Deployment of STATCOM with Fuzzy Logic Control for Improving the Performance of Power System under Different Faults Conditions

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***Abstract*—This paper purposes to demonstrate the effectiveness of fuzzy logic controller (FLC) over proportional integral (PI) controller for reducing the fault current and maintaining the voltage profile at different faults conditions using Static Synchronous Compensator (STATCOM) which is considered an effective FACTS (Flexible Alternating Current Transmission System) device. The study evaluates the performance of a power system equipped with STATCOM which is connected in shunt with bus B1 under various faults conditions, including single-phase and three-phase faults. The performance of the STATCOM is evaluated by using two different controllers: PI controllers and FLCs. A comparative analysis is done between the performances of the two different controllers using Matlab/Simulink software package. The results obtained conclude that the presented system gives better performance with STATCOM as compared to not using it under several faults conditions besides, the STATCOM gives better response with FLC as compared to PI controller. It is demonstrated that STATCOM with FLC can reduce the positive sequence fault current at bus B1 to 96.49% of its value without using STATCOM under line to ground fault and 98.17% under three line to ground fault whereas STATCOM with PI controller can reduce it to (99.57, 99.05%), respectively. Also, the bus voltage B1 is improved to 102.19% by using STATCOM with fuzzy controller under line to ground fault and 101.86% under three line to ground fault whereas STATCOM with PI controller can improve it to (100.21, 100.93%), respectively.**

Keywords*—Power System; Flexible Alternating Current Transmission System (FACTS); Static Synchronous Compensator (STATCOM); STATCOM Control; Proportional Integral (PI); Fuzzy Logic Controller (FLC); Faults Types.

I. INTRODUCTION

A. Background and Motivation

Generation and distribution companies are continually looking for new industries technologies that help to improve energy supply for consumers and overcome problems of disruption issues caused by increased demand for electrical energy and recent increases in fuel prices. In recent years, many of these companies have become increasingly interested in using Flexible Alternating Current Transmission System (FACTS) Technologies that provides effective ways to improve stability, reliability and performance of power transmission systems in traditional networks without establishing new transmission lines [1], [2].

FACTS devices are considered to be the best solutions for improving power quality, reliability and efficiency of the power grid [3]. They are based on thyristor devices with only gate on but no gate off. According to their connections, they could be divided into three groups: shunt-connected devices like Static Synchronous Compensator (STATCOM), series-connected devices like Static Synchronous Series Compensator (SSSC), and combined connection of series and shunt devices like Unified Power Flow Controller (UPFC) [4]-[8].

B. Overview of STATCOM

Among FACTS devices, The STATCOM is of special interest because it can improve the transmission capability of the power system by improving voltage regulation and stability. It can significantly provide smooth and fast reactive compensation for voltage support. It also improves damping of power oscillations and transient stability [1], [9]-[11].

The STATCOM involves a solid state voltage source converter (VSC) with GTO thyristor switches or other highly efficient semiconductors and transformers [12], [13]. The STATCOM is widely regarded as a promising technology. It is used as an advanced dynamic shunt compensation for transmission and distribution reactive power control [14], [15]. Therefore, it is recognized as the next-generation reactive power controller in the power system [16].

The STATCOM can simulate the reactor and capacitor electrically by providing the shunt current quadrature of the line voltage. The STATCOM reactive power (or current) can be changed by controlling the magnitude and phase angle of shunt converter output voltage [12], [13]. The STATCOM can stabilize the node voltage and allow the power network to operate securely even if the renewable resources change their output unexpectedly [17]. The use of STATCOM with renewables can improve system transmission proficiency and transient stability [18]-[21].

C. Controller Comparison

Two controllers' types are discussed in the research as follows:

1) The proportional integral (PI) controller requires accurate mathematical model values that are difficult to obtain and may not provide adequate results for parameters, load

variations, etc. [22]-[25]. Much attention has been paid to the implementation of the fuzzy logic controller (FLC) for STATCOM. The advantages of a fuzzy logic controller over a PI controller are that it does not require precise mathematical model values and can handle any nonlinearity with imprecise input values. Mamdani type FLC is mostly used and gives better results gives better results for STATCOM application compared to PI controller [25], [26].

2) Fuzzy logic is a mathematical procedure which characterizes data in an arithmetic progress, allowing the determination of adequate parameters in the power flow solutions [27], [28]. Fuzzy logic has been widely used in automatic and industrial control, including image processing, motors, robots and aircraft [29]. Generally, FLC has an inclusive range of applications [30], including controllers design for regulating the rotation of motors [31], quad rotors [32], [33], electric fans [34], Internet of Things (IOT) systems [35], and medical decision-making [36]. It can simulate human experience of the best way to control a system without precise model equations and deal with system problems. It also provides a solution to uncertainty by mimicking human experience in the form of rules that automatically guide the system [29]. Despite the enormous advantages of FLC, there are some disadvantages or limitations of FLC, such as the complexity of rule base design and the need for expert knowledge in fuzzy logic system [37]. Fuzzy systems are described as intelligent systems that apply data and reasoning to solve important problems that require significant engineering expertise to explain [38], [39].

There might be several reasons for a fault, such as a short circuit, a natural disaster, an overload, or negligence maintenance. System failures may manifest themselves in some ways, for example, three-phase fault, single line to ground fault and double line fault. In the system, the faults leads to an increase in the current level and may cause the black out to the whole area [40], [41]. The STATCOM can absorb the reactive power from the system in a manner which expressively decreases the fault currents [40].

Voltage instability problems represented voltage fluctuations, sags, and surges .etc. This can be described as a sudden increase or decrease in the amplitudes of the line voltage and current compared to the reference voltage level. These problems occur in power systems due to sudden system changes such as 3-phase faults and dynamic load changes [42], [43].

D. Literature Review

The reviews of some literatures related to this paper are given as below:

A. A. Z. Diab, T. Ebraheem, R. Aljendy, H. M. Sultan, and Z. M. Ali (2020) proposed a new scheme multilevel converter based STATCOM (MMC STATCOM) which can used for medium and high voltage applications. The recommended MMC STATCOM can operate without interruption in case of three-phase unbalance [44].

