



Fuzzy Logic Controller of STATCOM for Voltage Regulation

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ABSTRACT: Structure of control framework for AC-voltage controller STATCOM with fluffly rationale controller is like a nonlinear PI controller. In this, we have utilized a fluffly rationale controller rather than ordinary PI controller. Standard managementler for STATCOM furthermore a couple of usages of PI controller get PI grabs by method for an experimentation approach gives control parameters to the best execution at a given operators reason won't not be fruitful at a specific specialists reason. This endeavor proposes a new out of the crate new organization model maintained adaptable PI organization, which might self-switch the organization gets all through an unsettling impact. The parameters are changed in a manner that mistake sign is minimized. To get the fancied result, we should apply a standard based framework. The standard base for FLC is composed by the experience of contemplating the execution of STATCOM. The expected structure is maintained in MATLAB/SIMULINK PC code environment.

KEYWORDS- Adaptive management, Fuzzy Logic Controller, proportional-integral (PI) management, reactive powercompensation, STATCOM, voltage stability.

I. INTRODUCTION

Adaptable AC Transmission Systems (FACTS) utilizes power hardware gadget to control the genuine and receptive force in current force framework for the better use of the current system. They are utilized to soggy out force swings in this way lessening the transmission misfortune by legitimate receptive influence control and upgrade the transient dependability. Quick acting Static synchronous compensator (STATCOM) is broadly utilized as dynamic shunt compensator for receptive force control in the transmission system. VSC based STATCOM have been produced to control power framework motion amid issue condition. It has been accounted for by numerous scrutinizes that STATCOM with cutting edge controller can be utilized to create steadiness of arrangement of multi machine framework and a solitary machine endless transport framework. Numerous propelled control advancements have been proposed by the analysts for STATCOM in enhancing security of force framework steadiness.

Voltage quality may be a key thought in up the protection and whimsy of power structures. The static compensator (STATCOM), an all that very much wanted contraption for responsive power organization maintained entryway Side Street (GTO) thyristors, has grabbed a lot of energy within the latest decade for up foundation relentlessness [1]. Within the past, vacillated organization ways are made game plans for STATCOM organization. Ordinarily talking, it's impractical for utility architects to perform experimentation studies to search out proper parameters once a fresh out of the plastic new STATCOM is associated with a framework. Further, in spite of the fact that the administration increases are tuned to suit the anticipated circumstances, execution could likewise be dissatisfactory once a considerable alteration of the framework conditions happens, as once a line is overhauled or resigns from administration [13]-[14]. The case is often even worse if such transmission topology modification is as a result of a contingency. Thus, the STATCOM system might not perform well once principally required. A few, however restricted previous works within the literature mentioned the STATCOM PI controller gains so as to higher enhance voltage stability and to avoid long standardization. as an example, in [15]-[17] linear best managements supported the linear quadratic regular(LQR)

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controls are planned. This management depends on the designer’s expertise to get best parameters. In [18] an exceedingly new STATCOM state feedback style is introduced supported a zero set idea. Almost like [15]-[17] the ultimate gains of the STATCOM state feedback controller still rely upon the designer’s alternative. In [19]-[21] an exceedingly fuzzy PI management methodology is planned to tune PI controller gains. However, it is still up to the designer to settle on the particular, settled gains. In [22] the population-based search technique is applied to tune controller gains. However, this methodology typically desires a protracted period of time to calculate the controller gains. A trade off of performance and also the sort of operation conditions still needs to be created throughout the designer’s decision-making method. Thus, extremely economical results might not be forever accomplishable underneath a selected in operation condition. Completely different from these previous works, the motivation of this paper is to propose an impact methodology that may guarantee a fast and consistent desired response once the system operation condition varies in alternative words, the modification of the external condition won't have a negative impact, like slower response, overshoot, or perhaps instability to the performance. There are three inputs of FLC and one output. This input and output gains of FLC are tuned by trial method in such a way to satisfy the minimum error, and best output response is tuned by changing the gain and other parameters. The parameters are changed in such a way that error signal is minimized. To get the desired result, we must apply a rule-based system. The rule base for FLC is designed by the experience of studying the performance of STATCOM.

