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Original Article

ANFIS Hybridized FACTS Controller for Voltage Stability Improvement

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Abstract *- In long transmission lines, distribution network loads and generating units are all connected to a modern power system. Networks of interconnected power systems encounter a variety of instability-related problems. In a power system, dynamic instability is a problem that arises when there is a dynamic disturbance in the system network. By employing appropriate controllers to enhance system stability and synchronization, these difficulties were overcome in this study. Through individual and comparative simulation, the dynamic instability of the electrical system utilizing STATCOM and an Adaptive Neuro Fuzzy-Inference System (ANF-IS) was examined. To facilitate simulation, the IEEE 9 bus test system provided the necessary data. Profile of Voltage, Reactive power(Q), wind o/p voltage, and Active power (P) are the outcomes of the simulation. MATLAB 20 Simulink is used to simulate the systems model with grid partition in order to study the use of ANFIS. The incorporation of Adaptive Neuro-Fuzzy Inference System (ANFIS)-controlled STATCOMs aims In order to substitute the traditional PI controller, thus improving the overall performance of the STATCOM system. The study also looks into where FACTS controllers should be placed at the load side to optimize their efficiency in enhancing the voltage stability of the system.*

Keywords *- Dual Fed-Induction Generator (DF-IG), Wind Energy Conversion System (WECS), IEEE 9 bus, Static synchronous Compensator (STATCOM), Adaptive Neuro-Fuzzy Inference System (ANFIS), Voltage stability.*

1. Introduction

Linear Nowadays, the demand for energy has been rising recently, which has increased greenhouse gas emissions into the environment. Electric utilities are unable to fulfil the requirement for electricity in modern society due to growing living standards and urbanization. In order to meet load demand and solve power issues. Renewable energy sources have been a viable alternative to conventional energy sources throughout the past 30 years. From a technical and economic perspective, wind power is among the numerous sustainable energy resources available. In an unstable state, a power system can recover its stability or maintain it. When a disturbance occurs, the power system network restores equilibrium, a condition known as power system stability. One of the system's top concerns is voltage stability, which is also one of the most challenging research topics. It has to do with how well the system can sustain the voltage on each of its buses within reasonable parameters following a disruption. Voltage swings have actually caused major events (blackouts) all over the world. Insufficient reactive power is nearly related to the voltage breakdown. The requirement for reactive energy must, therefore, be continuously met. Various reasons, such as uneven load, increased load demand, disturbances, and shifting system conditions, can cause voltage instability. The goal of this research is to evaluate how well FACTS controller can recover system voltage in the load side of a metropolitan area by implementing a reactive power compensation approach [1]. The devices Static Synchronous Compensator (STATCOM), Dual-Feed Induction Generator (DFIG), ANFIS and IEEE 9 bus systems are used in this study. The wind energy system with DFIG-based variables is an advantageous alternative for the current situation of the energy market. The turbine blade and wound rotor induction generator couple through the gearbox of the wind energy system, utilizing the DFIG. In order to fulfill the function of the WECS, Active electricity is intended to be extracted from the wind system by the shunt converter. The series and shunt compensators are coupled to a DC bus and the capacitor for the DC-link functions as a buffer for electricity energy [2]. In low voltage power systems, both reactive and active powers are autonomously managed here. In order to maintain grid voltages, the generator can also supply reactive power, but in the case of a large voltage power system, the DFIG converter is not capable of providing that much reactive power to the system, so in that situation, we implemented the FACTS controller. This study proposes a unique approach to enhance stability by connecting a Flexible Alternating Current Transmission System (FACTS) controller on the load side of the system. A number of researchers have integrated the FACTS device into a transmission line in the literature; however, these studies have a load-side focus. In the current scenario of power systems using DFIG, STATCOM is utilized to increase voltage stability. The transient response and overload capacity of STATCOM are better [3]. It has been demonstrated that the STATCOM's position and capacity have a significant influence on enhancing voltage stability.

Numerous research and investigations have been carried out on the subject of STATCOM control. According to research by Yousif and Mohammed [4], In the event of unforeseen circumstances, such as malfunctions or abrupt changes in load, a STATCOM that employs Proportional-Integral (PI) control is suggested. The process of try and error used in the other studies produces PI controller advancements [5, 6], with compromises between performance and efficiency. Saxena and Kumar's research [7] examined the effects of adding and modifying the STATCOM specifications of a wind-diesel combination power system using an ANFIS controller that frequently experiences load and power input disruptions. After proposing and implementing a model of PI control in the Simulink environment of MATLAB, Stephen and Raglend [6] tested the model under a range of load levels and a number of extreme disturbances. By using a straightforward design for STATCOM, Tripathi and Barnawal [8] were able to get around issues that arise at the Common Coupling Point (PCC) because of nonlinear load. The main purpose of this research is to assess how well the FACTS controller can recover system voltage in the load side of a metropolitan area by implementing a reactive power compensation approach, and the execution of the FACTS device is improved by ANFIS. The value of (Vd.c) d.c. capacitor voltage loop and voltage employed by the controller of ANFIS is constructed and compared to conventional PI. The Fuzzy Inference System Takagi–Sugeno (FIS) is the foundation of the ANFIS, an artificial Neural network that combines FIS with ANN to enhance the fault tolerance, training speed, and adaptability of traditional ANNs.

An integration of STATCOM at the appropriate location of the load side is crucial to enhancing voltage stability throughout the system. The STATCOM integrated system can improve the profile of the voltage and flexible power flow of the system. The research utilizes MATLAB 2020 software for analysis and simulation purposes [9]. MATLAB 2020 has a smooth integration with Simulink, an excellent instrument for modeling and simulation. From algorithm research to system simulation and implementation, a smooth workflow is made possible by combining MATLAB and Simulink.