S. O. Farees, M. Gayatri, and K. Sumanth (2014) presented comparison of static voltage stability for STATCOM and SVC with fuzzy logic controller using Matlab/Simulink to verify the proposed controller performance. The results investigated that STATCOM gives better performance than conventional SVC [45].

S. Mohagheghi, G. K. Venayagamoorthy, and R. G. Harley (2006) illustrated a novel fuzzy logic controller for STATCOM connected to the power system. The STATCOM can provide an additional voltage support and increase dynamic performance of the system. Simulation results demonstrated that the proposed controller gives better performance than a conventional PI controller during faults [46].

S. Pati, K. B. Mohanty, and S. K. Kar (2018) illustrated the effectiveness of fuzzy logic controller (FLC) over other types of controller such as PI controller for improving voltage profile of load bus for micro-grid system using STATCOM. Performance comparison of the controllers is prepared under different conditions. The comparative study concludes that FLC outperforms the other proposed controllers [47].

Y. Xu and F. Li (2014) discussed numerous STATCOM control approaches including several applications of PI controllers. It mentions a new control method relied on adaptive PI control, that can adjust the control gains through operating condition changes and gives the plug-and-play ability for STATCOM operation. The results verified that the adaptive PI control gives reliable excellence under numerous operating conditions [48].

C. Rajesh and G. B. S. Rao (2014) described dynamic performance of STATCOM under L-G and LLL-G faults. The STATCOM operating characteristic through steady state, inductive and capacitive modes has been competitive for design in order to prevent over-currents and trips in the STATCOM [49].

K. Sundararaju and R. Senthilkumar (2014) studied power system with and without STATCOM using fuzzy logic controller. In order to accomplish a superior control over the real time system, The STATCOM is applied with a better control scheme. With this comprehensive study the real time has presented its possibility in terms of voltage profile enhancement and reactive power compensation [50].

S. Arockiaraj, B. V. Manikandan, And A. Bhuvanesh (2023) illustrated STATCOM for improving the load bus voltage profile with two different controllers” PI and fuzzy logic controller” for the control purpose of the STATCOM. The STATCOM performance with both the controllers is simulated with different conditions using Matlab/Simulink. The results demonstrated that the fuzzy logic controller offers better performance as compared to the conventional PI controller under different load conditions [51].

P. Kumkratug (2011) introduced the scheme control of enhancing the power system dynamic performance with using STATCOM. Fuzzy logic control is applied to control the system. The simulated results indicated that the STATCOM based fuzzy logic controller can achieve the superior performance of the system [12].

M. Y. Suliman (2016) proposed STATCOM design arrangement using Neuro-Fuzzy logic controller. The simulation results demonstrated that the recommended controller is robust and consistent compared to the other conventional controllers since it requires less than cycle in order to reach the steady state and also gives less oscillation [52].

S. Mirsaeidi, S. Devkota, X. Wang, D. Tzelepis, G. Abbas, A. Alshahir, et al (2022) presented an inclusive review of current proposals in order to enhance the efficiency of the power system by using FACTS devices [53].

L. Ribeiro and D. Simonetti (2022) presented the operation of single phase STATCOM, and its performance when employing voltage control or current control in a low voltage STATCOM [54].

O. M. Kamel, A. A. Z. Diab, M. M. Mahmoud, A. S. Al-Sumaiti, and H. M. Sultan (2023) recommended a new isolated micro grids (MG) structure to reduce the voltage and frequency instabilities and improve the dynamic performance of the system. The study presents a hybrid island MG model that considers multiple forms of sustainable energy (PV and wind) including Electric vehicles (EVs) and STATCOM integration. The results demonstrated that both EV and STATCOM are important parts to improve the stability of power systems [55].

M. Rohit and N. K. Sharma (2022) illustrated the FACTS devices benefits for improving the power system performance. Different controllers of FACTS have been presented [56].

B. Musa and M. Mustapha (2015) proposed the STATCOM approach, in which the device is described and applied to provide controllable bus voltage and reactive power compensation [57].

F. M. Khater, Z. Elkady, A. M. Amr, D.-E. A. Mansour, and A. E. El Gebaly (2024) proposed the STATCOM device to offer voltage support for the grids. The employment of STATCOM consents for precise control of the grid voltage. Also, the STATCOM could regulate the active and reactive power flow of the systems [58].

P. Vaidya and V. K. Chandrakar (2022) introduced the use of a super capacitor as a storage device integrated with the voltage converter of the STATCOM in order to enhance the performance of STATCOM under sudden large disturbances in the power grid [59].

I. Y. Fawzy, M. A. Mossa, A. M. Elsawy, and A. A. Z. Diab (2024) presented an overview of three FACTS devices including STATCOM, SSSC and UPFC in order to improve power system. The system was investigated under single-phase and three-phase faults with Matlab/Simulink software. The results showed that the power system performance can be accurately improved with FACTS devices and UPFC provides better performance compared to other types of FACTS [60].

E. Aims and Contributions

The main contribution of the present research is the focus on the STATCOM device which belongs to the FACTS groups with using two different controllers for improving power system performance. The purpose of this paper is to provide an overview of the STATCOM device and study the system under single phase and three phase faults using Matlab/Simulink software package. The obtained results investigated that the power system performance can be enhanced precisely with STATCOM with FLC which it gives the better performance as compared to PI controller.

II. Overview of STATCOM and Controller

A. STATCOM

A STATCOM is a reactive power compensation controller connected to the shunt [61]. The shunt FACTS device "STATCOM" which supplies reactive power to the power network and absorb reactive power from the network can control the line voltage and as a result further improve the power system stability. Furthermore, the tuning and coordination between the controller and the Power system makes the system more stable [62]-[64]. The development of power electronics, especially the GTO thyristor, made it possible to introduce such technology as an acceptable alternative to the traditional SVC. The schematic layout of the STATCOM is shown in Fig. 1.

