STATCOM with Energy Storage for Power System Oscillation

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Abstract-**The motto of present paper is to find out theenhancement of damping the electricity gadget oscillationthrough co-ordinated model of 'Static SynchronousCompensator' (STATCOM) located in shunt withtransmission line.Side.This isachievedusing a signal estimation technique based on a modifiedrecursive least square (RLS) set of rules, which permits a fast,selective, and adaptive estimation of the low-frequency electromechanical oscillations from locally measured indicators duringpower gadget disturbances. The proposed method is powerful inincreasing the damping of the device at the frequencies of interest,additionally inside the case of device parameter uncertainties and at variousconnection points of the compensator.**

Index terms- **Energy storage, low-frequency oscillation, poweroscillation damping (POD), recursive least square (RLS), staticsynchronous compensator (STATCOM).**

I. INTRODUCTION

Along side the growing scale of the electricity systemand pressured operation inside the transmission network,extra electromechanical oscillations are found intoday's strength structures. As soon as started, the oscillationsmay maintain for some time and then disappear through thedamping toque from the machine, or retain to growand motive gadget instability via losingsynchronism. In consistent kingdom operation, the primaryobjective of statistics gadgets is to manipulate energy waft andimprove transmission functionality. However, in recentyears, the utility of facts gadgets in suppressingsystem oscillations has attracted growing interestsfor research and improvement. The electromechanicaloscillation seems in a electricity device due to theinteractions a number of the machine components. Most ofthe oscillation modes are generator rotors swingagainst every different. The oscillation normally happens inthe frequency variety of zero.2 hz to two.five hz. The inter-areaoscillations, which can be typically within the lower frequencyrange of 0.2 hz to 1 hz, are exhibited as one group ofmachines swing relative to different businesses. Comparedwith decrease frequency, the higher frequency oscillationmodes generally involve one or generatorsswinging against the rest of the power system, which iscalled neighborhood mode oscillation. The oscillations stabilityanalysis and manage is an crucial and lively subject matter inpower machine studies and applications. In the past,energy system stabilizer (pss) is identified as anefficient and reasonable method to damp oscillations.in recent years, as a new answer, various factscontrollers were advanced for damping of powersystem oscillations. Primarily based on the control theoryapplied, the supplied controllers may be divided to twogroups: linear controllers and nonlinear controllers. Inlinear control, the machine dynamics are linearizedaround the pre-selected device running pointaccording to lyapunov's linearization approach. Thelinearized gadget is an approximation of the originalsystem at the operating factor. Therefore, thesecontrollers suffer from the overall performance degeneracyproblem whilst gadget running point deviates fromthe pre-designed point. Nonlinear control techniquescan offer extra effective control of strength systemsdue to their functionality to deal with nonlinear operatingcharacteristics. There are already some researches onnonlinear facts controller design for damping powersystem oscillations in current years. The feedbacklinearization (fl) technique has been utilized in factscontroller layout in. Power based totally manage lyapunovfunction approach (clf) have been efficaciously implemented inseries statistics gadgets controller in. The adaptive controlis used in records controller design in. The h∞ manipulate isalso effectively applied in tcsc controller to dampinter-area oscillations in. Those nonlinear controllershave suitable overall performance if the machine version is accurateand the parameters are exactly acquired. Theshortcoming is that the robustness isn't always guaranteed inthe presence of modelling inaccuracies. I.e. Parameteruncertainty and un-modelled dynamics, particularly in this approach.

II. ARCHITECTURE OF THE STATCOM

The STATCOM is one of the most essential shuntconnected FACTS controllers to govern the energy flowandmake better transients stability. A STATCOM is acontrolled reactive energy source. It offers voltagesupports by generating or soaking up capacitor banks.

STATCOM has three running components:

(i) STATIC:based on solid nation switching gadgets with no rotatingcomponents,

(ii)SYNCHRONOUS: analogous to a great synchronousmachine with 3 sinusoidal phase voltage at fundamentalfrequency,

(iii)COMPENSATOR: rendered with reactivecompensation.