1.1. Novelty and Application

- This research gives power system operator planners and researchers crucial information to ensure the stability and dependability of contemporary electrical systems and aids in their decision-making about the integration and application of STATCOM technology.
- Creating a new self-correcting Static synchronous reactive compensator for wind turbines that enhances the stability of the system voltage in both steady-state and transient modes under challenging
- When resolving the problem in FACTS devices, the parameters that ought to be regarded as the optimal execution in terms of the maximum accomplishment percentage, the rate of confluence and efficacy and the precision of the resolution are examined.
- This focus also discusses the advantages and disadvantages of several advanced techniques that have been applied to the resolution of voltage stability problems.
- Results obtained provide an overview of each amended document's useful objectives, test systems used, methodologies used, and kinds of FACTS devices studied.
- The wind energy system has been evaluated and implemented with STATCOM-based ANFIS and PI to improve overall performance and stability. The performances of the two newly released controllers have been thoroughly compared and displayed.
- In order to improve the stability of power systems, including wind farms with DFIG, this work provides an ANFIS-PID controller for the STATCOM that takes advantage of nonlinear modeling.

2. Methodology

2.1. DFIG-Based WECS

This part presents a comparison of different controllers for increasing voltage stability in power systems. The system's coupled load and generator are unbalanced in interconnected power system networks. Because power system loads fluctuate and are not constant, adopting an appropriate controller is the ideal method for balancing generation and load. The DFIG system was typically utilized to evaluate the gathered data taken from the 9-bus IEEE test system. A DFIG-based WECS was used for the simulation. The two elements of reactive power change after wind farm access and the impact of the speed of wind on the wind system have been fully analyzed and simulated for the actual system comprising DFIG. Dual Fed Induction Generators (DFIGs) are induction devices where the rotor and stator coil are each coupled to a source. The DFIG's rotor is attached to the Rsc-to-Gsc converters in the system, which is mostly based on WT, and the stator directly linked with the grid [10]. Analyzing and contrasting the system with several controllers simulated. The issue of unstable power systems that emerge in networks of power systems as a result of disturbances, shifting system conditions, imbalanced loads, and rising load demand is discussed in this research. After modeling each part of the suggested systems and controllers, the system was performed with MATLAB 20 software, and the outcomes were compared

[11]. Figure 1 represents the Configuration of a power system with A wind conversion system based on DFIG, which consists of an IEEE 9 bus system.

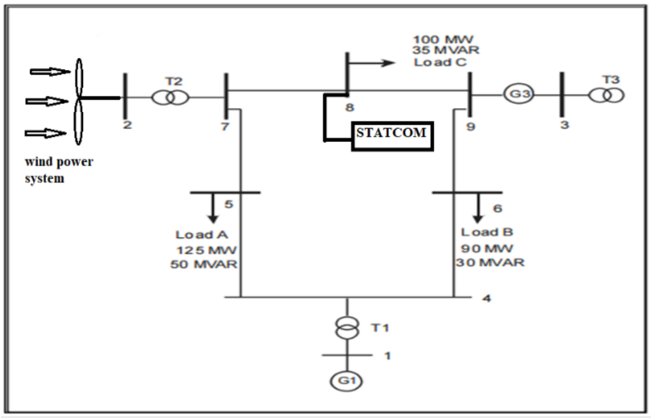

Fig. 1 Configuration of power system

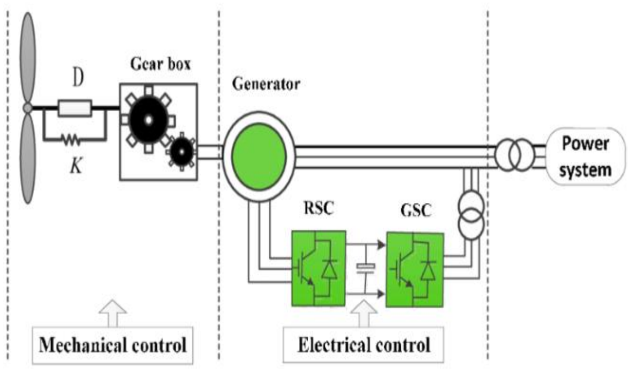

Fig. 2 DFIG based WECS

2.2. Simultaneously, Modeling of STATCOM

A STATCOM is a device of a Q power shunt compensator device taped at the common coupling point. It has the ability to produce or absorb reactive power within the system. In the recommended DFIG system, a static synchronous compensator is positioned alongside a leaky reactance of a step-down transformer, a DC capacitor, and a 3-phase GTO-based VSC. P and Q power trade-in between the STATCOM and the power source is brought on by the voltage differential between the terminal voltage of DC and the STATCOM bus AC voltage [12]. This voltage difference can be modified by changing the phase angle and voltage magnitude, as shown by Equation (1)

$$V_o(t) = V_o \sin(wt-\psi) \quad (1)$$

The STATCOM shown in terms of voltage current is given by Equation (2).

$$V_{dc} = \frac{Idc}{Cdc} = \frac{c}{Cdc}(I_{Lod} \cos\psi + j\, I_{Log} \sin\psi) \quad (2)$$

The simulation and analysis were done with the help of MATLAB 2020 software. A system's behavior can be predicted via MATLAB simulation, which is helpful for a number of reasons.

- Evaluating new designs: Using simulation tools to assess new designs can be beneficial.
- Diagnosing problems: Simulation software can be used to identify issues with current designs.
- Testing in difficult conditions: To test a system under difficult-to-replicate circumstances, like a satellite in orbit, you can utilize simulation software.

2.3. Principle Operation of STATCOM

In phase with the system's voltage by controlling Q power, STATCOM aims to minimize voltage variance. It has the ability to constantly and linearly adjust current for inductive XL and capacitive XC. In the mode of Inductive and capacitive resistance, the voltage across leakage reactance VL and inverter voltage $V_{STATCOM}$ add up to the terminal voltage V_{bus} shown in Figure 2. This indicates that Reactive power will be supplied to the system by the STATCOM if its o/p voltage ($V_{STATCOM}$) is greater than the terminal voltage of bus (V_{bus}), and if VSTATCOM and V_{bus} are in phase, Reactive power is absorbed by STATCOM if $V_{STATCOM}$ is smaller than V_{bus} from the power system. When Vbus is equal to VSTATCOM, there won't be any power exchange, and STATCOM will function in floating mode [13].