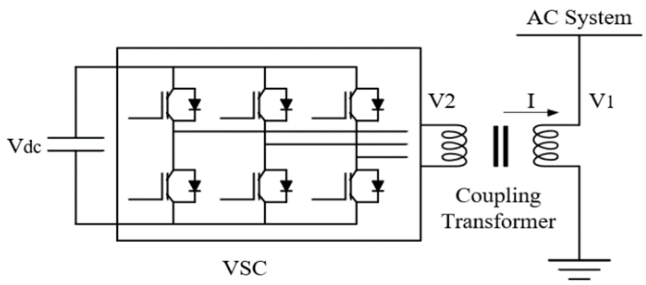


Fig. 1. Basic configuration of STATCOM

The active power (P) and reactive power (Q) of the transmission lines are presented as follows:

$$P = \frac{V1 \; x \; V2}{X} sin\, \delta \tag{1}$$

$$Q = \frac{V1^2}{X} - \frac{V1 \; x \; V2}{X} cos\, \delta \tag{2}$$

Where $V1$ and $V2$ are output voltage of the inverter and the bus voltage of the system respectively and X is the line reactance from the inverter to the system bus [61].

The relationships between the system AC voltage and the STATCOM AC shunt voltage provide reactive power flow control. When the voltage across the STATCOM terminals is higher than the system voltage, the STATCOM acts as a capacitor and the reactive power of the system is injected by the STATCOM. When the STATCOM voltage is lower than the AC voltage, the STATCOM acts as an inductor and the flow of reactive power is reversed. Both voltages are the same and there is no exchange of current between the STATCOM and the system under normal operating conditions. Fig. 2 shows the voltage and current characteristics of a STATCOM. Many studies have shown that STATCOM can improve power system dynamics and system stability in renewable energy applications [65].

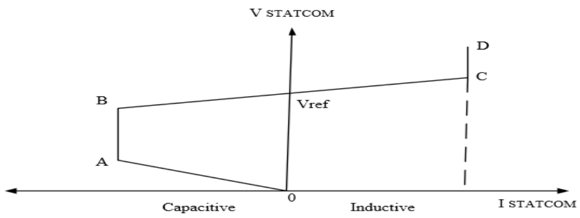


Fig. 2. STATCOM V-I characteristics

B. Fuzzy Logic Controller

Fuzzy logic controller (FLC) is more functional and valuable than other classical controllers like PI controller, PID controller etc. It took up less storage space and is suitable for non-linear systems [66]. It plays an essential part in several practical applications and has many fuzzy inference mechanisms [67]. Both the Mamdani and Takagi-Sugeno methods are of wide interest in various scientific fields [68]-[70]. Mamdani-type is selected in this study as it is computationally proficient and more compact.

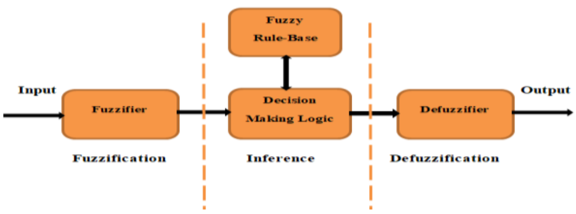


Fig. 3. FLC structure

The structure of the FLC system is shown in Fig. 3 which comprises four major components. These components [71]-[78] are

1. Fuzzification interface (FUZZIFICATION)
2. Decision making logic (FUZZY INFERENCE ENGINE)
3. Knowledge base (FUZZY RULE BASE)
4. Defuzzification interface (DEFUZZIFICATION)

The basic configuration of the fuzzy logic comprises four important components [79] , which are:

Fuzzification (Fuzzifier): It is the process of transforming a numeric value to the linguistic value or mapping the input space to fuzzy set defined on the discourse universe. Thus it converts input data into appropriate linguistic values that may be observed as labels of the fuzzy sets.

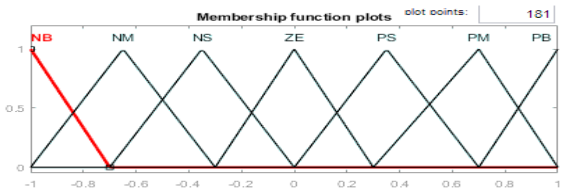
Knowledge base (FUZZY RULE BASE): It comprises a database and a linguistic rule base. The data base provides the necessary definitions for defining linguistic rules and fuzzy data processing in fuzzy logic. The rule base characterizes the goals and guiding policy of experts in the field with the help of linguistic guiding rules.

Decision making logic (FUZZY INFERENCE ENGINE): It is the core the FLC. It has the ability to simulate human decision making on fuzzy concepts and inference of fuzzy control functions using fuzzy implications and fuzzy logical inference rules.

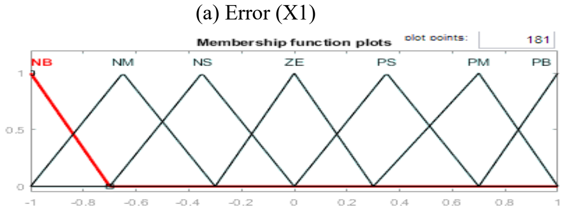
Defuzzification (Defuzzifier): It performs the following functions: Scale mapping, which transforms the range of values of the output variables into the corresponding universes of discourse. defuzzification, which creates a non-fuzzy control function from the derived control function.

Mamdani Method: It is used in this work in which is computationally efficient and more compact. There are two inputs and one output, the inputs are X1 and X2 and then the output is indicated by Y. In this system, the error and the change in error are denoted as X1 and X2. The output Y is represented as fuzzy output [80].