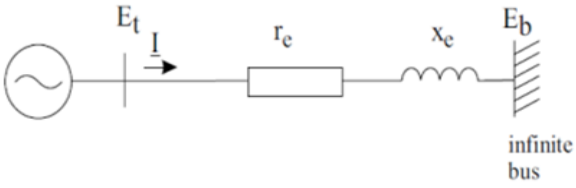

Fig1: *One machine to infinite bus system*

Modern electric power machine is facing manychallenges because of daily growing complexity in theiroperation and shape. In the recent beyond, one in all theproblems that got extensive interest is the energy systeminstability. With the dearth of recent generation andtransmission facilities and over exploitation of the existingfacilities geared by increase in load demand make thesetypes of issues extra forthcoming in modern powersystems. Demand of electrical energy is constantly risingat a very excessive charge due to fast industrial development . Tomeet this call for, it's miles essential to elevate the transmittedpower in conjunction with the present transmission centers. Theneed for the strength drift manage in electrical power systemsis for that reason glaring. With the accelerated loading of transmissionlines, the hassle of transient stability after a major faultcan grow to be a transmission energy restricting thing. To solvethe problem of brief stability in the late Nineteen Eighties, theelectric Power Research Institute (EPRI) brought a newapproach to resolve the trouble of designing and operatingpower structures; the proposed idea is called flexibleac Transmission Systems (FACTS). The mainobjectives of FACTS are to growth the transmissioncapacity and control electricity glide over designatedtransmission routes. FACTS are described with the aid of the IEEE as "apower digital based device and different static equipmentthat provide manipulate of 1 or greater AC transmissionsystem parameters to decorate controllability and increase power transfer capability".

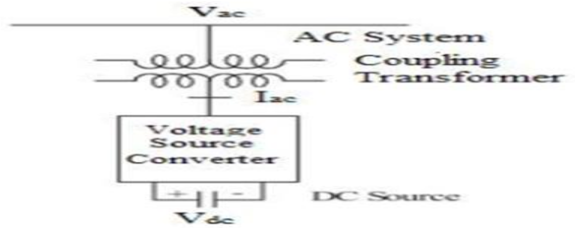

Fig2: *Basic Structure of STATCOM*

"A Static synchronous compensator is a shuntconnected static VAR compensator whose capacitive orinductive output current can be controlled independent ofthe ac system voltage".The concept of STATCOM wasproposed by Gyugyi in 1976. Power Converter employedin the STATCOM mainly of two types i.e. is VoltageSource Converter and Current Source Converter. InCurrent source Converter direct current always has onepolarity and the power reversal takes place through reversalof dc voltage polarity while In Voltage Source Converterdc voltage always has one polarity, and the power reversaltakes place through reversal of dc current polarity.

III. MODELING OF CONTROLLER DESIGN

A simplified power system model, such as the one depictedin Fig. 3, is used to study the impact of the E-STATCOM on thepower system dynamics. The investigated system approximatesan aggregate model of a two-area power system, where eacharea is represented by a synchronous generator.

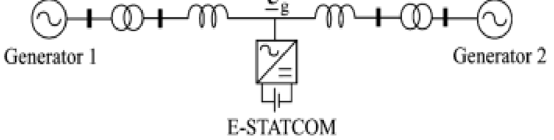

Fig. 3. *Simplified two-machine system with E-STATCOM*

The synchronous generators are modeled as voltage sourcesof constant magnitude $(V_{g1}, V_{g2})$and dynamic rotor angles$(\delta_{g1}, \delta_{g2})$behind a transient reactance(X'_{d1}, X'_{d2}) . The transmission system consists of two transformers represented bytheir equivalent leakage reactance $(X_{t1}, X_{t2})$and a transmission line with equivalent reactance$(X_L = X_{l1} + X_{l2})$. Thelosses in the transmission system are neglected for simpler analytical expressions. If the mechanical damping in the generatorsis neglected, the overall damping for the investigated systemis equal to zero. Therefore, the model is appropriate to allow aconservative approach of the impact of the E-STATCOM whenused for stability studies [14].

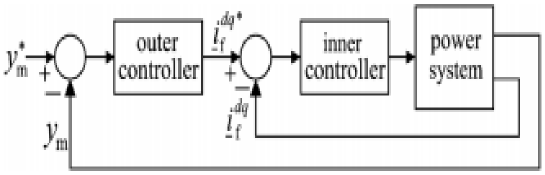

Fig. 4. *Block diagram of the control of E-STATCOM*

The control of the E-STATCOM consists of an outer control loop and an inner current control loop, as shown in Fig. 4.The outer control loop, which can be an ac voltage, dc-linkvoltage or POD controller, sets the reference current for theinner current controller. The generic measured signal $y_m$depends on the type of outer loop control. The control algorithmis implemented in dq-reference frame where a phase-lockedloop (PLL) [15] is used to track the grid-voltage angleθ_g fromthe grid-voltage vector e_g. By synchronizing the PLL with thegrid-voltage vector, the d- and q-components of the injected current (i_f^dandi_f^q) control the injected active and reactive power,respectively. In the notation in Fig. 2, the superscript “* ” denotes the corresponding reference signals.