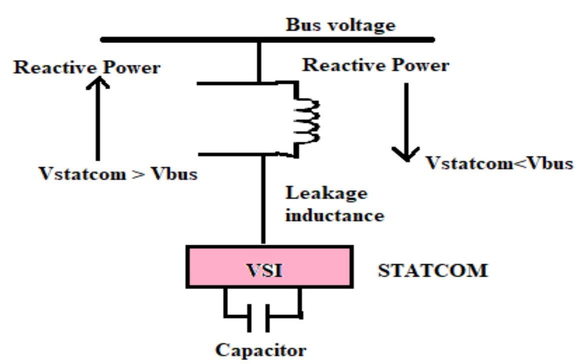

Fig. 3 STATCOM operating principle

Pout o/p voltage of STATCOM and voltage drop at the resistance and line reactor addition of all give the terminal voltage V bus (AC side).

V_{bus} = voltage at the terminal of the bus
$V_{STATCOM}$ = STATCOM output voltage
$R + j\omega L = XL$ = Reactance of Inductive
Vdc = DC voltage of the capacitor.

For active (p) power, reactive (Q) power, and STATCOM output voltage, the general mathematical equation for STATCOM is as follows.

$$P = (V_{bus} \times V_{STATCOM} \div X_L) \sin \alpha \quad (3)$$

$$Q = (V_{bus} \times V_{bus} / X_L) - (V_{bus} \times V_{STATCOM} \div X_L) \cos \alpha \quad (4)$$

2.4. The Control Circuit of STATCOM

The primary purpose of the FACTS device STATCOMs control circuit is to autonomously regulate both real and reactive power delivered to the system while maintaining voltage control over the capacitor of Dc-link. Figure 3 illustrates the fundamental control technique utilized for the STATCOMs. A number of elements make up the control strategy, including the generator pulse, current regulator, Locked Loop of Phase (PLL), measurement network and the conversion from Abc to Dq0. Locked Loop of Phase (PLL) that latches onto the primary voltage of three-phase V1's positive-phase portion. The d-q- components of the AC 3-phase voltage is V, and currents I shown on the schematic as (Vd, Vq, Id and Iq) are calculated using the PLL output (angle θ=ωt) [14]. Measurement network is configured to assess the d-q-axis AC positive sequence components of voltages and current to facilitate regulation, in addition to monitoring the DC voltage Vdc. Two independent PI controllers, one for DC voltage regulation and one for AC voltage regulation, comprise an external control loop represented in Figure 3. The controller of PI for AC network voltages generates the reference currents I-qref used by the current source controller. Iq signifies the current component orthogonal to a voltage that dictates reactive energy transmission. For DC voltages, the PI controller generates The current of reference I-dref for the current source controller; in this context, Id represents the current component aligned with a voltage that regulates real power transmission. The inner side circuit for regulating current includes a current regulator. The controller of PI works in the control mode of voltage, and the current regulator uses reference currents of Id and Iq-ref for AC- DC voltage, respectively, to control the amplitude and phase voltage produced by the SPWM converter (V2d, V2q). Based on the V1 measurement (V1d, V1q), the feed-forward regulator provides guidance for the current regulator by predicting the V2 o/p voltage (V2d, V2q) [15].

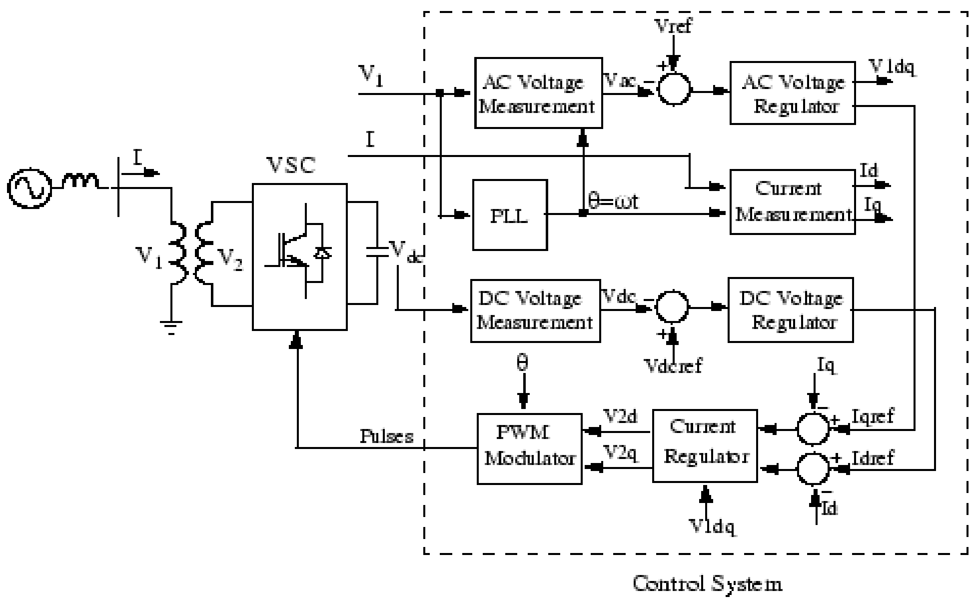

Fig. 4 Control circuit of STATCOM

Table 1. STATCOM parameter

Power	
Nominal voltage of line -line and frequency (Vrms L-L, fnn(Hz))	[500 e3, 50]
Rating of Converter (VA)	[100e6]
Impédance of Converter (R(pu), L(pu))	[0.22 /30, 0.462]
Initial curent of Converter (Mag(pu), Pha(deg))	[0, 0]
DC link Nominal voltage (V)	[4000]
Entire similar capacitance (F) of the DC link	[750e-6/2]
Controller	**Voltage Regulation**
Vac gains by regulator [Kp, Ki]	[5 3200]

Gains in Vdc [Kp, Ki] for regulator	[0.1e-3 20e-3]
Gains for the current regulator [Kp, Ki, Kf]	[0.3 10 0.23]
IGBT/Diode	
Rin (Ohms): Internal Resistance	1.00E-03
Rs (Ohms) of snubber resistance	1.00E+05