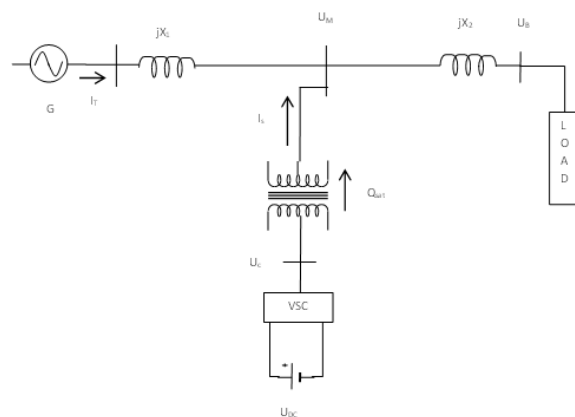


Fig1. Dynamic model system with STATCOM

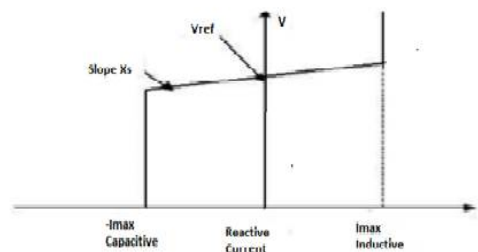


Fig2. V-I Characteristics of STATCOM

II. STATCOM MODEL AND CONTROL

A. STATCOM model with fuzzy logic controller (flc). Structure of control system for AC-voltage regulator STATCOM with fuzzy logic controller. The fuzzy main controller is similar to a nonlinear PI controller. Nine fuzzy sets or linguistic variables are defined for E, ΔE1 & ΔE2, and nine for output signal. Fuzzy logic controller is a better option than conventional PI controller because it provides higher level of automation by incorporating expert knowledge and it also robust nonlinear control. In this, we have used a fuzzy logic controller instead of conventional PI controller. There

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are three inputs of FLC and one output. This input and output gains of FLC are tuned by trial method in such a way to satisfy the minimum error, and best output response is tuned by changing the gain and other parameters. The parameters are changed in such a way that error signal is minimized. To get the desired result, we must apply a rule-based system. The rule base for FLC is designed by the experience of studying the performance of STATCOM.

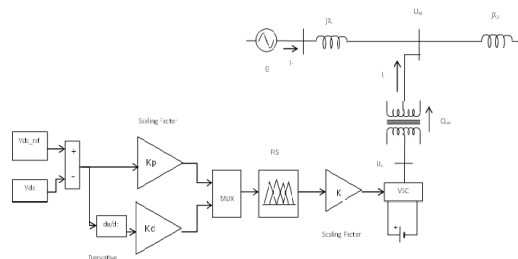


Fig. 3 Block diagram of STATCOM model with fuzzy logic controller (FLC)

III. ADAPTIVE PI CONTROL OF STATCOM

A. Idea of the planned adjective PI management technique the STATCOM with mounted PI management parameters might not reach the specified and acceptable response within the facility once the ability system operative condition (e.g., hundreds or transmissions) changes. Associate adjective PI management technique is conferred.

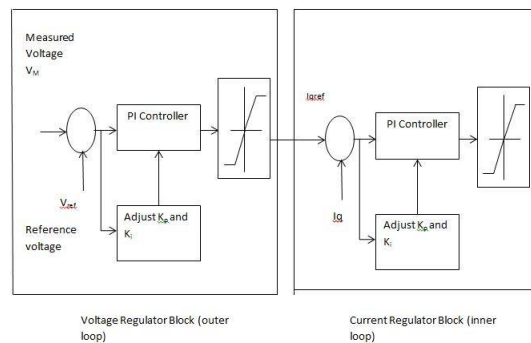


Fig. 4 Adaptive PI control block for STATCOM

Here specified response and to avoid activity trial-and-error studies to search out appropriate parameters for PI controllers once a replacement STATCOM is put in in an exceedingly facility. With this adjective PI management technique, the propellant self-adjustment of PI management parameters is complete. Associate adjective PI management block for STATCOM is shown in Fig. 3. In Fig. 3, the measured voltage and therefore the reference voltage, and the q-axis reference current and therefore the q-axis current square measure in per-unit values. The proportional and integral components of the transformer gains square measure denoted by k_{p-v} and k_{i-v} , severally. Similarly, the gains and represent the proportional and integral components, severally, of the present regulator. During this system, the allowable voltage error k_d is set to zero. The k_{p-v} , k_{i-v} , k_{p-i} and k_{i-i} can be set to associate capricious initial price like merely one.0. One exemplary desired curve is associate graphical record in terms of the voltage growth, shown in Fig. 4 that is ready because the reference voltage within the outer loop. Alternative curves may additionally be used than the delineate graphical record as long because the measured voltage returns to the specified steady-state voltage in desired time period. {The process|the technique} of the adjective voltage-control method for STATCOM is represented as follows.