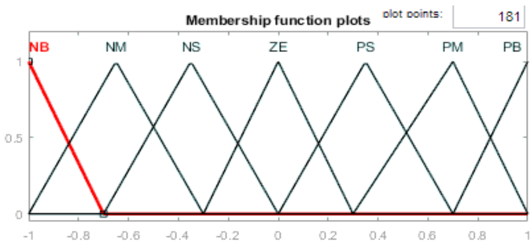
The fuzzy logic controller turns a lingual control strategy into an automatic control strategy, and the fuzzy rules are formed either by an expert or by using a knowledge database. Selecting the following seven fuzzy levels or sets (Membership functions) that provides a numerical definition of each of the Fuzzy logic states for better results [81]: NB (negative big); NM (negative medium); NS (negative small); ZE (zero); PS (positive small); PM (positive medium); PB (positive big) as can be seen in Fig. 4.



(a) Error (X1)



(b) Change of Error (X2)



(c) Output (Y)

Fig. 4. Membership functions of the proposed fuzzy controller

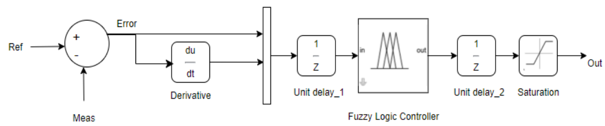


Fig. 5. Block diagram of fuzzy logic voltage or current control

A fuzzy inference system is a general computational framework based on the concepts of fuzzy set theory. The rule base elements are defined by the theory that large transient errors need coarse control that requires coarse input/output variables, whereas steady-state small errors need fine-tuning. which requires fictitious input/output variables [81]. Thus, the rule table elements are attained according to Table I where, E is error and ΔE is the change of error. Fuzzy logic voltage or current control can be described as shown in Fig. 5 in which error and change in error used as inputs to fuzzy logic controller. The block diagram is suitable for voltage and current control. The flowchart of fuzzy logic control system is shown in Fig. 6. All steps of fuzzy control is shown in this flowchart.

TABLE I. THE RULE BASE OF FUZZY CONTROLLER

E	ΔE						
	NB	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

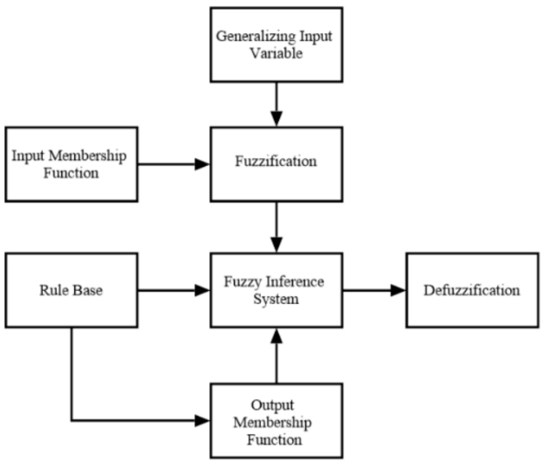


Fig. 6. Flowchart of fuzzy logic control system

III. SYSTEM UNDER STUDY

A detailed model of a 48-Pulse, GTO-based unified power flow controller (500 kV, 100 MVA) is shown in Fig. 7. It consists of 100-MVA, three-level, 48-pulse GTO-based Converter connected in shunt at bus B1. The shunt and converter can exchange power through a DC bus. This converter can be operated as STATCOM controlling voltage at bus B1.

The shunt converter operates as a STATCOM and it controls the bus B1 voltage by controlling the absorbed or generated reactive power while also allowing active power transfer to the series converter through the DC bus. The reactive power variation is obtained by varying the DC bus voltage. The four three-level shunt converters operate at a constant conduction angle (Sigma= 180-7.5 = 172.5 degrees), thus generating a quasi-sinusoidal 48-step voltage waveform. Table II indicates data parameters of STATCOM in the model under study.

TABLE II. THE DATA OF STATCOM USED IN THIS PAPER

STATCOM	STATCOM (Qref)	T1	0.3
		T2	0.5
		Q1	+0.8
		Q2	-0.8
	STATCOM Vref (pu)	Initial	1
		Final	1.005
		Step Time	0.3*100
	Technical Data STATCOM	S (MVA)	100
		V (KV)	500
		C(μF)x2	2500/one

The performance of power system with STATCOM is presented and checked under different faults. The possible cases for investigation are listed below:

Case 1: The power system under single line to ground fault was inserted at load B using STACTOM with fuzzy controller.

Case 2: The power system under three phases to ground fault was inserted at load B using STACTOM with fuzzy controller.