The real-world examples of where FACTS controllers have successfully improved voltage stability are

- Better use of the resources already available in the transmission system.
- In many nations, expanding energy transfer capacity and managing the transmission lines are crucial, particularly in deregulated markets where the locations of bulk load centers and generation can fluctuate quickly. Setting up more transmission lines' load flow to accommodate the growing power demand is often constrained by both financial and environmental factors. These needs are met in part by the FACTS Controller utilizing the transmission networks that are in use now.
- Enhanced availability and dependability of the transmission system: Numerous factors influence the availability and dependability of transmission systems. While faults cannot be avoided, the FACTS Controller can lessen their consequences and strengthen the safety of the electrical supplies by reducing the frequency of line trips. For example, an excessive line voltage caused by a significant load rejection may cause a line trip. By counteracting the overvoltage, STATCOMs prevent tripping lines.
- Enhanced stability of the dynamic and transient grid: Transmission systems may become unstable because of factors such as linked networks and lengthy transmission lines, the impacts of fluctuating loads, and line failures. Lower loop flows, line power flows, or even line tripping may result from this increased capacity for energy transmission, and a lower chance of line tripping are the outcomes of FACTS controllers stabilizing transmission networks [16].
- Higher-quality supplies for delicate industries: Superior electrical supplies with steady voltage, steady frequency, and uninterrupted power are essential for modern industry. Manufacturing processes can be interrupted by voltage dips, frequency changes, or supply disruptions, which can result in significant financial losses. FACTS Controllers can assist in supplying the necessary level of quality.
- Environmental benefits: The FACTS Controllers are environmentally beneficial. They don't emit any emissions or waste, and they don't contain any harmful materials. By making greater use of already-existing facilities, FACTS contributes to more economical electrical energy distribution, which lessens the demand for additional transmission lines [17].

2.5. Adaptive Neuro Fuzzy Inference System

Artificial neural networks with fuzzy logic control, or ANFIS, are used to generate test results. The fuzzy logic controller has several limitations and requires an expert to make it proficient and deliver optimal results. As a result, if an expert assigns the incorrect rule, a fuzzy logic controller may perform worse than a PID controller. Moreover, we frequently lack an adequate understanding of the system's behavior. Consequently, we are unsure of the fuzzy logic controller's proper rule during implementation [18]. ANN is suitable for use to make the controller fuzzy logic expert itself to overcome this limitation. ANN requires input and output data, so make it an expert among ANN, FUZZY and ANFIS; ANFIS is the easiest and most accurate technique to get the best result. With minimal input and output training data, ANFIS is a very common method for modeling complicated, nonlinear systems. It combines the benefits of fuzzy logic control for handling Inconclusive information and the ability of ANNs to gain knowledge from processes. Figure 5 represents the schematic diagram of ANFIS; it shows the number of inputs, membership function, rules and output. Here, we have taken 10 membership functions, so 10 membership functions as seen in Figure 6.

In the figure below, see the training set of ANFIS; at the first stage, we have to upload data for training. The training data is uploaded from the workspace, and the data is loaded. The second stage is to generate Fuzzy Inference System (FIS). There are a number of sections available, but we are using a grid partition because it will create a fuzzy logic controller itself. If we generate FIS, it asks about the membership function, we use 10, and the type of input variable function is triangular, then train the FIS by selecting appropriate epoch 50 and zero error tolerance. Figure 5 represents the final output of the given data at the end of the 50 iterations; the minimum error is obtained as 0.000130 and almost equal to zero [19]. In this system, we use one input and one output with 10 memberships function. In this way, ANFIS is implemented and substitutes the traditional PI controller and improved the performance of the FACTS controller [20].

Advantages of ANFIS:

- Comparing Control strategies based on artificial intelligence, such as neural networks and fuzzy logic, to PI controllers, the latter may not be the ideal option for nonlinear systems with variable speed operation.
- Overshoot, oscillation, and delayed reaction are the PI controllers' additional shortcomings.

- Artificial intelligence encompasses a wide range of advanced control approaches, such as ANFIS, which are more appropriate for nonlinear systems and variable speed operation.

2.5.1. Implementing ANFIS in Real-World Scenarios

- ANFIS has proven to be dependable and effective in real-world applications such as load forecasting for South African distribution networks and wind power output prediction, providing useful information for energy management and operation [21].
- For long-term load projections, another study evaluated data from the Malaysian Metrological Department using ANFIS and ANN models; ANFIS demonstrated higher accuracy than ANN models [22].
- Additionally, research on long-term forecasts of industrial and natural energy consumption has demonstrated the effectiveness of ANFIS in power systems, underscoring its potential to solve energy-related issues [23].

These studies collectively show the importance of ANFIS in tackling power systems and effective energy utilization issues, demonstrating its adaptability and effectiveness across a range of fields and applications.