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- 1) The bus voltage $v_m(t)$ is measured in real time.
- 2) Once the measured bus voltage over time, the target steady-state voltage, that is ready to 1.0 per unit (p.u.) within the discussion and examples, $v_m(t)$ is compared with v_{nn} . supported the specified reference voltage curve, k_{p-i} and k_{i-i} are dynamically adjusted so as to create the measured voltage match the specified reference voltage, and therefore the q-axis reference current is obtained.
- 3) Within the inner loop, I_{qref} is compared with the q-axis current I_q . Exploitation the similar management technique just like the one for the outer loop, the parameters k_{p-i} and k_{i-i} is adjusted supported the error. Then, an appropriate angle is found and eventually the dc voltage in STATCOM is changed specified STATCOM provides the precise quantity of reactive power injected into the system to stay the bus voltage at the specified price.

It ought to be noted that the present and I_{max} and I_{min} the angle α_{max} and α_{min} square measure the bounds obligatory with the thought of the most reactive power generation capability of the STATCOM controlled during this manner. If one in every of the most or minimum limits is reached, the most capability of the STATCOM to inject reactive power has been reached. Certainly, as long because the STATCOM size has been befittingly studied throughout designing stages for inserting the STATCOM into the ability system, the STATCOM mustn't reach its limit unexpectedly

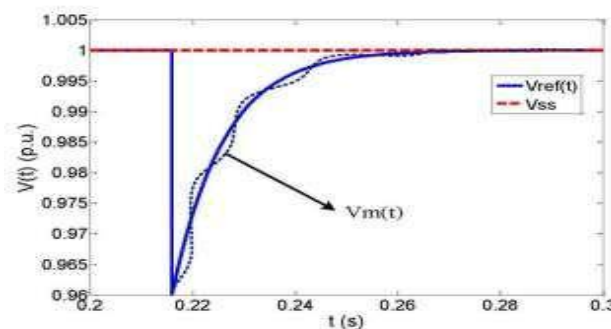


Fig. 5 Reference voltage curve.

Since the inner loop management is analogous to the outer loop management, the mathematical technique to mechanically regulate PI controller gains within the outer loop is mentioned during this section for illustrative functions. the same analysis is applied to the inner loop.

$$\begin{bmatrix} V_{dl}(t) \\ V_{ql}(t) \\ 0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_{al}(t) \\ V_{bl}(t) \\ V_{cl}(t) \end{bmatrix} .$$

IV. FLOWCHART OF OPERATING PROCEDURE FOR FUZZY LOGIC CONTROLLER IN STATCOM

To enhance the performance of D-STATCOM a prototype is designed using MATLAB 2012a version; Fig below shows the flow chart of the control strategy of the system.



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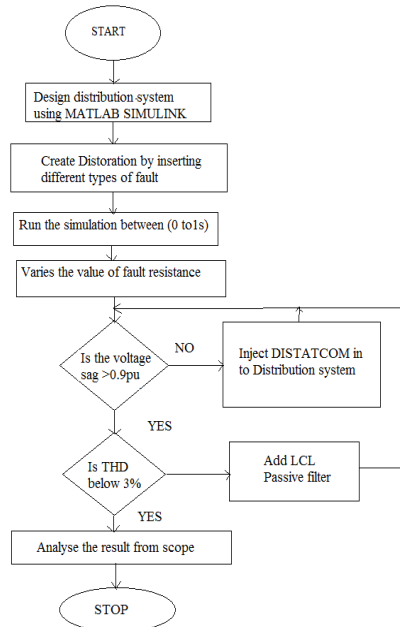


