Power System Oscillation Damping Controller by using STATCOM with an Energy Storage system: A Review

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Abstract— This paper manages the survey of Enhancement of Power System Dynamic Stability by a static synchronous compensator (STATCOM). In control frameworks, and particularly appropriation frameworks, control electronic gadgets are getting more typical. They are used both as interfaces in client loads, and as an answer in the framework itself. One explanation for the later, is the expanded enthusiasm for control quality, a term which focuses on the nature of the voltages and streams, concentrated on bends from perfect power supplies. For enhancing the power quality, is to utilize control electronic controllers. A stand out amongst the most well-known controllers are the static synchronous compensator (STATCOM) which can be connected for some employments. Be that as it may, by furnishing STATCOMs with vitality stockpiles, extra applications can be gotten. Consequently, there is a requirement for an examination to decide the power quality applications and additional advantages that are picked up by outfitting STATCOMs with vitality stockpiles. A Static Synchronous Compensator (STATCOM) is utilized to enhance the voltage profile of the heap transport. Two distinct controllers: PI and fluffy rationale are utilized for the control motivation behind the STATCOM.

Key words: Energy Storage, Low-Frequency Oscillation, Power Oscillation Damping (POD), Recursive Least square (RLS), Static Synchronous Compensator (STATCOM), Fuzzy Logic Controller, PI Controller

I. INTRODUCTION

Static synchronous compensator (STATCOM) is a key gadget for support of the strength in an air conditioner control framework. This gadget has been connected both at dissemination level to alleviate control quality wonders and at transmission level for voltage control and power wavering damping (POD) [1] – [3].Although normally utilized for responsive power infusion just, by furnishing the STATCOM with a vitality stockpiling associated with the dc-connection of the converter, a more adaptable control of the transmission framework can be accomplished [4], [5]. An establishment of a STATCOM with vitality stockpiling is as of now found in the U.K. for control stream administration and voltage control [6]. The presentation of wind vitality and other circulated age will make ready for more vitality stockpiling into the power framework and assistant solidness upgrade work is conceivable from the vitality sources [7]. Since infusion of dynamic power issued briefly amid transient, joining the strength upgrade work in frameworks where dynamic power infusion is fundamentally utilized for different purposes [8] could be alluring.

The present power framework is an interconnected power framework. In interconnected power framework, there has been unconstrained framework wavering at low frequencies arranged by 0.2 to3.0 Hz. With a specific end goal to soggy the power framework swaying, expanding the power framework wavering dependability, the establishment of PSSs is both efficient and compelling. As of late showed up FACTS based stabilizers offer an elective method to soggy out the power framework wavering. The static synchronous compensator (STATCOM) depends on the rule that a voltage source inverter creates a controllable AC voltage source behind a transformer-spillage reactance with the goal that the voltage contrast over the reactance produces dynamic and receptive power trade between the STATCOM and the transmission organize. Be that as it may, there are crucial contrasts between these FACTS gadgets. The first is amongst SVC and TCSC as controlled-impedance sources and the STATCOM and TCPS as controlled-voltage sources. The second contrast is that STATCOM has created from a switch mode voltage-source converter arrangement with a vitality stockpiling gadget (DC capacitor) while SVC, TCSC and TCPS depend on stage controlled thyristors/diodes which don't have any vitality stockpiling gadgets.

Besides, the STATCOM can be utilized for network association of sustainable power sources to full the lattice codes. In its fundamental structure, the STATCOM can just trade responsive power with the matrix, yet in the event that furnished with a vitality stockpiling, the STATCOM can likewise trade dynamic power. The execution and uses of STATCOMs are dissected in this work.

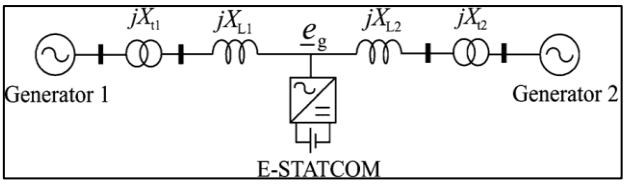

Fig. 1: Simplified Two-Machine System with E-STATCOM.