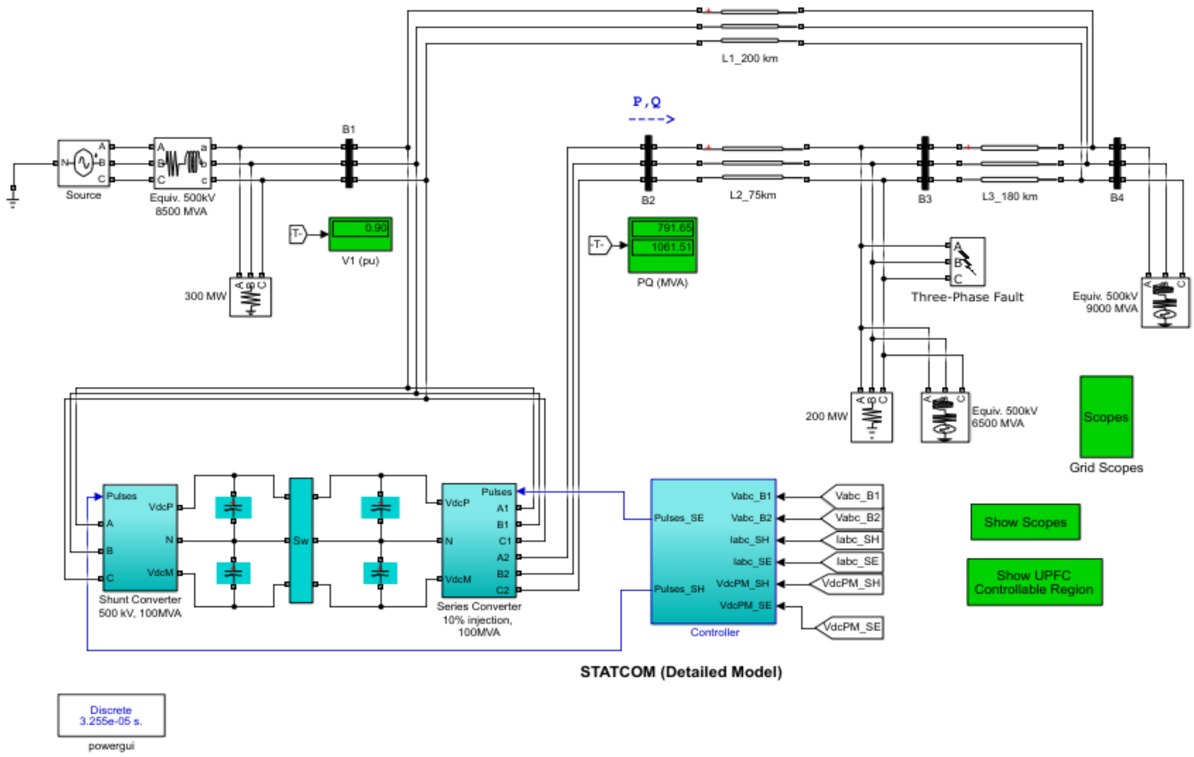


Fig. 7. The proposed model in Matlab/Simulink

IV. Simulation Results

The simulation procedure is prepared using MATLAB/Simulink software package. In this simulation, a short circuit fault with different faults types is injected at t = 0.3 sec. The fault was inserted at load B and, the grid parameters are measured in each case. In this arrangement, the fault current with STATCOM was also observed. It is possible to use STATCOM with FLC in order to reduce the fault current. Two different controllers are used to improve power system under faults conditions.

A. The Power System Using Statcom with Fuzzy Controller Under Abnormal Conditions

1) Case 1: Single Line to Ground Fault

The power system performance using STATCOM with PI controller and fuzzy controller under single line to ground fault inserted at load B is illustrated in Fig. 8 to Fig. 15. They show that the positive sequence of fault current at buses 1, 2, 3 and 4 is highly increased, while, the buses voltages are slightly decreases at faulty period.

The fault current positive sequence is increased and reached to the maximum value (25.17 per unit (pu)) at bus 1 (B1) then, it settled down to value (21.11 pu) without STATCOM. The values, respectively would be (25.19 and 21.02 pu) with STATCOM-PI controller and (24.97 and 20.37 pu) with STATCOM-Fuzzy controller, whereas the peak fault current positive sequence at buses B2, B3 and B4, respectively would be (18.38, 9.56, 16.68 pu), thereafter, they settled to (14.27, 8.99, 15.88 pu) without STATCOM. Similarly, the values would be (18.33, 9.302, 16.70 pu) and settled to (14.34, 8.98, 15.87 pu) with PI controller and (18.8, 9.23, 16.56 pu), (15.00, 8.94, 15.75 pu), respectively with Fuzzy controller.

The buses voltages are decreased during single line to ground fault at buses B1, B2, B3 and B4, respectively to values (0.876, 0.864, 0.741, 0.896 pu) without using STATCOM. They would be (0.878, 0.866, 0.742, 0.897 pu) with using STATCOM-PI controller and (0.896, 0.882, 0.749, 0.902 pu) with using STATCOM-Fuzzy controller.

These figures demonstrated that better performance of power system under single phase fault is achieved with STATCOM using fuzzy controller as compared to using PI controller as it could reduce fault current and voltage deviation of the system and improve the voltage of the system.

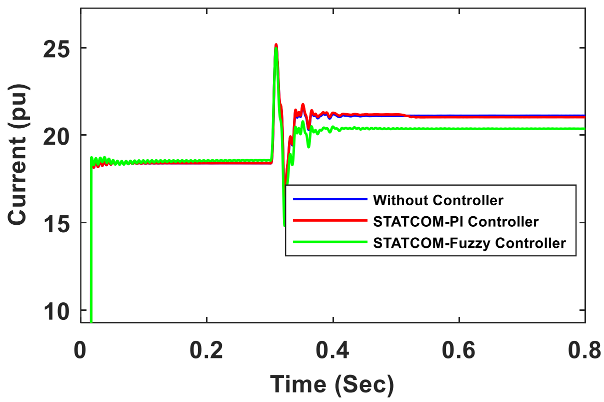


Fig. 8. The current wave shape of B1 in pu using STATCOM controllers for single line to ground fault in load B inserted at t = 0.3 sec

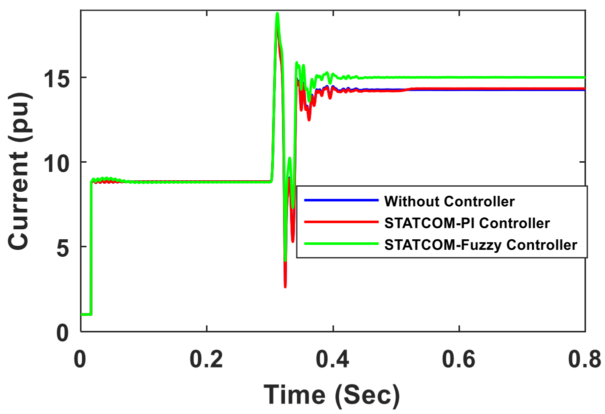


Fig. 9. The current wave shape of B2 in pu using STATCOM controllers for single line to ground fault in load B inserted at t = 0.3 sec

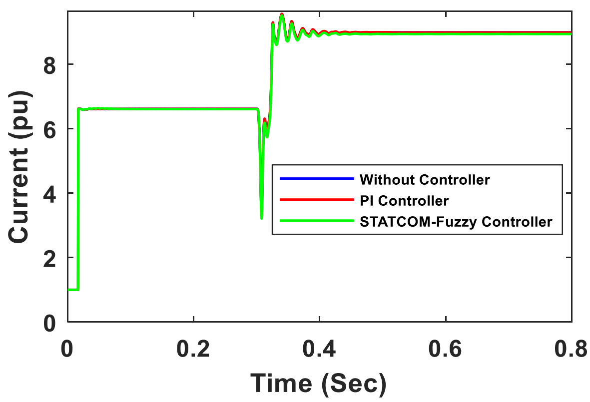


Fig. 10. The current wave shape of B3 in pu using STATCOM controllers for single line to ground fault in load B inserted at t = 0.3 sec