Fig 6Flowchart Of Operating Procedure For Fuzzy Logic Controller (FLC) In STATCOM

V. ALL VALUES OF ALL THE PARAMETERS

	Original Control
Lowest Voltage after disturbance	0.9938 p.u.
Time (sec) when V= 1.0	0.4095 Sec
Δt to reach V = 1.0	0.2095 Sec
Var Amount at Steady State	97.76 MVar
Time to reach Steady State Var	0.4095 Sec

Performance comparison for the original system parameters

For STATCOM:

Rated Power = 100 MVar

Rated voltage= 138 kV

Interface inductor (L) = 2.86 mH

Resistance (Rs) = 0.0898 Ω

For Power Transformer (Y/Y):

Rated Voltage 220 kV/33 kV

Rated Power: 300 MVA

Three Phase Load

Load 1:



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P= 100 MW
Q= 80 MVAR

VI. FLOWCHARTS OF THE ADAPTIVE PI CONTROL PROCEDURE

1. The accommodative PI management method begins at begin. The bus voltage over time () is sampled in line with a desired rate. Then () is compared with .If () = , then there is no reason to alter any of the known parameters $K_{p_V(t)}$, $K_{i_V(t)}$, $K_{p_I(t)}$ and $K_{i_I(t)}$. The power system is running swimmingly. On the opposite hand, if () \neq , then accommodative PI management begins.

2. The measured voltage is compared with , the reference voltage outlined in (10). Then, $K_{p_V(t)}$ and area unit adjusted within the transformer block (outer loop) supported (23) and (24), that results in associate updated I_{qref} viaa current electrical circuit as shown in Fig.3

3. Then, the I_{qref} is compared with the measured q-current I_q . The management gains $K_{p_I(t)}$ and $K_{i_I(t)}$ area unit adjusted supported (25) and (26). Then, the phase α is decided and felt a electrical circuit for output, that basically decides the reactive power output from the STATCOM.

4. Next, if $|\Delta V(t)|$ is not at intervals a tolerance threshold V_c , which may be a terribly tiny price like 0.0001 p.u., the transformer block and current regulator blocks area unit re-entered till the amendment is a smaller amount than the given threshold V_c .

VII. SIMULATION RESULT WAVEFORM OF FUZZY LOGIC CONTROLLER (FLC)

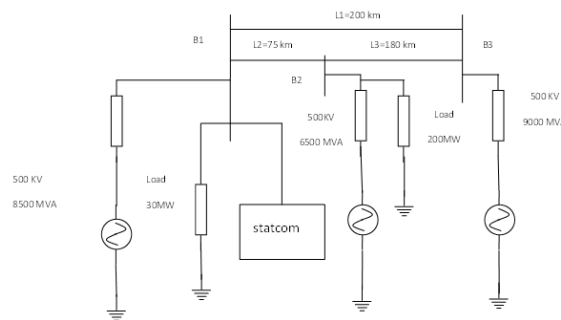


Fig. 7. Studied system

If there is the necessity to unceasingly perform the voltage-control method, that is typically the case, then the method returns to the measured bus voltage. Otherwise, the voltage-control method stops (i.e., the STATCOM management is deactivated). In the system simulation diagram shown in Fig. 6, a 100-MVAR STATCOM is enforced with a 48-pulse VSC and connected to a 500-kV bus. this can be the quality sample STATCOM system in Matlab/Simulink library, and every one machines utilized in the simulation square measure kinetic models. Here, the eye is concentrated on the STATCOM management performance in bus voltage regulation mode. within the original model, the compensating reactive power injection and therefore the regulation speed square measure chiefly suffering from PI controller parameters within the transformer and therefore the current regulator. the first management are compared with the planned adjustive PI management model. Assume the steady-state voltage, $v_{ss} = 1.0$ p.u.



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A. Change of PI Control Gains

The other system parameters remain unchanged while the PI controller gains for the original control are changed to k_{p-v} , k_{i-v} , k_{p-i} and $k_{i-i} = 1$. The dynamic control gains, which are independent of the initial values before the disturbance but depend on the post fault conditions.

Based on the Fuzzy control model can be designed, and the results are shown in Figs. respectively.