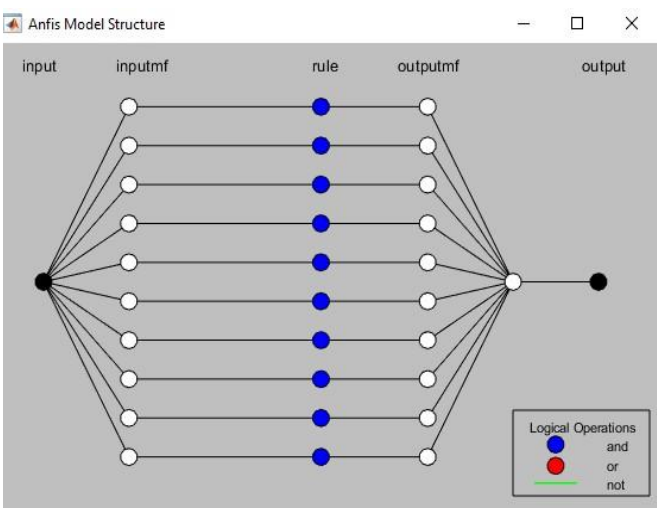

Fig. 5 Schematic diagram of ANFIS controller

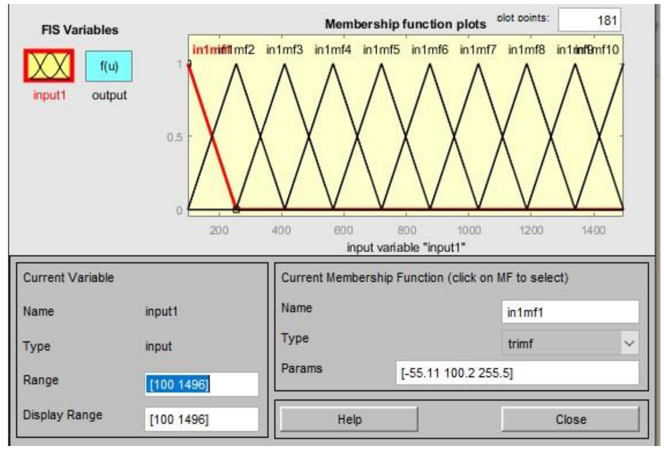

Fig. 6 Input membership function Fuzzy Logic Controller (FLC)

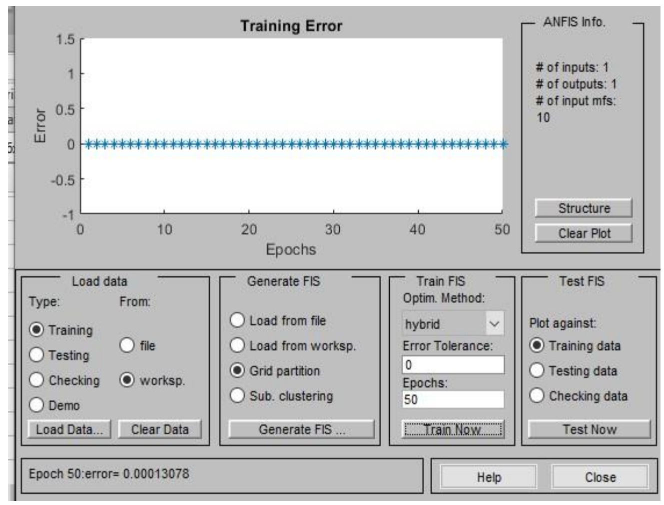

Fig. 7 Training set for ANFIS Output of ANFIS

3. Results and Discussion

This tabular result was produced using a graphical representation, as shown below. It is evident that while ANFIS precisely improves the outcome that is closest to normal, STATCOM improves the system overall. Figure 8 represents the bar graph of the result. This graph clearly represents the FACTS Device, which improves the voltage stability very closely. This facts device is improved by ANFIS. We obtained the result in terms of values represented on the bar graph.

Table 2. Presents a clear comparison between ANFIS and STATCOM

Bus 8	Normal Condition	Fault at bus8	With STATCOM	With ANFIS
Voltage in KV	230	185.67	226	229.1
Current in Kamp	0.242	0.2821	0.2382	0.2447
Active power kW	129.1	98.21	132.7	139.4
Reactive power in MVAR	23.37	28.95	29.7	22.79

