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Static Synchronous Compensator (STATCOM) and Static VAR Compensators (SVCs) -based neural network controllers for improving power system grid

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ABSTRACT- The stability of the electrical network is considered a major challenge in the development of energy systems based on various sources. This research provides a comparison of the dynamic performance of FACTS devices such as STATCOM and SVC. These techniques, which are integrated stability devices with a multi-source power system, are used. The neural network technology unit is used to control FACTS devices to enhance the performance of power sources under abnormal and different conditions. Testing is conducted under conditions of three-phase short circuit to ground at bus (3) in the system. MATLAB/Simulink is used for modeling and simulation. The obtained results demonstrate the impact of the control unit based on SVC and STATCOM in reducing system oscillations and improving dynamic system performance during the post-fault period. The comparison confirms the superior dynamic performance and quick fault recovery of the control unit.

Keywords: FACTS; dynamic performance; ANN- neural network technology; STATCOM; SVC.

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1. INTRODUCTION

1.1 STATCOM based PI

STATCOM based Integration Proportional." In the context of power systems and control, this could mean using a Static Synchronous Compensator (STATCOM) in a control system with a proportional-integral (PI) controller for some specific purpose [1].

Here's a breakdown:

1. *STATCOM (Static Synchronous Compensator)*: A STATCOM is a type of flexible alternating current transmission system (FACTS) device used in power systems. It can control the flow of reactive power and voltage to improve grid stability and power quality [2]. STATCOMs use power electronics to generate or absorb reactive power as needed.

2. *Integration*: Integration usually refers to the integral part of a PI controller, which is a common type of controller used in control systems. To reduce static state errors in the control system is to take advantage of the base part.

3. *Proportional*: Response to present error ton by the relative part of the PI controller. The results are commensurate with present errors (the difference between actual and desired values).

Using a PI controller in conjunction with STATCOM to control voltage or reactive power in the system allows this combination to have more accurate control over the systems performance. Itcan be called "STATCOM based Integration Proportional" as in *figure 1*.

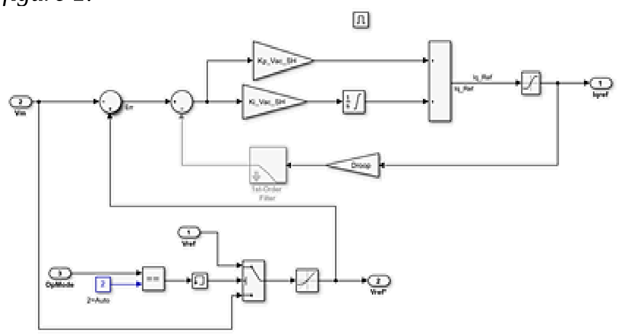

Figure 1. MATLAB/Simulink of STATCOM-Based PI

1.2 Static VAR Compensators (SVCs) based PI

To achieve precise control of (SVCs), Proportional-Integral (PI) controllers are often employed *figure 2*.

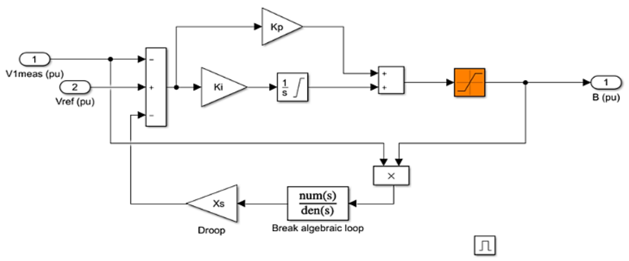

Figure 2. MATLAB/Simulink of SVC-Based PI

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So Static VAR Compensators (SVCs) are used in power system for reactive power compensation and voltage control [3]

Here's how SVCs depends on PI controllers:
1. Overview of SVC Operation:
• An SVC is a power electronics-created device that can produce or absorb reactive power as required to control the voltage and continue power system stability.

2. PI Controller for SVC:
• A PI controller is a normal style of feedback control system used in SVCs. It involves of two parts:
• Proportional (P) Component: This component products an output signal relative to the error, which is the variation between the wanted reference voltage (usually a stable set point) and the real measured voltage. The proportional term provides direct correction to the error.
• Integral (I) Component: The integral constituent integrates the error over time and products an output based on the growing sum of past errors [4]. The integral term removes any steady-state error and confirms that the system settles at the preferred set point.