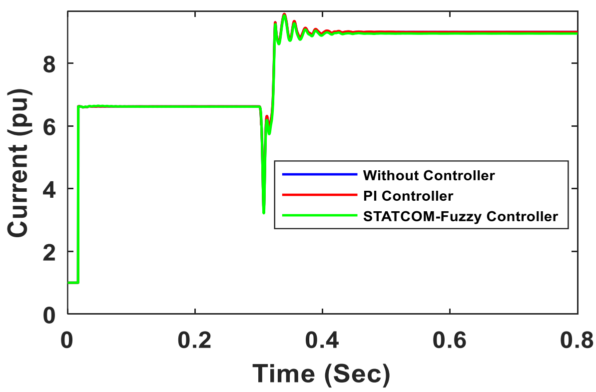


Fig. 11. The current wave shape of B4 in pu using STATCOM controllers for single line to ground fault in load B inserted at t = 0.3 sec

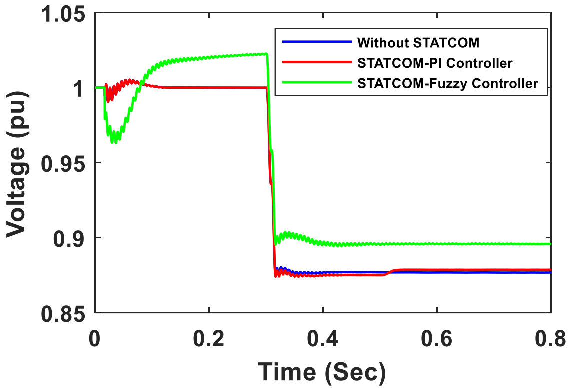


Fig. 12. The voltage wave shape of B1 in pu using STATCOM controllers for single line to ground fault in load B inserted at t = 0.3 sec

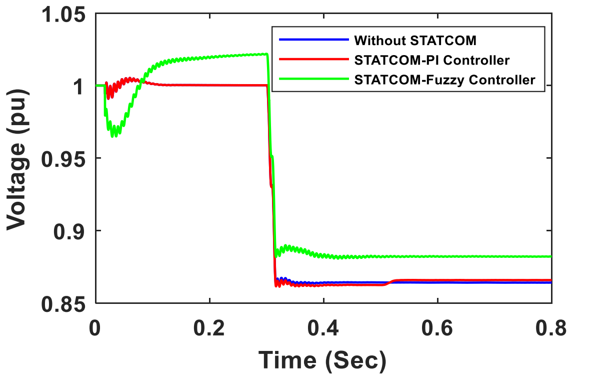


Fig. 13. The voltage wave shape of B2 in pu using STATCOM controllers for single line to ground fault in load B inserted at t = 0.3 sec

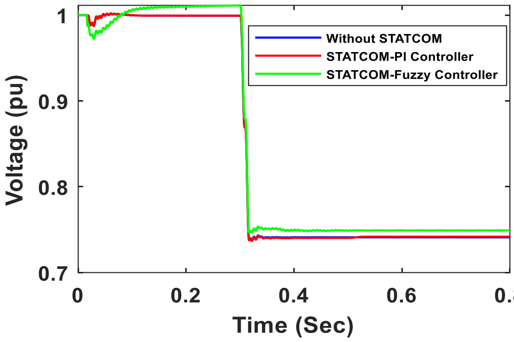


Fig. 14. The voltage wave shape of B3 in pu using STATCOM for single line to ground fault in load B inserted at t = 0.3 sec

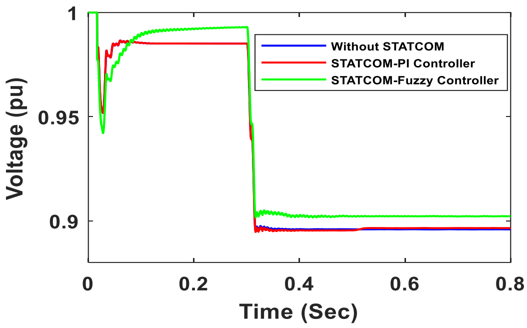


Fig. 15. The voltage wave shape of B4 in pu using STATCOM for single line to ground fault in load B inserted at t = 0.3 sec

2) Case 2: Three Line to Ground Fault

The power system performance using STATCOM with PI controller and fuzzy controller under three line to ground fault inserted at load B is illustrated in Fig. 16 to Fig. 23. They show that the positive sequence of fault current at buses 1, 2, 3 and 4 is highly increased, while, the buses voltages are slightly decreases at faulty period.

The fault current positive sequence is increased and reached to the maximum value (49.06 pu) at bus 1 (B1) then, it settled down to value (44.15 pu) without STATCOM. The values, respectively would be (49.11, 43.73 pu) with STATCOM-PI controller and (48.04, 43.34 pu) with STATCOM-Fuzzy controller, whereas the peak fault current positive sequence at buses B2, B3 and B4, respectively would be (52.16, 26.25, 32.68 pu), thereafter, they settled to (45.11, 25.45, 31.23 pu) without STATCOM. Similarly, the values would be (52.62, 26.28, 31.38 pu) and settled to (45.51, 25.49, 31.15 pu) with PI controller and (53.67, 26.5, 31.45 pu), (45.9, 25.53, 31.08 pu), respectively with Fuzzy controller.

The buses voltages are decreased during three line to ground fault conditions at buses B1, B2, B3 and B4, respectively to values (0.528, 0.479, 0.0, 0.641 pu) without using STATCOM. They would be (0.533, 0.483, 0.0, 0.642 pu) with using STATCOM-PI controller and (0.538, 0.488, 0.0, 0.643 pu) with using STATCOM-Fuzzy controller.