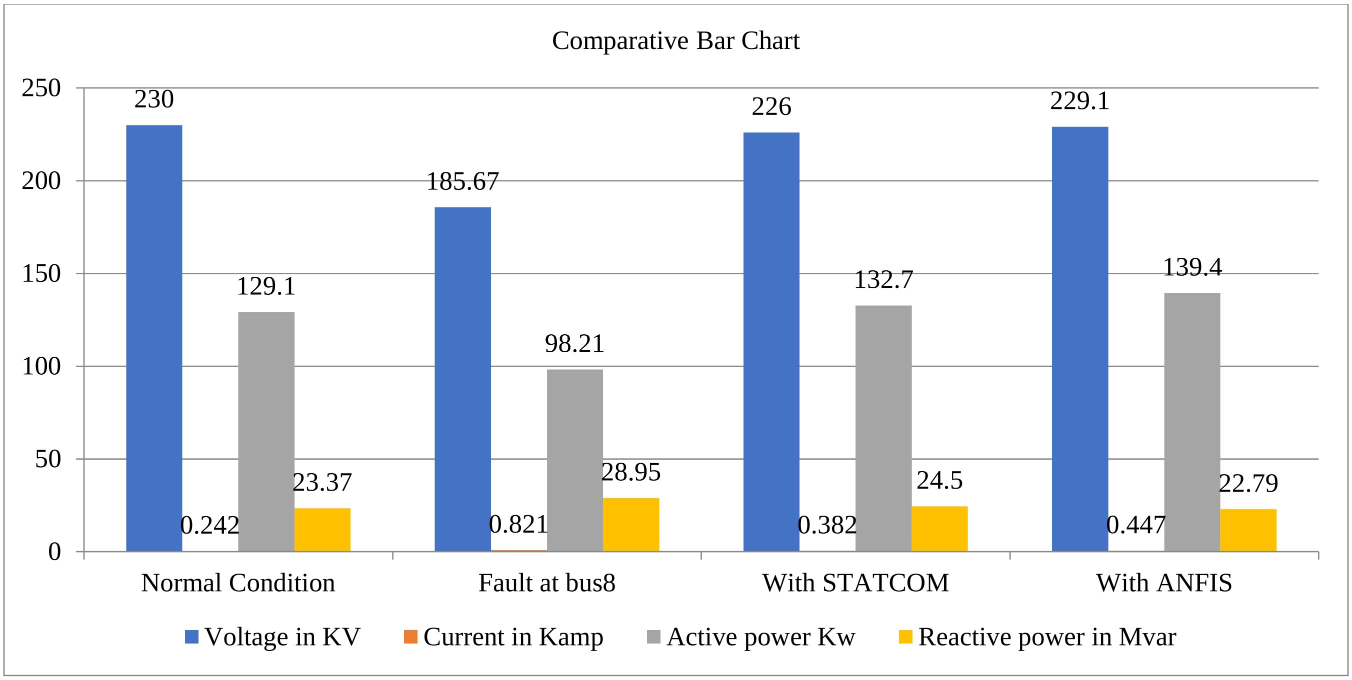

Fig. 8 Bar chart of comparative analysis FACTS device and ANFIS

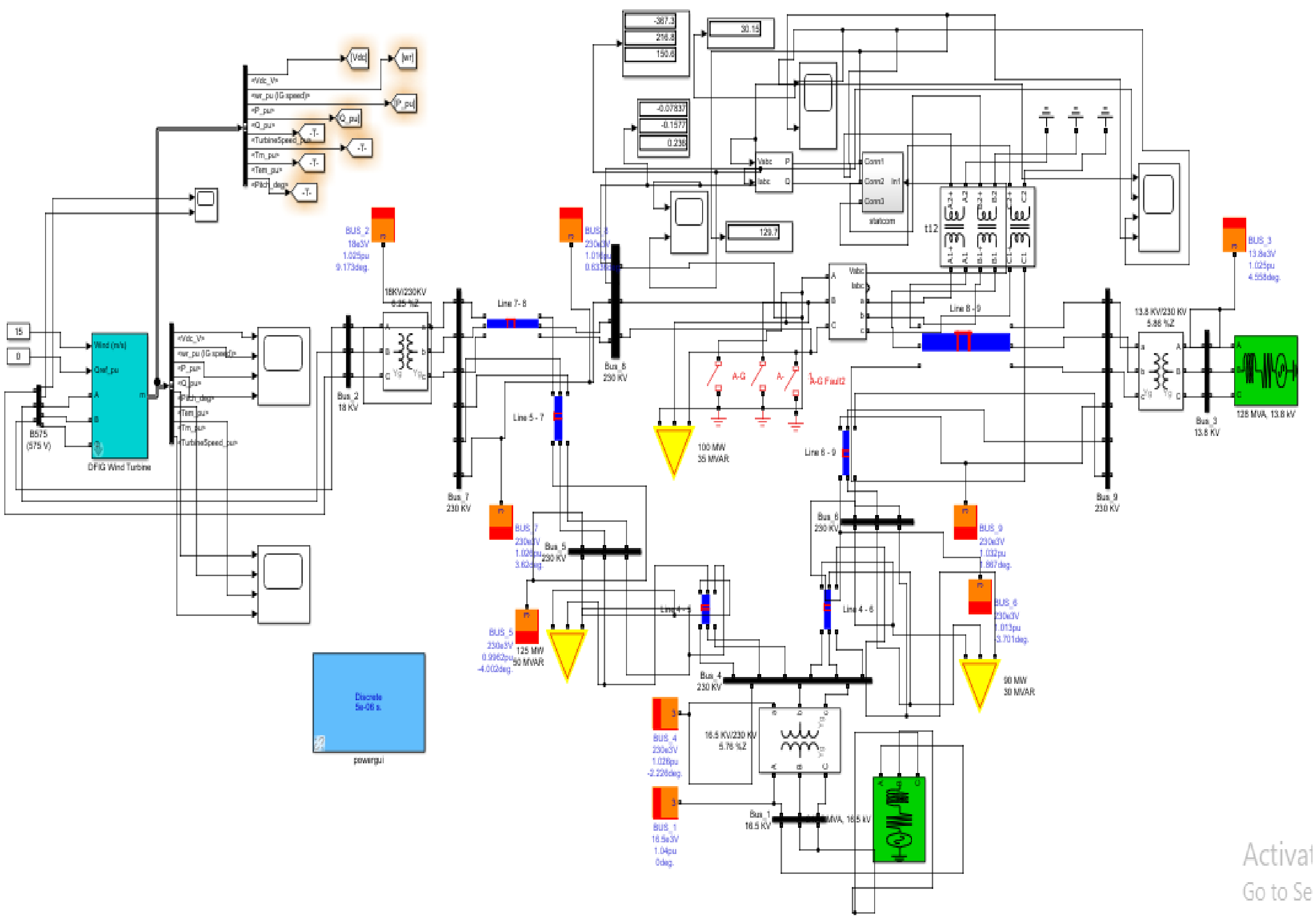

Fig. 9 Complete model IEEE 9 bus with FACTS device and ANFIS

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3.1. Healthy Condition Standard IEEE 9 Bus System with Wind Generation

Figure 10 represents a healthy situation. In healthy conditions, the system is stable. The total generation is in stable condition, which is 340 MW of power observed in the graph of active (P) power, reactive (Q) power in healthy condition, voltage and current from the wind side and bus system. Wind generation consists of a pitch control system, wind model, and duly fed induction generator connected by two masses and integrated with the IEEE-9 Bus system. Looking at the literature, it seems that some papers don't generate as much power and don't produce as clear results when it comes to normal situations. Obtained result values are mentioned in Table 2; from this, we can say that according to the parameter, we obtained accurate results.

3.2. Faulty Condition with Standard IEEE-9 Bus System Connected WG

Figure 11 represents a disturbance in this system when the LLL-G fault occurs at Bus-8, the main bus connected on load 100 MW. The change arises from the occurrence of a three-phase LLL-G fault at Bus-8 in the absence of STATCOM, impacting the wind park terminal voltage, current, produced real power and absorbed reactive power. When a fault occurs on Bus-8, it affects the wind generation system; then, at the time of fault duration, the voltage of the main bus-8 is reduced. During the fault period, 0.2 to 0.8 maximum voltage drop occurs. To rephrase, the overall exported active power (P) from Bus-8 experiences a reduction. Looking at the literature, it seems that some papers don't reflect after occurring fault and don't produce as clear results when it comes to faulty situations.

