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Controllers for Power Oscillation Damping by STATCOM With Energy Storage

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***Abstract*— This paper offers with the outline of an adaptive power oscillation damping (POD) controller for a static synchronous compensator (STATCOM) outfitted with vitality stockpiling. That is done the use of a signal estimation technique taking into account a changed recursive least square (RLS) calculation, which allows a fast, particular, and versatile estimation of the low-recurrence electro-mechanical motions from locally measured signals over the span of power machine unsettling influences. The proposed methodology is successful in developing the damping of the system on the frequencies of interest, also inside the instance of system parameter instabilities and at various association purposes of the compensator. To begin with, the assessment of enthusiastic and receptive vitality infusion into the quality contraption could be played out the utilization of a simple four-system machine adaptation. A control procedure that improves dynamic and responsive force infusion at different association variables of the STATCOM will be inferred utilizing the rearranged model. Small signal analysis of the element execution of the proposed control system could be executed. Here two controllers proposed and efficiency of the proposed controller is verified by simulation results.**

***Index Terms*— POD, STATCOM, signal estimation technique, RLS and Small signal analysis.**

I. INTRODUCTION

Static synchronous compensator (STATCOM) increases the stability of an ac power system. It can be applied at distribution level to overcome power quality problems and even at transmission level for voltage control and power oscillation damping (POD) [1]–[3]. It typically applied only for injection of reactive power, by combining the STATCOM with an energy storage connected to converter′s dc-link, a more flexible control of the transmission system can be achieved [4], [5]. Because injection of active power is used temporarily during transient, incorporating the stability improvement function in systems where active power injection is mainly used for other purposes [8] can be impressive. Low-frequency electromechanical oscillations (of range of 0.2 to 2 Hz) are most common in the power system and are of concern of secure operation of the system, especially in a transmission system that is weak[9]. Hence, FACTS controllers, both in series and shunt configuration, have been majorly used to increase stability of the power system [1]. Using reactive power injection, the first swing stability and POD can be obtained by varying the voltage at the point of common coupling.
In this paper, a control strategy for the E-STATCOM when used for POD will be investigated. Because of the

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selected local signal quantities measured in the system, the control strategy includes the injection of active and reactive power to provide uniform damping in the power system at different locations. It will be shown that the implemented control algorithm is robust against system parameter uncertainties. For this, a fuzzy logic controller and recursive least square (RLS)-based estimation algorithm will be used.

II. Modelling of Controller

Simplified model of two machine system is as shown below in Fig1. The control of the E-STATCOM consists of an outer control loop and an inner current control loop, as shown in Fig. 2.

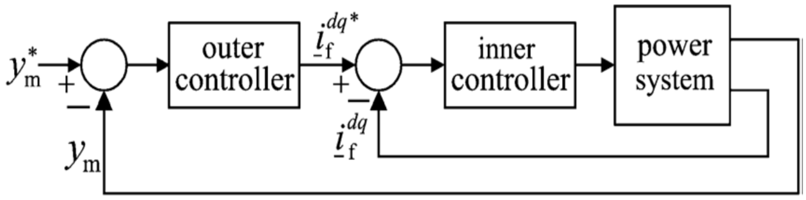

Figure.1.Simplified two-machine system with E-STATCOM

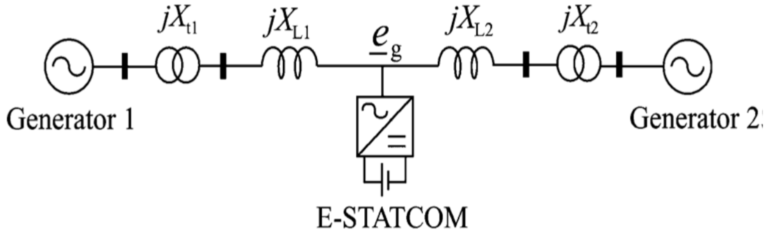

Figure.2.Block diagram of the control of E-STATCOM

The outer control loop, which can be an ac voltage, dc-link voltage or POD controller, sets the reference current for the inner current controller. The generic measured signal Y_m depends on the type of outer loop control. The control algorithm is implemented in dq-reference frame where a phase-locked loop (PLL) [15] is used to track the grid-voltage angle θ_g from the grid-voltage vector $\underline{e}_g$. By synchronizing the PLL with the grid-voltage vector, the d and q components of the injected current (i_f^d and i_f^q) control the injected active and reactive power, respectively. In the notation in Fig. 2, the superscript "*" denotes the corresponding reference signals