These figures showed that better performance of power system under three line to ground fault is achieved with STATCOM using fuzzy controller as compared to using PI controller as the system fault current and voltage deviation are decreased, besides the system voltage is improved with using fuzzy controller.

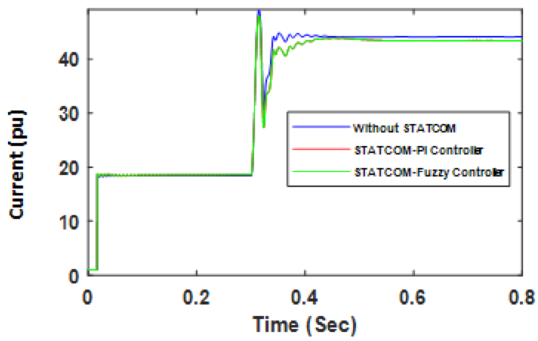


Fig. 16. The current wave shape of B1 in pu using STATCOM controllers for three line to ground fault in load B inserted at t = 0.3 sec

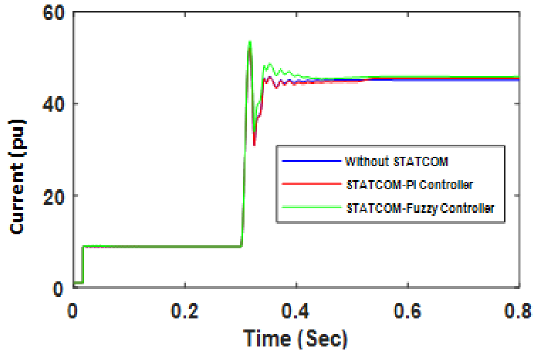


Fig. 17. The current wave shape of B1 in pu using STATCOM controllers for three line to ground fault in load B inserted at t = 0.3 sec

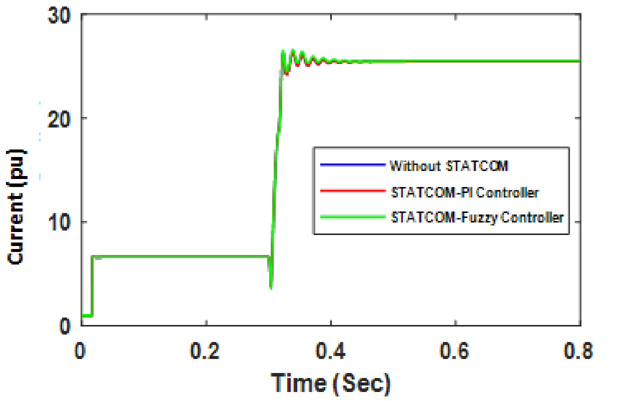


Fig. 18. The current wave shape of B3 in pu using STATCOM controllers for three line to ground fault in load B inserted at t = 0.3 sec

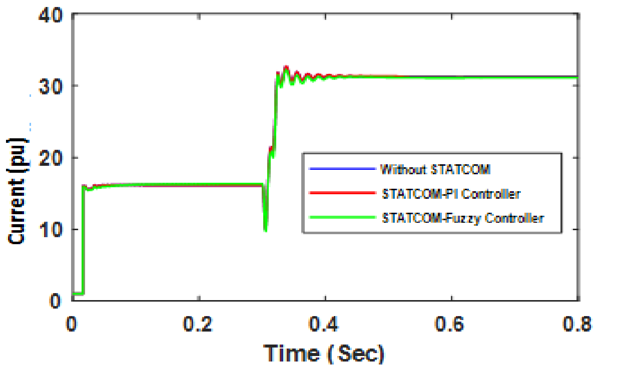


Fig. 19. The current wave shape of B4 in pu using STATCOM controllers for three line to ground fault in load B inserted at t = 0.3 sec

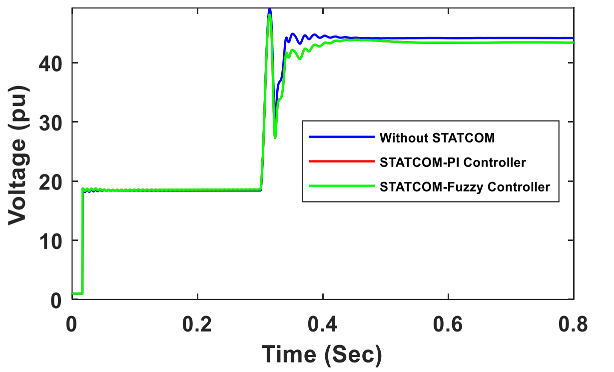


Fig. 20. The voltage wave shape of B1 in pu using STATCOM controllers for three line to ground fault in load B1 inserted at t = 0.3 sec

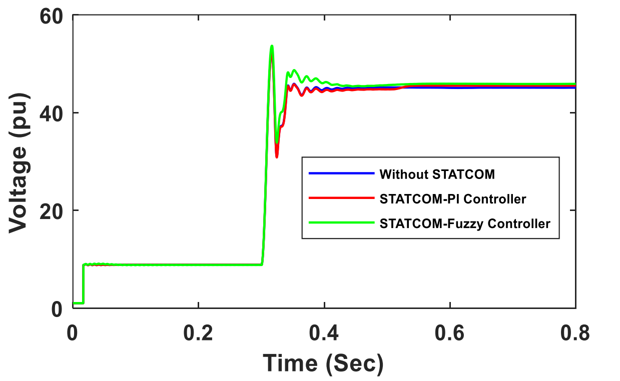


Fig. 21. The voltage wave shape of B2 in pu using STATCOM controllers for three line to ground fault in load B1 inserted at t = 0.3 sec