II. STATCOM

A. Advantages of STATCOM in Control Frameworks

With the progressing deregulation of the electric utility industry, various changes are consistently being acquainted with a once unsurprising business. With power progressively being considered as a ware, transmission frameworks are being pushed nearer to their solidness and warm cutoff points while the emphasis on the nature of energy conveyed is more prominent than any time in recent memory. Furthermore, dynamic responsive power bolster is ending up more essential, particularly in urban territories where neighborhood (i.e., at the heap) age is being decreased or dispensed with. In the deregulated utility condition, money related and advertise powers will request a more ideal and gainful task of the influence framework as for age, transmission, and dispersion.

B. STATCOM Portrayal

Fig. 2 shows the proportional circuit of a STATCOM. In this plan, the arrangement protection Rs represents the aggregate of the inverter conduction misfortunes and the transformer winding protection misfortunes. The spillage inductance of the transformer is spoken to by Ls. The protection Rc which is in shunt with the capacitor C likewise de-note for the misfortunes identified with the exchanging of the inverter and additionally the misfortunes of the capacitor. Vas, Vbs and Vcs also signify the three-stage yield voltages of STATCOM; in addition, Val, Vbland Vclre-show voltages of the three-stage transport; and, i as, ibsand icsare the yield streams of the three-stage STATCOM [2, 6].

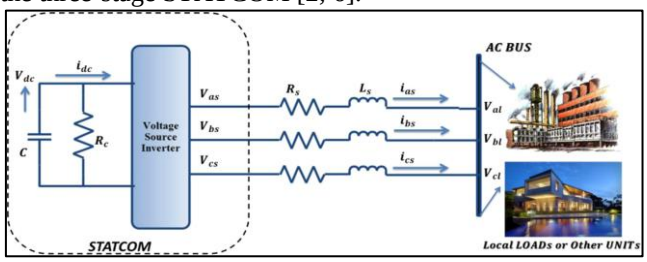

Fig. 2: The General Scheme of STATCOM

C. STATCOM Description

Mathematical model of a three-phase STATCOM can be given as follows:

$$L_s\frac{di_{as}}{dt} = -R_s i_{as}+V_{as}-V_{al} \quad (1)$$

$$L_s\frac{di_{bs}}{dt} = -R_s i_{bs}+V_{bs}-V_{bl} \quad (2)$$

$$L_s\frac{di_{cs}}{dt} = -R_s i_{cs}+V_{cs}-V_{cl} \quad (3)$$

$$\frac{d}{dt}\left(\frac{1}{2}cv_{dc}^2(t)\right) = -[Vas\ Ias + Vbs\ Ibs + Vcs\ Ics] = -\frac{V_{dc}^2(t)}{R_c} \quad (4)$$

Taking advantage of abc/dq transformation Eqs. (1) to (4) can be simplified as follows:

$$\frac{d}{dt}\begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{ds} \end{bmatrix} = \begin{bmatrix} -\frac{R_s}{L_s} & \omega & \frac{K}{L_s}\cos\alpha \\ -\omega & -\frac{R_s}{L_s} & \frac{K}{L_s}\sin\alpha \\ -\frac{3K}{2c}\cos\alpha & -\frac{3K}{2c}\sin\alpha & -\frac{1}{R_c C} \end{bmatrix}\begin{bmatrix} i_{ds} \\ i_{qs} \\ V_{ds} \end{bmatrix} - \frac{1}{L_s}\begin{bmatrix} V_{dl} \\ V_{ql} \\ 0 \end{bmatrix} \quad (5)$$

where i_{ds} and i_{qs} respectivelyrepresentthecurrentsof d and q corresponding to i_{bs}, i_{bs}, and i_{cs}; the relation between the dc voltage and the peak phase to neutral voltage on the ac side is denoted by Factor K; V_{ds} represents the voltage of the dc side; α denoted the phase angle at which the voltage of the STATCOM leads the bus voltage; speed of the rotating angle of the voltage vector is denoted by ω; and V_{dl} and V_{ql} are respectively the d and q axis voltage corresponding to V_{al}, V_{bl} and V_{cl}. Since V_{ql} is assumed to be0, considering the definition of the instant an eousactive and reactive power, (6) and (7)can be obtained as bellow coordination:

$$dl=\frac{3}{2}\ v_{dl}\ i_{ds} \quad (6)$$

$$ql=\frac{3}{2}\ v_{dl}\ i_{qs} \quad (7)$$

Given to the above mentioned equations, the traditional control strategy can be obtained, and accordingly, the control block diagram of the STATCOM is shown in Fig. 3.