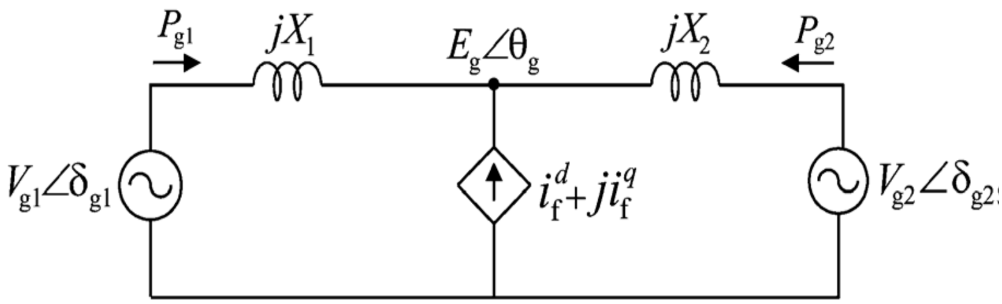

Figure .3.Equivalent circuit for two machine system with STATCOM

For the system in Fig. 3, the change in active power output from the generators due to injected active and reactive power from the E-STATCOM is calculated as in

$$\Delta P_{g1,\,Q} = \left[\frac{Vg1\ Vg2\ \sin(\delta g10-\delta g20)\,a\,(1-a)}{E2g0}\right] Q_{inj}$$

$$\Delta P_{g2,\,Q} = -\left[\frac{Vg1\ Vg2\ \sin(\delta g10-\delta g20)\,a\,(1-a)}{E2g0}\right] Q_{inj}$$

The above equations are used to get the power output from the generators injected from the active and the reactive power for the converters location..

III. POD CONTROLLER

POD controller consists of Phase Locked Loop(PLL) block, RLS estimator and PI or Fuzzy Logic controller. In this section PLL, PI controller and Fuzzy Logic controller are discussed, RLS estimator will be discussed in next section. The Block diagram of POD controller is shown in Fig.4(a) and Fig.4(b)

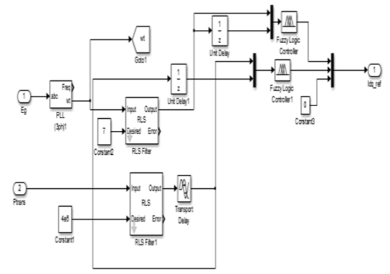

Fig4(a).Block diagram of the POD controller with PI

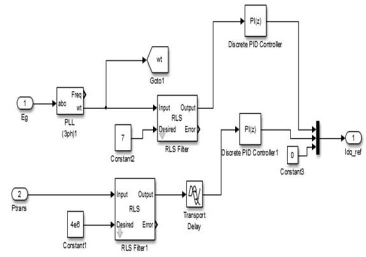

Fig4(b).Block diagram of the POD controller with Fuzzy logic.

Phase Locked Loop

The PLL (3ph) block models a Phase Lock Loop (PLL) closed-loop control system, which tracks the frequency & phase of a sinusoidal three-phase signal by using an internal frequency oscillator. The control system adjusts the internal oscillator frequency to keep the phases difference to 0. The figure shows the internal diagram of the PLL.

The three-phase input signal is converted to a dq0 rotating frame (Park transform) using the angular speed of an internal oscillator.

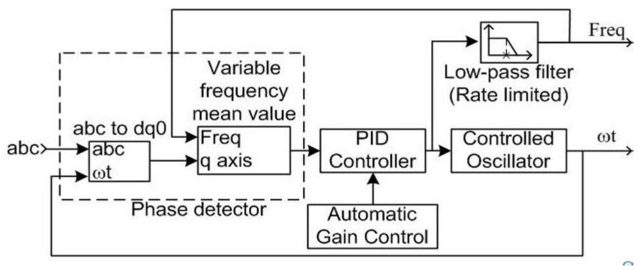

Figure.5.Block diagram of PLL

PI Controller

The PID manipulate scheme is known as after its three correcting terms, whose sum constitutes the manipulated variable (MV). The proportional, integral, and derivative terms are summed to calc1ulate the output of the PID controller. PI controller is a one of the earliest commercial controllers. Its easy to be tuned. This controller has been demonstrated to be remarkably effective in regulating a wide range of methods. lt does not longer require a real version and hence, used for tactics whose fashions are drastically difficult to be driven. However, in spite of the benefits of the PI controller, there remain numerous drawbacks. It can't scope nicely in a few instances consisting of such as Non-linear processes (changing in r1unning factor),time varying parameters