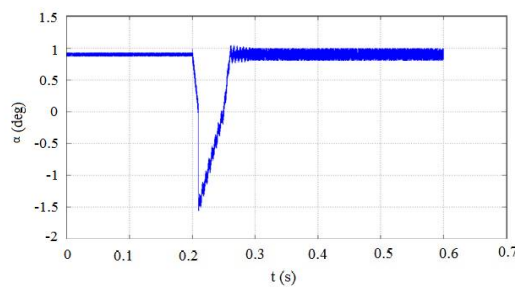
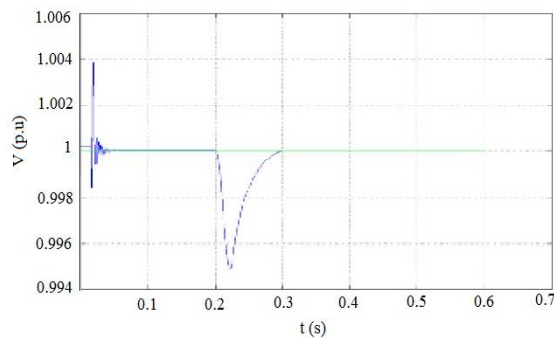
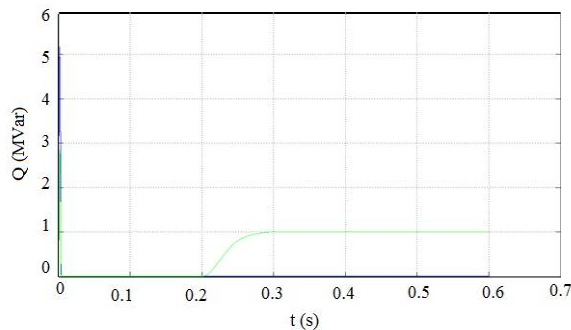


Fig.8 Results of α with changed PI control gains



(a)



(b)

Fig.9 Results of (a) voltages and (b) output reactive power with changed PI control gains

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B. Change of Transmission Network

The PI controller gains remain unchanged, as in the original model. However, line 1 is switched off at 0.2 s to represent a different network which may correspond to scheduled transmission maintenance. The adaptive PI control model can be designed to automatically react to changes in the transmission network. The results are shown in Figs the initial transients immediately after 0.2 s lead to an over absorption by the STATCOM, while the adaptive PI control gives a much smoother and quicker response, as shown in Fig.

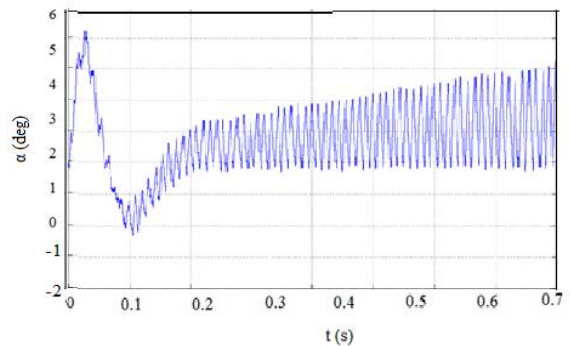
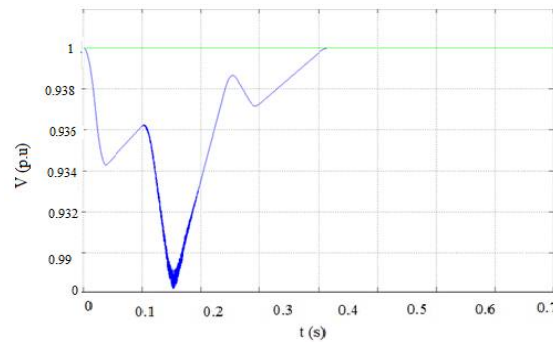
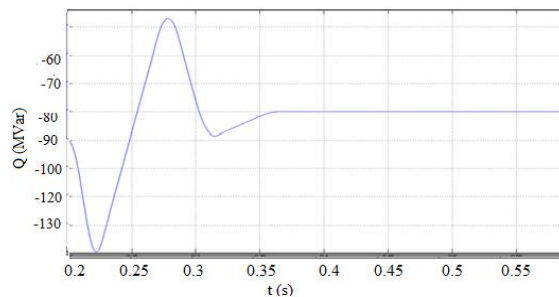


Fig.10 Results of α with change of transmission network



(a)



(b)

Fig.11. Results of (a) voltages and (b) output reactive power with a change of transmission network



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C.Two Consecutive Disturbances

In this case, a disturbance at 0.2 s causes a voltage decrease from 1.0 to 0.989 p.u. and it occurs at substation A. After that, line 1 is switched off at 0.25 s. The results are shown in. it is apparent that the adaptive PI control can achieve much quicker response than the original one, which makes the system voltage drop much less than the original control during the second disturbance.