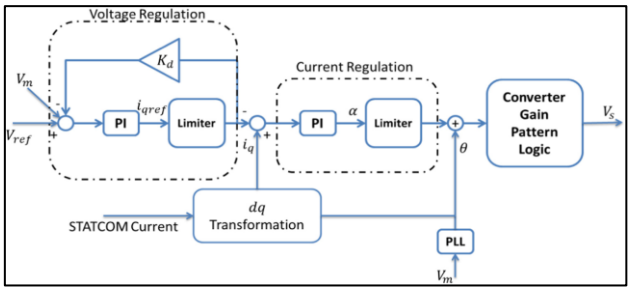

Fig. 3: The Block Diagram of PI Controller for STATCOM

As demonstrated by Fig. 2, the phase- locked loop (PLL) is in charge of providing a synchronizing signal that will be used as the reference angle for the measurement system. Measured voltage of the bus line Vmis compared to the reference voltage Vref, and accordingly reactive reference current Iref will be provided by the voltage regulator. The allowable voltage error attherated responsive current flow is denoted by droop factor Kd. The reactive current of the STATCOM Iq is compared with reference current Iqref, and the yield of the current regulatoris calculated using the angle stage shift between the inverter voltage and the framework voltage. Given the upper bound for responsive power that can be generated by the STATCOM, alimit will be imposed on the value of control that is denoted by the value of limiter.

III. VSC-BASED STATCOM CONTROLLER OUTLINE

The STATCOM is chiefly utilized for dynamic compensation to give voltage bolster, transient steadiness enhancement and to increment damping. An improved STATCOM structure is appeared in Fig. 1 [4]. On a basic level, a STATCOM is one self-commutating voltage-sourced inverter which associated with the bus bar through the coupling reactance. The converter can be controlled to yield shifting voltage, the voltage contrast between the converter terminal and bus bar will create reactive current Iq flowing in or out from the bus bar. The current can be controlled be either capacitive or inductive by the inverter controller. The strong VSC based STATCOM controller is utilized to build the damping of neighborhood mode and between area mode motions.

A. Neighborhood Mode Controller Outline

Since the neighborhood mode typically displays as one machine swinging against different machines in the framework, the single machine unending framework appeared in Fig. 2 is appropriate to be connected in the controller plan. In this framework, one generator is associated with an endless transport through a twofold circuit transmission line. The shunt STATCOM gadget is associated at the center purpose of the tie lines since it is the best establishment place of shunt associated Actualities gadgets in genuine framework [1].

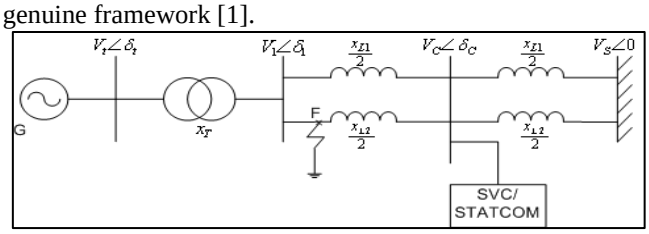

Fig. 4: A Single Machine Infinite Bus System

The main objective of STATCOM is for voltage control. The STATCOM works under constant voltage principle in voltage control mode. However, for transient stability enhancement or damping improvement purpose, the STATCOM terminal voltage may not be kept as a constant voltage. The limitation of reactive compensation is system current rating, which can be expressed as Iq min < Iq < Iq max. When STATCOM is working within the control range, the terminal voltage can be controlled to desired value by adjusting the injected current. Otherwise, STATCOM is worked on its rated current.