Fuzzy Logic Controller

Fuzzy logic is a very powerful method of reasoning when mathematical formulations are infeasible and input data are imprecise. These above problems are encounter in many control applications in which we know, how the system is behaving but find it difficult to express the derived behavior in terms of mathematical model are in analytical formula. In this case fuzzy logic is a powerful tool for designing the control system accurately. In the block diagram shown, the controller is between a pre-processing block and a post-processing block.

IV. RLS ALGORITHM

As described in the introduction, effective power oscillation damping for various power system operating points & E-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 a modified RL**S** algorithm. One can compute filtered output, filter error and filter weights for given input and desired signals using RLS adaptive filter algorithm.

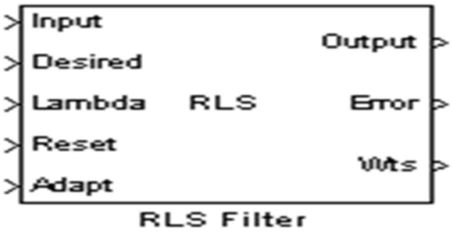

Figure.6.Block diagram of RLS filter

V. SIMULATION RESULTS

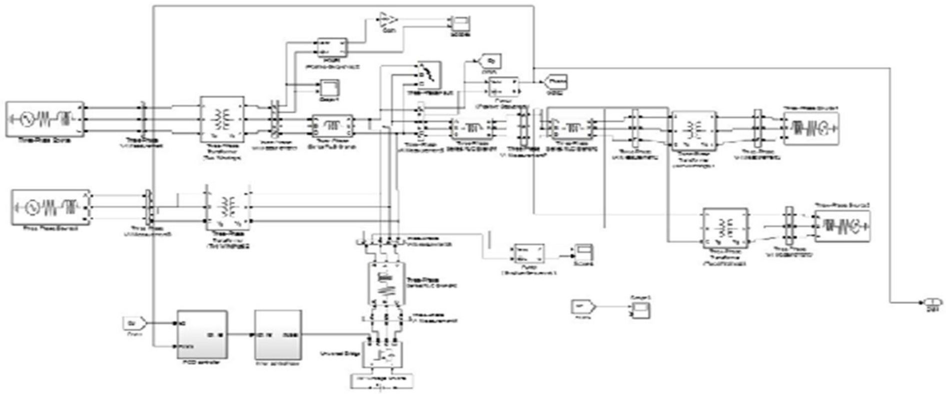

Figure.7.Simplified two-area four machine power system

The POD controller described in earlier Section is here verified via MATLAB simulation using the well known two-area four-machine system in Fig.7. The implemented system is rated 20/230 kV, 900 MVA and the parameters for the generators and transmission system together with the loading of the system are given in detail in [9].

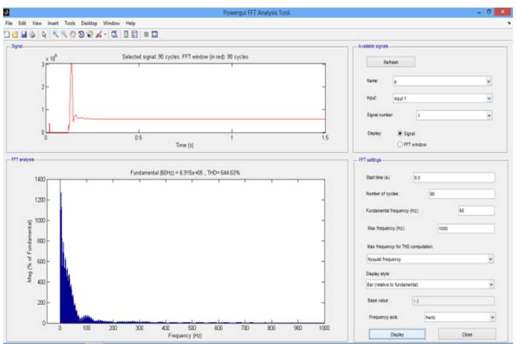

Fig.8. Graph Representing THD value of the PI System when only P injected

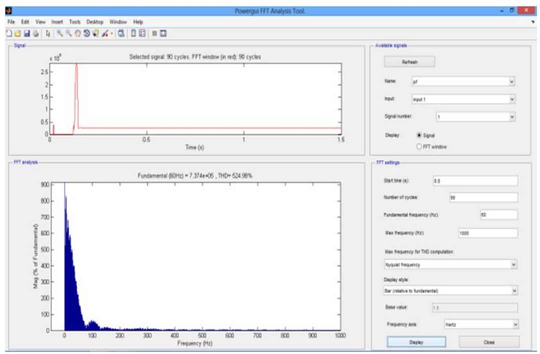

Fig. 9. Graph Representing THD value of the Fuzzy System when P injected

It can be seen that the Total Harmonic Distortion (THD) value at 0.0sec start time with 90 cycles and frequency of 60Hz for PI system is 644.63% and for Fuzzy system is 524.96%.