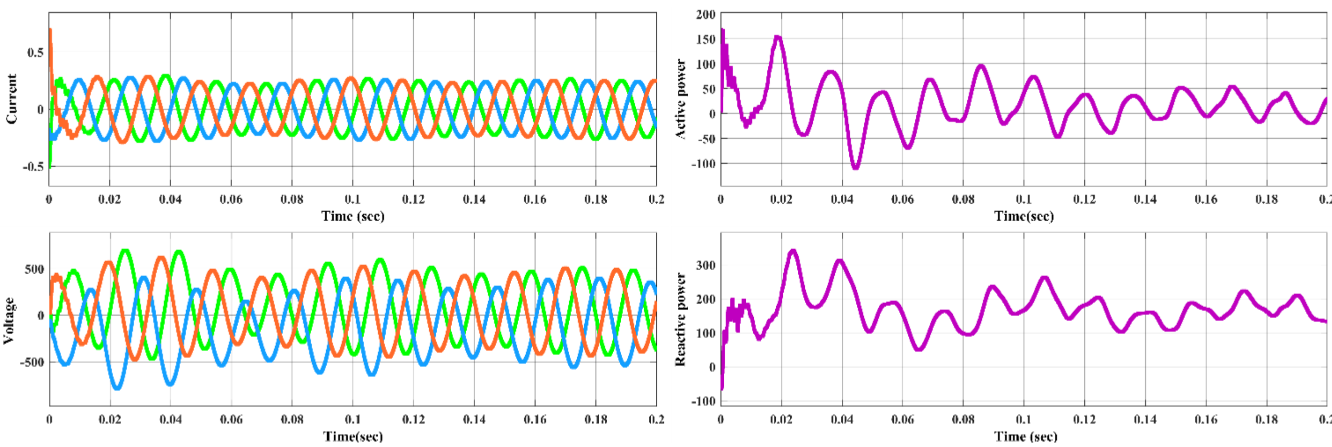

Fig. 10 Voltage current active and reactive power in normal condition

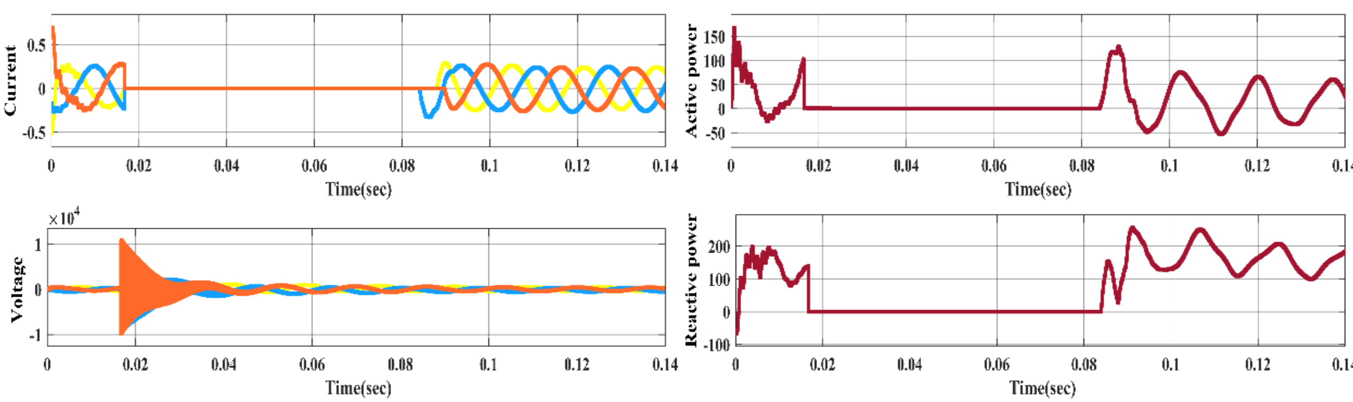

Fig. 11 Voltage current active and reactive power in faulty condition

3.3. WG Connected to IEEE 9 Bus System with Fault Compensated by STATCOM

Figure 12 represents the connection of wind generation with the standard 9-Bus system with fault and STATCOM. When a fault occurs, this fault period voltage is dropped and generated. Active power is decreased and absorbs reactive power, which increases with STATCOM. It also tries to maintain the system voltage in steady state condition. After the issue has been fixed, the generator speed has returned to normal, and the mechanical and electromagnetic torques are once again balanced. After the fault clearance, reactive power (Q) is provided by the power system to recover the air-gap flux in case of an LLL-G fault, and the system resumes steady operation.