That the largest voltage drop during the second disturbance event (starting at 0.25 s) with the original control is 0.012 p.u., while it is 0.006 p.u. with the proposed adaptive control.

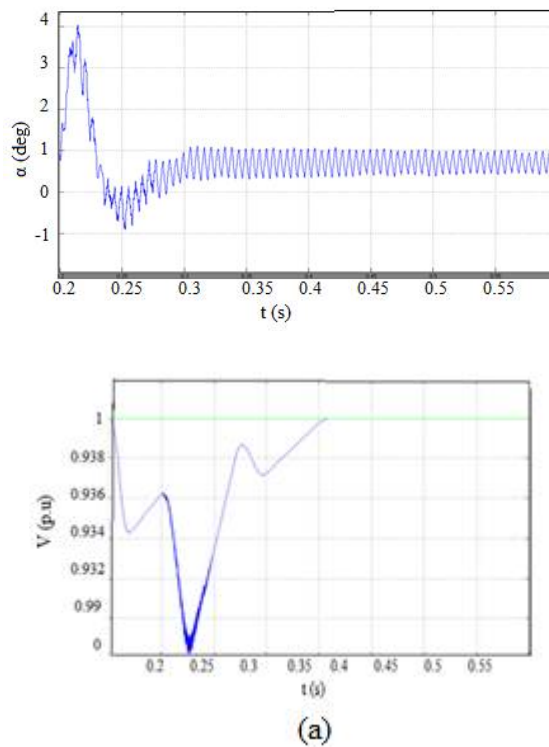


Fig.12 Results of α with two consecutive disturbances

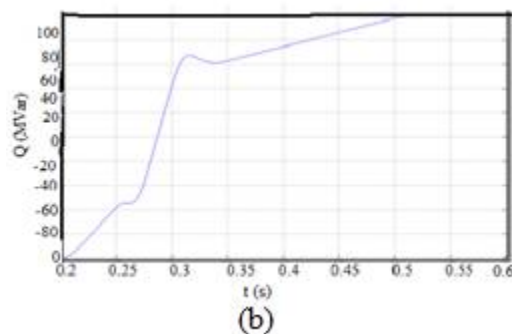


Fig.13 Results of (a) voltages and (b) output reactive power with two consecutive disturbances



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VIII. CONCLUSION AND FUTURE SCOPE

The principle target of the proposed framework is to build up a circuit for improving transient steadiness at 33KV network. Fluffy rationale controller was utilized as a part of controlling STATCOM. It was found that numerical demonstrating in synchronous turning outline diminishes the circuit multifaceted nature. In the writing, different STATCOM control strategies have been talked about including numerous uses of PI controllers. In any case, these past works get the PI picks up by means of a trial-and-blunder approach or broad studies with a tradeoff of execution and materialness. Thus, control parameters for the ideal execution at a given working point may not generally be successful at an alternate working point. Subsequent to the conformity is self-governing; this gives the "fitting and-play" ability for STATCOM operation. In the reproduction examine, the proposed versatile fluffy rationale control for STATCOM is contrasted and the routine STATCOM control with pretuned altered PI increases to check the benefits of the proposed technique. The outcomes demonstrate that the versatile PI control gives reliably brilliant execution under different working conditions, for example, distinctive introductory control increases, diverse burden levels, and change of the transmission system, successive unsettling influences, and an extreme aggravation.

IX. FUTURE WORK

In contrast, the conventional STATCOM control with fixed fuzzy logic controller gains has acceptable performance in the original system, but may not perform as efficient as the proposed control method when there is a change of system conditions. Future work may lie in the investigation of multiple STATCOMs since the interaction among different STATCOMs may affect each other. Also, the extension to other power system control problems can be explored.

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