})^{2} \}}$$

$$V_{R(a)} = V_{D(a)} * \cos(\varnothing^1) - V_{Q(a)} * \sin(\varnothing^1)$$

$$V_{P(a)} = V_{D(a)} * \sin(\varnothing^1) + V_{Q(a)} * \cos(\varnothing^1)$$

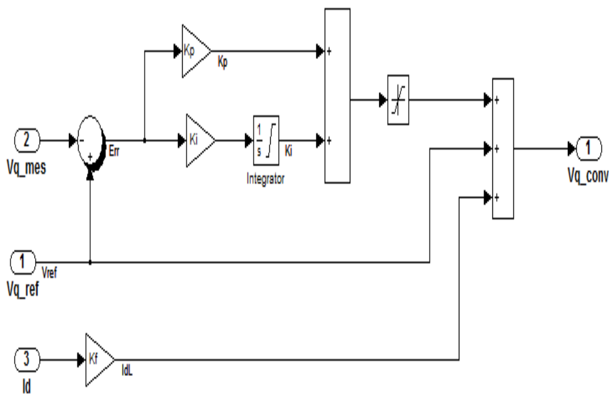


Fig-5: PI control based injected voltage regulator of SSSC control

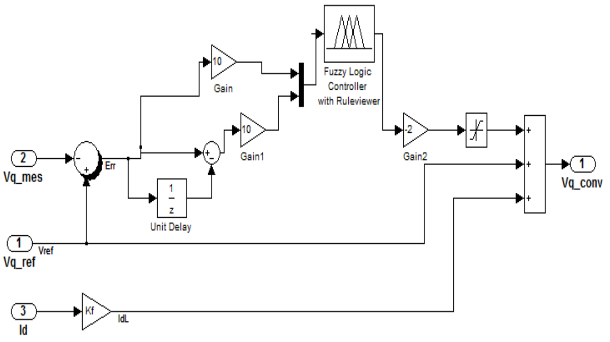


Fig.6: Fuzzy logic replacement in injected voltage regulator of SSSC control in place of PI control

Section IV:

Results and case studies:

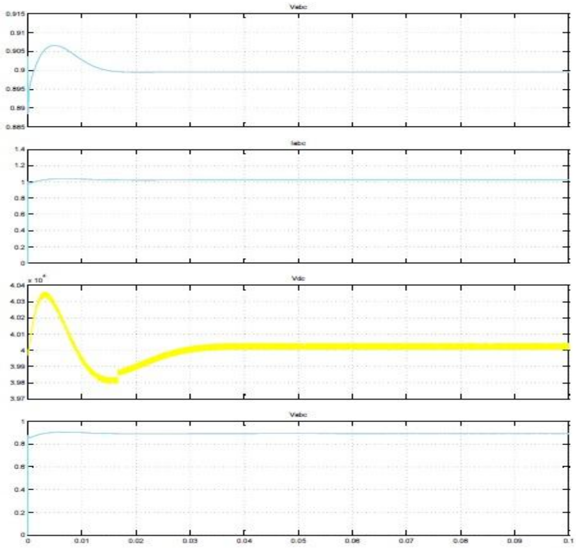


Fig.7: voltage and current with PI control

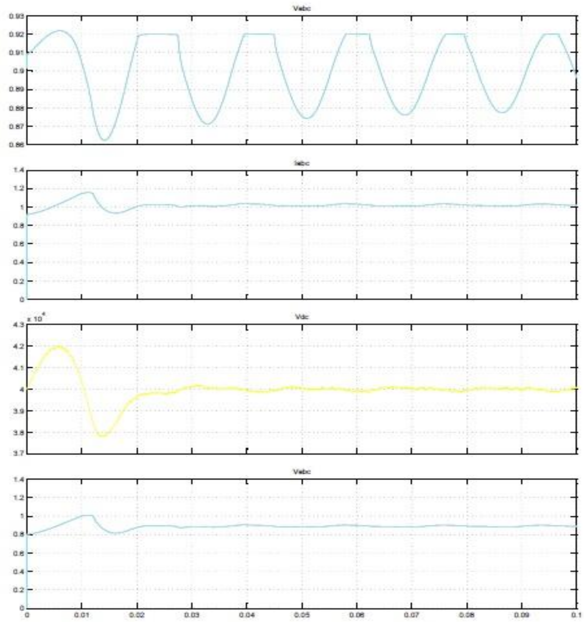


Fig 8: voltage and current with fuzzy logic control

THD ANALYSIS

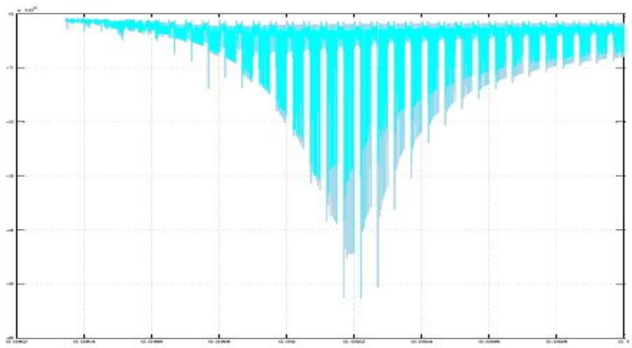


Fig-9: THD WITH PI

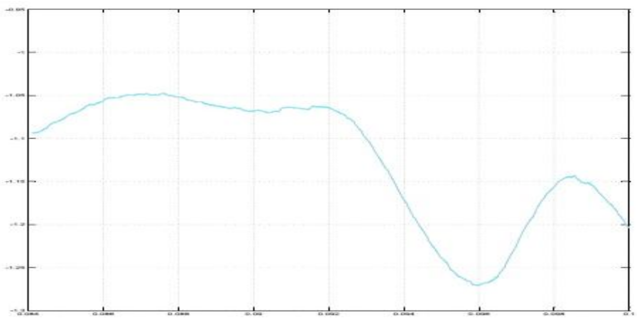


Fig-10: THD WITH FUZZY

III. RESULT ANALYSIS

- Error can be determined in fig 8 compared to fig 7 and hence bandwidth can be reduced and hence damping ratio increases which increases the gain K of the system.
- Sensitivity increases as can be compared in both figures 7 & 8 and hence static and dynamic security and stability in power system becomes more sensitive to disturbances. It can be seen that the changed system is more sensitive to disturbances (even noise disturbances).
- Settling time is improved, also rise time and overshoots are minimized reducing the transient time and making response of system fast.
- Per unit Voltage regulation is improved.
- Necessary oscillation's are seen in the proposed control system.
- There is a significant improvement in the THD value from 56.70% to 38.86% when fuzzy logic controller was connected; this shows that the system is moving towards stability.
- Damping of oscillation is also reduced and system becomes more stable as can be seen in fig 8.

Section V:

Conclusion:

In this paper, a fuzzy logic controller based SSSC is proposed to control SSSC for improving power system transient and steady state stability alongwith system damping. Fuzzy logic controller works according to model system behaviour. Controller input parameters are carefully chosen to provide considerable damping for power system.

The range of controller is determined based on simulation results of the fuzzification method. Simulation results indicate that this controller can improve stability of the system in the case of transient and steady state stability and provide considerable damping of power system oscillation and also increases the gain of system by reducing the bandwidth.

Future scope:
Work can be carried out now by this controller in the improvement of static and dynamic security system and results can be obtained also the fuzzy logic controller can be optimized using neural networks and a neuro fuzzy logic control can be formed in future.

REFERENCES

[1] Zenk H, Akpinar, A.S.“PI, PID and fuzzy logic controlled SSSC connected to a power transmission line, voltage control performance comparison” IEEE 2013 fourth international conference on POWERENG, ISSN 2155- 5516.

[2] R. Thirumalaivasan, M. Janaki, and Nagesh Prabhu, “Damping of SSR Using Sub- Synchronous Current Suppressor With SSSC” , IEEE Transactions On Power Systems, Vol. 28, No. 1, February 2013

[3] H.F.Wang and F.Li, “Design of STATCOM multivariable sampled regulator”, IEEE conference on electric utility de-regulation and power technologies, April 2000

[4] N.G. Hingorani and L. Gyugyi, “Understanding FACTS, Concepts and Technology of Flexible AC Transmission System”, Wiley-IEEE press, 1ed., Dec. 1999

[5] N.G. Hingorani. “High power electronics and Flexible AC transmission system”, IEEE Power Engineering review, Jul. 1988

[6] N.G.Hingoroni, “Flexible AC transmission systems”, IEEE spectrum (40-45) April 1993

[7] H.F.Wang, "Applications of damping torque analysis to STATCOM control " , Elsevier, Electrical Power and Energy Systems 22, 2000, 197–204

[8] H.F.Wang, “Phillips-Hefron model of power systems in-stalled with STATCOM and applications”, IEE proceedings on generation, transmission and distribution, vol. 146, no.5, September 1999, pp 521-527

[9] Panda, S., 2010. Modelling, simulation and optimal tuning of SSSC-based controller in a multi machine power system. World J.Model. Simulation, 6: 110-121

[10] Tamer Abdelazim, O. P. Malik, “Adaptive Fuzzy Control of SSSC to Improve Damping of Power System Oscillations”,IEEE conference 2006.

[11] Manju p, subbiah v “Intelligent control of unified power flow controller for stability”enhancement of transmission systems”,IEEE 2nd international conference ,ICACC, 2010,vol.3.

[12] D.Harikrishna, R.S.Dhekekar, N.V.Srikanth, “ A novel approach to dynamic stability enhancement using PID damped fuzzy susceptance controlled SVC”,IEEE Power System Conference and Exposition PSCE 2011, pp. 1-6, March 2011

[13] V.K chandrakar and A.G kothari “fuzzy logic based static synchronous Series compensator for transient stability improvement” IEEE international conference of power system 2004

[14] A.M. Sharaf, M. S. El-Mours, “Transmission System Reactive Compensation and Stability Enhancement Using 48-pulse Static Synchronous Series Compensator (SSSC)” IEEE 35th North American Power Symposium, Rolla, Missouri, Oct, 2003.

[15] Narain G. Hingorani, Lazlo Gyugyi, “Understanding Facts: Concepts and Technology of Flexible AC TransmissionSystems” John Wiley &Sons, Incorporated, November 1999.

[16] Zenk H., Zenk O. and Akpinar A. S., “Two Different Power Control System Load-Frequency Analysis Using Fuzzy Logic Controller,” in INISTA 2011, Dogus University, İstanbul, Turkey, 2011.