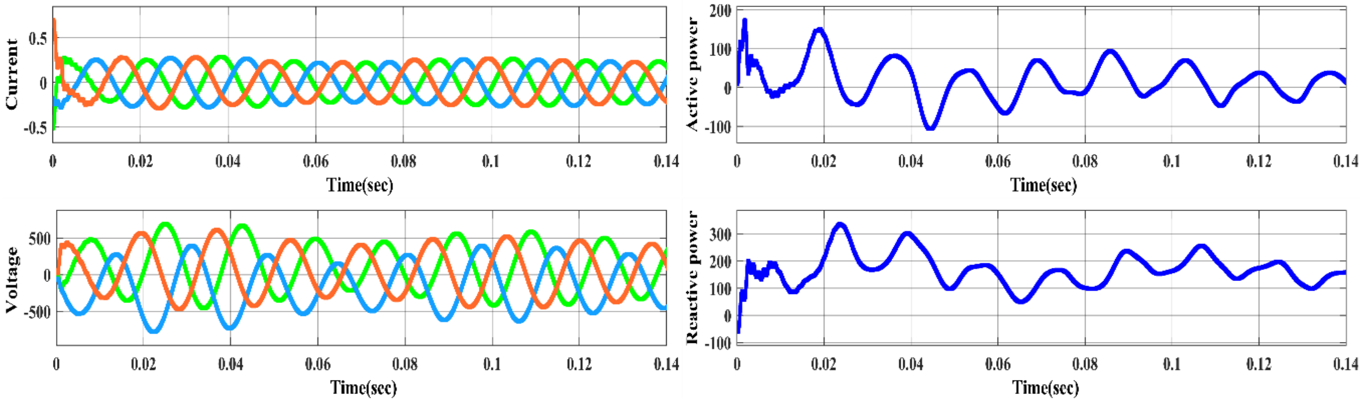

Fig. 12 Voltage current active and reactive power with STATCOM condition

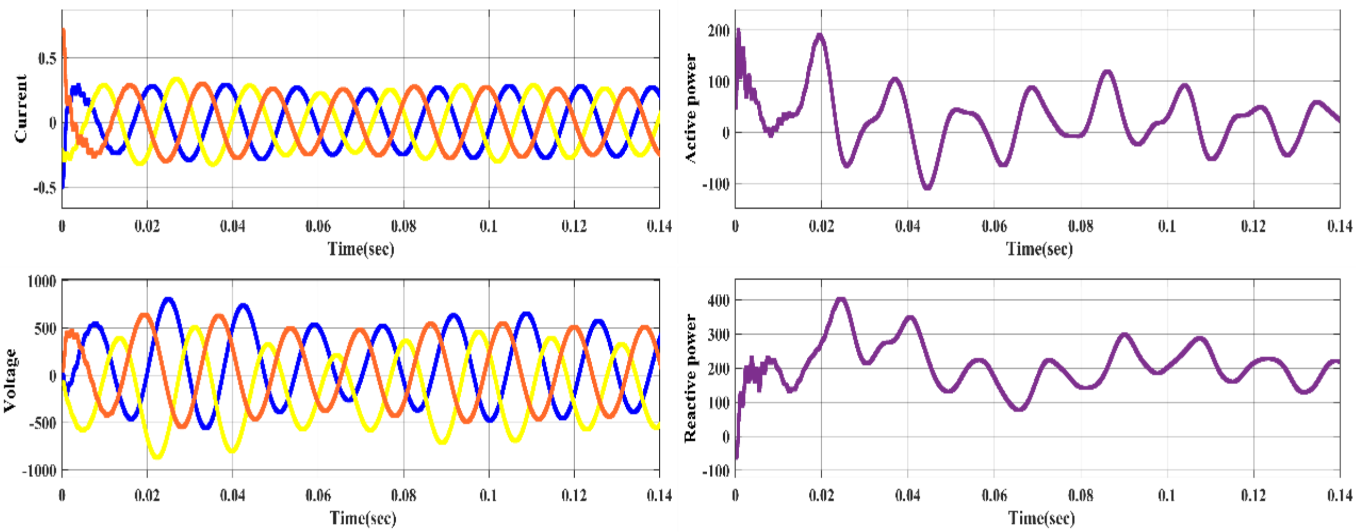

Fig. 13 Voltage, current, active and reactive power ANFIS

3.4. WG connected to IEEE 9 Bus System with Fault Compensated by ANFIS

Figure 13 represents the connection of wind generation with the standard 9-Bus system with fault and ANFIS. When the fault occurs, this fault period voltage is dropped and generated. Active power is decreased and absorbs reactive power, which increases with ANFIS. It also tries to maintain the system voltage in steady state condition.

The generated active power is decreased by a fault, which also increases and absorbs reactive power, which decreases. After the issue has been fixed, the generator speed has returned to normal, and the mechanical and electromagnetic torques are once again balanced. After the fault clearance, the power system provides reactive power (Q) to recover the air-gap flux in case of an LLL-G fault.

The wind farm has the capability to stay connected under this faulty situation with and without an ANFIS connection when the fault occurs. After the fault is fixed, the system resumes steady-state operation.

4. Conclusion

This approach goes into great detail on how problems like fault currents impact the load side or the distribution system overall. We put the recommended technique into practice and acquired the simulated result in the form of the voltage outline, reactive power, current, and active power at different fault conditions that occur at the load bus. Normal and faulty conditions are used to test the parameters of voltage profile, reactive power, and system stability. For the faulty condition, the STATCOM is installed on the load bus. The number of simulation results at various fault conditions at the load bus were acquired, and the results were compared with the initial state without STATCOM. During fault situations, applications involving huge wind farms have been identified as potentially problematic regarding reactive power consumption, control, and voltage stability.

Prior to implementing STATCOM, the excessive fault current should be considered. The influence of STATCOM on the fault current is noteworthy, particularly when the fault arises at the load buses, according to several simulations and analyses. We obtained simulated results in healthy conditions obtained the values of active (p) power and reactive (Q) power are P = 129.1 Mw and Q = 23.37 Mvar; in faulty conditions, the active power gets reduced to 98.21 Mw, and reactive power should be increased to 28.95 Mvar this condition to be improved by the FACTS controller the STATCOM is advised and mount to the system at the load side at the load bus where the faulty situation occurs then we obtained active power is 132.7 Mw and reactive power 29.7 Mvar. For the performance improvement of STATCOM, we prefer ANFIS in terms of active power, which is 139.4 mw, and reactive power, which is improved by 22.79 Mvar, which is exactly the normal state of reactive power. This is simply the result of the bus on which a fault occurs. But from the result, the 3 buses are compared for comparative study. After getting this result, I can say that the system has improved by the FACTS controller by up to 90-95 %. To provide suitable reactive control during faulty situations, the STATCOM is advised and mounted to the system at the load side at the load bus. It is also concluded that the FACTS Controller is a superior device for maintaining the system on the transmission side and the load side.

4.1. Future Scope

- In order to improve voltage stability, this research has shown a considerable interest in developing reactive power coordinating strategies. In order to prevent system instability, reactive power coordination is essential. Issues with both transient and steady-state stability can be resolved when the wind sources and STATCOM controller work together properly.
- A short transient overload capacity (often between 150 and 200 percent) can be displayed by STATCOMs for two to three seconds. Therefore, using STATCOMs' overloading capacity can help with significant voltage stability problems.
- Future developments in research aimed at enhancing load-side performance across bus systems under diverse fault scenarios may be possible thanks to the integration of ANFIS and STATCOM. Optimized Control Algorithms: Leveraging advanced optimization techniques with ANFIS to determine optimal STATCOM configurations and responses for various fault scenarios.
- Moreover, one efficient method for achieving grid code compliance for wind farms is to determine the best placement and rating of STATCOMs while taking various fault sites into account.
- Combining ANFIS with STATCOM provides a promising method to enhance power system reliability and stability under fault conditions. This integration could be essential for the future of intelligent power systems, potentially enabling fully autonomous grid management solutions.

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