B. P-I Controller

P-I controller is fundamentally used to wipe out the enduring state mistake coming about because of P controller. Be that as it may, as far as the speed of the reaction and general security of the framework, it has a negative effect. This controller is for the most part utilized as a part of regions where speed of the framework isn't an issue. Since P-I controller has no capacity to foresee the future blunders of the framework it can't diminish the ascent time and wipe out the motions. In the event that connected, any measure of I ensures set point over.

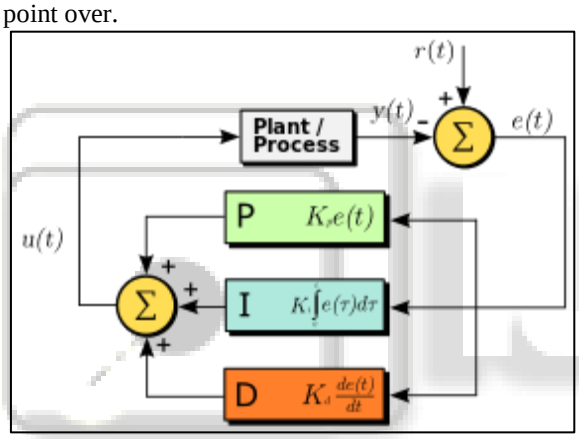

Fig. 5: PID Controller

A proportional– integral– subsidiary controller (PID controller) is a control circle input mechanism (controller) usually utilized as a part of modern control frameworks. A PID controller ceaselessly computes a mistake value as the contrast between a deliberate procedure variable and a coveted set point. The controller endeavors to limit the mistake after some time by alteration of a control variable, for example, the situation of a control valve, a damper, or the power provided to a warming component, to another esteem dictated by a weighted aggregate.

C. Proposed Control System

1) Fuzzy Logic Controller

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC. The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

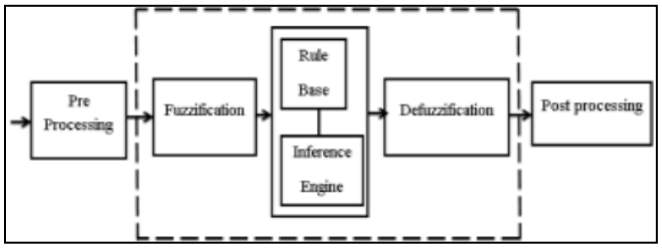

Fig.6: Fuzzy Logic Controller

a) Fuzzification

Enrollment work esteems are doled out to the semantic factors, utilizing seven fluffy subsets: NB (Negative Enormous), NM (Negative Medium), NS (Negative Little), ZE (Zero), PS (Positive Little), PM (Positive Medium), and PB (Positive Huge). The parcel of fluffy subsets and the state of enrollment CE (k) E (k) work adjust the get down to business to suitable framework. The estimation of info mistake and change in blunder are standardized by an information scaling factor.

b) Induction Strategy

A few structure strategies, for example, Max– Min and Max-Spot have been proposed in the writing. In this paper Min technique is utilized. The yield participation capacity of each control is given by the base administrator and greatest administrator.

c) Defuzzification

As a plant more often than not requires a non-fluffy estimation of control, a defuzzification arrange is required. To figure the yield of the FLC, „height" technique is utilized and the FLC yield adjusts the control yield. Further, the yield of FLC controls the switch in the inverter. In UPQC, the dynamic power, responsive power, terminal voltage of the line and capacitor voltage are required to be kept up. To control these parameters, they are detected and contrasted and the reference esteems. To accomplish this, the enrollment elements of FC are: mistake, change in blunder and yield.

IV. CONCLUSION

The voltage profile of the single alternator based radial micro grid system is improved using a STATCOM. The controllers used for the control of STATCOM i.e. PI and fuzzy logic controller are designed in this work. The performances of both the controller are evaluated under three different load conditions such as linear RL load, nonlinear load and dynamic load. It is found that the steady state error is more with PI controller whereas fuzzy logic controller gives accurate results without any steady state error. Again the overshoots, undershoots and settling time are also less with fuzzy logic controllers. The voltage deviation due to load change with fuzzy logic controllers is much less than conventional PI controllers.

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