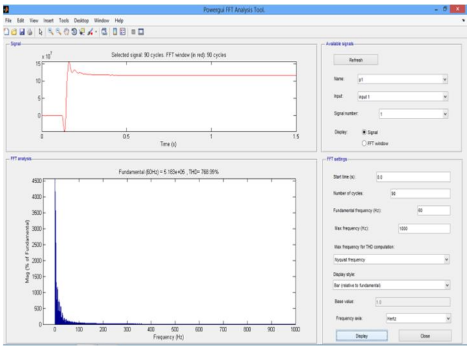

Fig.10. Graph Representing THD value of the PI System when only Qinjected

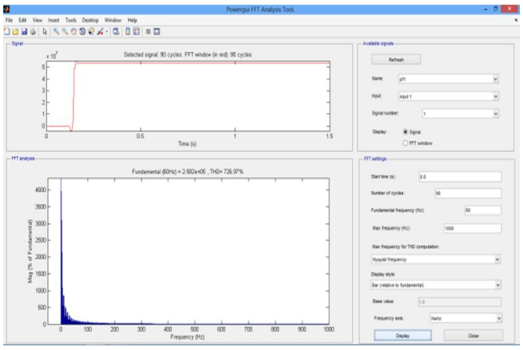

Fig.11. Graph Representing THD value of the Fuzzy System when Q injected

It can be seen that the Total Harmonic Distortion (THD) value at 0.0sec start time with 90 cycles and frequency of 60Hz for PI system is 768.99% and for Fuzzy system is 726.97%.
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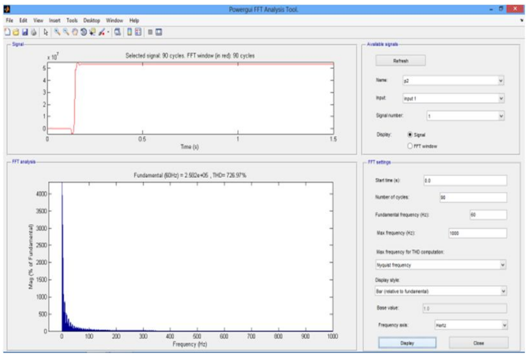

Fig.12.Graph representing THD value of the PI system when when both P and Q injected

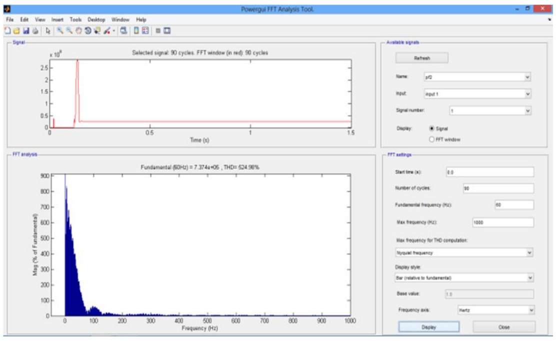

Fig.13.Graph representing THD value of the Fuzzy system P and Q injected

Measured transmitted active power output following a three-phase fault with E-STATCOM connected to POD using fuzzy controller by only P injected (blue solid), only Q injected (green solid), both P and Q injected (magenta solid).

VI. CONCLUSION

The focus of paper has been in Power oscillations Damping (POD).The final aim of this work has been to identify a control strategy that allows stabi1ity enhancement from the compensator with low amount of injected active power, leading to a cost-effective uti1ization of energy storage. A control algorithm for POD is developed using a signal estimation technique based on Recursive Least Square (RLS) algorithm. We have investigated the dynamic performance of the system by using a simple four machine model of the power system. By looking at THD values, we can say that the Fuzzy system has reduced the THD value compared to the PI system and hence we can conclude that, the Fuzzy logic based POD controller is efficient than the PI based POD controller.

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