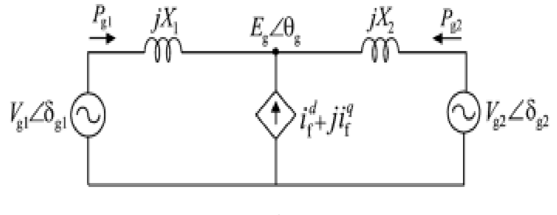

Fig. 5.*Equivalent circuit for two-machine system with E-STATCOM.*

In this paper, the outer control loop is assumed to be aPOD controller, and the detail of the block will be describedin Section IV. For this reason, we assume that the injectedactive and reactive powers in the steady state are zero. Whendesigning a cascaded controller, the speed of outer control loopis typically selected to be much slower than the inner one toguarantee stability. This means that the current controller canbe considered infinitely fast when designing the parameters ofthe outer controller loop. Therefore, the E-STATCOM can bemodeled as a controlled ideal current source, as depicted in theequivalent circuit in Fig.5, for analysis purpose.The level of power oscillation damping provided by the

converter depends on how much the active power output fromthe generators is modulated by the injected current, . For thesystem in Fig. 5, the change in active power output from thegenerators due to injected active and reactive power from theE-STATCOM.

IV. POD CONTROLLER DESIGN

The derivation of the POD controller from locally measured signals will be made in this section.

A. Derivation of Control Input Signals

Considering the simplified two-machine system in Fig. 3,the active power output from each generator should change in proportion to the change in its speed to provide damping [9]. It can be observed that the effect of the power injected by the compensator on

the generator active power outputhighly depends on the parameter , i.e., on the location of theE-STATCOM. Using the equivalent system in Fig. 5, a controlinput signal that contains information on the speed variation ofthe generators can be derived.

B. Estimation of Control Input Signals

As described in the Introduction, effective power oscillation damping for various power system operating points andE-STATCOM locations require fast, accurate, and adaptive estimation of the critical power oscillation frequency component.This is achieved by the use of an estimation method based on amodified RLS algorithm. For reasons described in the previoussubsection, the derivative of the PCC-voltage phase and thetransmitted power should be estimated for controlling the active and reactive power injection, respectively. The aim of thealgorithm is therefore to estimate the signal components thatconsist of only the low-frequency electromechanical oscillation in the measured signals θ_g and P_{tran}.

To describe the estimation algorithm, an input signal whichcould be either or , as shown in Fig.6, is considered.Following a power system disturbance, will consist of an average value that varies slowly and a number of low-frequencyoscillatory components, depending on the number of modes thatare excited by the disturbance.

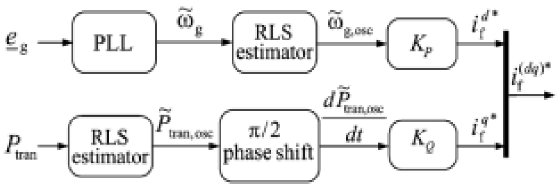

Fig. 6. *Block diagram of the POD controller.*

Modification in the Conventional RLS Algorithm:

A high forgettingfactor results in low estimation speed with good frequency selectivity. With increasing estimation speed (decreasing λ), thefrequency selectivity of the algorithm reduces. For this reason,the conventional RLS algorithm must be modified in orderto achieve fast transient estimation without compromising itssteady-state selectivity.

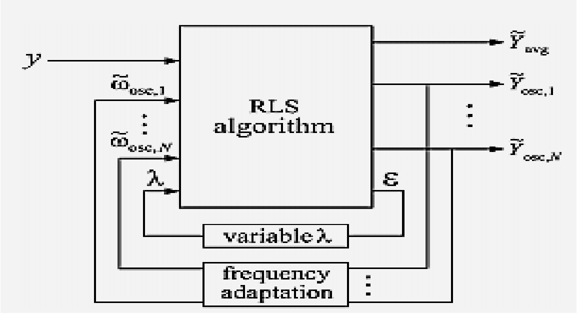

Fig.7. *Block diagram of the modified RLS estimator for multiple oscillationmodes.*

Modification for Multiple Oscillation Modes: The investigated control method has been derived under the assumption ofa single oscillatory frequency component in the input signal. Abrief description of how the proposed algorithm can be extendedfor multi-area system with multiple oscillation modes will bebriefly presented here for future reference.

The RLS described inthe sections (including variable forgetting factor andfrequency adaptation for each considered oscillation mode) canbe modified as described in Fig. 7. Thus, the POD controller in Fig. 6 can be modified accordingly to control each mode independently.

V. SIMULATION RESULTS

The POD controller described in Section III is here verifiedvia PSCAD/EMTDC simulation using the well known two-areafour-machine system in Fig. 7. The implemented system is rated20/230 kV, 900 MVA and the parameters for the generators andtransmission system together with the loading of the system aregiven.

VI. CONCLUSION

An adaptive POD controller by means of E-STATCOM has beendeveloped in this paper. For this, a modified RLS set of rules hasbeen used for estimation of the low-frequency electromechanical oscillation components from locally measured signalsduring power device disturbances. The estimator enables afast, selective and adaptive estimation of sign additives atthe electricity oscillation frequency.

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