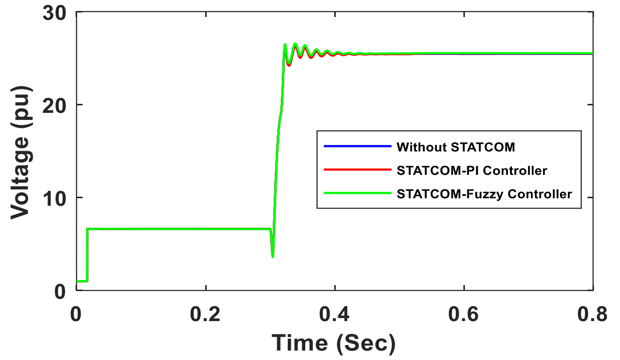


Fig. 22. The voltage wave shape of B3 in pu using STATCOM controllers for three line to ground fault in load B inserted at t = 0.3 sec

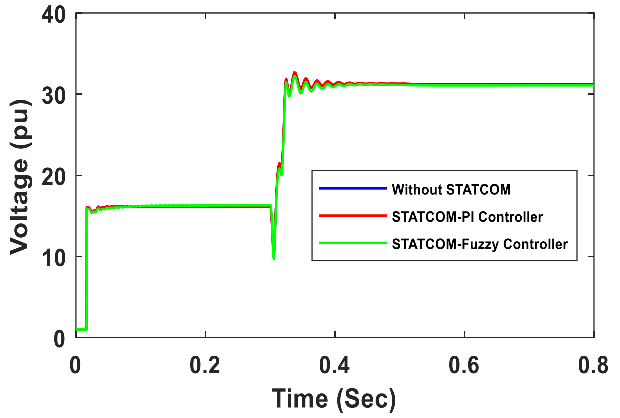


Fig. 23. The voltage wave shape of B4 in pu using STATCOM controllers for three line to ground fault in load B inserted at t = 0.3 sec

Table III shows the effect of STATCOM controllers in positive sequence fault current for different faults types. It is noted that the fault current is reduced with fuzzy controller and gives the best results as compared to PI controller or not using STATCOM. As the STATCOM in this study is shunt-connected to bus B1 and with comparing the positive sequence fault current at bus B1 with and without using this device under different faults. It is observed that STATCOM can precisely reduce the positive sequence fault current of bus B1 besides; STATCOM with fuzzy controller gives the better results than PI controller. The positive sequence fault current is reduced to (96.49, 98.17 %), respectively by using STATCOM with fuzzy controller under line to ground fault and three line to ground fault whereas it is reduced to (99.57, 99.05%) by using STATCOM with PI controller.

Table IV shows the effect of STATCOM controllers in bus voltages for different faults types. It is noted that the voltage is improved with fuzzy controller and gives the best results as compared to PI controller or not using STATCOM. It is detected that STATCOM can precisely improve the buses voltage under different faults moreover; STATCOM with fuzzy controller gives the better results than PI controller. The bus voltage B1 is increased to (102.19, 101.86 %), respectively by using STATCOM with fuzzy controller under line to ground fault and three line to ground fault whereas it is increased to (100.21, 100.93%) by using STATCOM with PI controller.

TABLE III. EFFECTS OF STATCOM CONTROLLERS IN FAULT CURRENT FOR DIFFERENT FAULTS

Fault Type	Bus ID	Without STATCOM	With STATCOM PI Controller		With STATCOM Fuzzy Logic Controller	
		Positive sequence Current (pu)	Positive sequence Current (pu)	Percentage reduction (%)	Positive sequence Current (pu)	Percentage reduction (%)
Line to ground fault	B1	21.11	21.02	99.57	20.37	96.49
	B2	14.27	14.34	100.49	15.00	105.12
	B3	8.99	8.98	99.89	8.94	99.44
	B4	15.88	15.87	99.94	15.75	99.18
Three line to ground fault	B1	44.15	43.73	99.05	43.34	98.17
	B2	45.11	45.51	100.89	45.90	101.75
	B3	25.45	25.49	100.16	25.53	100.31
	B4	31.23	31.15	99.74	31.08	99.52

TABLE IV. EFFECT OF STATCOM IN BUS VOLTAGES FOR DIFFERENT FAULTS

Fault Type	Bus ID	Without STATCOM	With STATCOM PI Controller		With STATCOM Fuzzy Logic Controller	
		Positive sequence Voltage (pu)	Positive sequence Voltage (pu)	Percentage increase (%)	Positive sequence Voltage (pu)	Percentage increase (%)
Line to ground fault	B1	0.8768	0.8786	100.21	0.8960	102.19
	B2	0.8641	0.8658	100.20	0.8820	102.07
	B3	0.7410	0.7418	100.11	0.7493	101.12
	B4	0.8960	0.8965	100.06	0.9021	100.68
Three line to ground fault	B1	0.5282	0.5331	100.93	0.5380	101.86
	B2	0.4787	0.4833	100.96	0.4875	101.84
	B3	0.0	0.0	0.0	0.0	0.0
	B4	0.6408	0.6420	100.19	0.6427	100.30

V. CONCLUSION AND FUTURE WORK

Simulation results of the power system with STATCOM are carried out under different faults types for enhancing system ability and performance using Matlab/Simulink software package. The STATCOM is interlinked with the transmission lines with different distances. This paper shows that this STATCOM has been assessed as fault current limiter which is capable of decreasing fault current and voltage deviation besides improving voltage of the power system. The performance of the STATCOM is assessed by using two different controllers: PI controllers and FLCs. Matlab/Simulink software package is used to perform a comparative analysis between the performances of the two different controllers under unbalanced conditions. The results demonstrated that the STATCOM with FLC could improve the power system and give better performance than PI controller under different conditions. The results illustrated that STATCOM which is connected in shunt with bus B1 can reduce the positive sequence fault current of bus B1 to (96.49, 98.17 %), respectively and improve the bus voltage to (102.19, 101.86 %) by using STATCOM with FLC under line to ground fault and three line to ground fault while the positive sequence fault current is decreased to (99.57, 99.05%) and the bus voltage is improved to (100.21, 100.93%) by using STATCOM with PI controller. For the future works, it is required to study the system with additional FACTS devices such as SSSC and UPFC under abnormal conditions at different positions of the system.

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