3. Process of SVC beside PI Controller:
• The SVC's PI controller continuously observes the voltage at the point of adjustment within the power system.
• The measured voltage is compared to the desired reference voltage (set point).
• The error (the difference between the measured and desired voltages) are fed into the PI controller.
• The relational constituent of the controller directly responds to the error and regulates the firing angle of the thyristor-controlled reactor (TCR) or thyristor-switched capacitor (TSC) to variation the reactive power output.
• The integral module helps reject any steady-state error by integrating the error over time and creating continuous changes to the reactive power output.
• The combined action of the P and I works confirms that the SVC rapidly responds to voltage variations and keeps the voltage at the favorite set point.

4. Benefits of PI-Controlled SVCs:
• Voltage Regulation: PI-controlled SVCs can exactly adjust the voltage at a detailed point in the power system, helping to continue voltage stability in desired limits.
• Rapid Response: The proportional component permits for instant correction of voltage deviations, though the integral module eliminates long-term errors, confirming a rapid besides correct response.
• Enhanced Power Quality: By regulating the reactive power output as required, SVCs beside PI controllers can improve power quality by justifying voltage drops and waves and lessening harmonic distortion.

In summary, SVCs based on PI controllers are essential components of modern power systems, helping to confirm voltage constancy and power quality as in *figure 2*. The combination of proportional and integral control allows SVCs to respond rapidly to voltage disturbances and maintain the desired voltage set point.

2. MATERIALS AND METHODS

2.1 How Backpropagation Algorithm Works

The Backpropagation method in neural networks calculates the gradient of the loss function with respect to a certain weight using the chain rule. The computational process is conducted in a sequential manner, computing one layer at a time, as opposed to a native direct calculation as in figure 3. The computation of the gradient is provided, however, the manner in which the gradient is used is not explicitly specified [5]. The calculation in the delta rule is generalizing as following steps: -

The inputs X is received through the pre-established pathway.
The input is represented by a mathematical model that incorporates real-valued weights, denoted as W.

The selection of weights is often done in a random manner.
The task at hand includes determining the output of each neuron in a neural network, initial at the input layer, passing through the hidden layers, and finally reaching the output layer. Determine the difference between the observed outputs and the probable outputs [5].

Error B= Actual Output – Desired Output
6. The weights are adjusted by spreading the fault from the output layer back to the hidden layer in demand to reduce it.

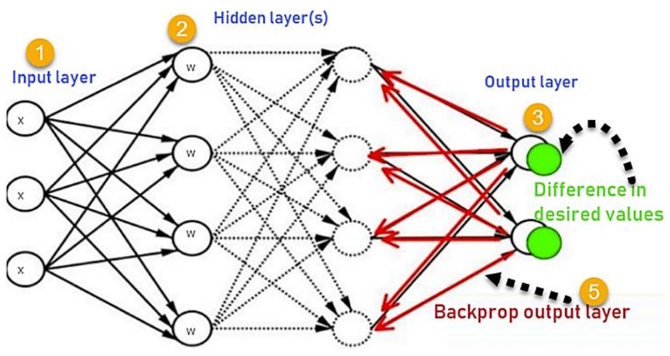

Figure 3. Configuration (Back Propagation)

3. THEORY AND CALCULATION

3.1 STATCOM-based ANN

The application of STATCOM (Static Synchronous Compensator) and its combination with an Artificial Neural Network (ANN) in the situation of electrical power systems. STATCOM is a flexible device used for reactive power compensation in addition voltage regulation in power systems. When integrated with an ANN, it can improve its operation in controlling and stabilizing the power system. Here's the key points from your explanation:

1. STATCOM Indication: STATCOM is a shunt-connected reactive power compensation device that uses solid-state switching converters. It can separately control lagging or leading reactive current, and its voltage source converter (VSC) products 3-phase voltages.

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2. Applications: STATCOM has several applications, counting harmonic cleaning, enhance system stability, and avoiding voltage fall down. When integrated through wind turbines, it can develop the operation of wind power systems.

3. Reactive Power Regulator: STATCOM can move reactive power between itself and the utility grid (UG). The control arrangement contains adjusting the STATCOM's amount voltage based on certain parameters, such as system voltage and transformer leakage reactance.

4. Simulink Model: You've cited that there is a Simulink style for the STATCOM-based ANN. Simulink is a general simulation and modelling tool used in many fields, counting power systems. The model seems to contain measuring system voltage, comparing it with a reference value, and using an ANN to determine the reactive reference current. This current reference is then compared to the actual STATCOM reactive current, and the output of the current regulatory controls the phase shift of the PWM (Pulse-Width Modulation) inverter.

The integration of STATCOM with an ANN is possible used to enhance the control of reactive power in the power system, agreeing for more efficient and constant process figure 4. The ANN can modify and learn from the system's conduct, making it a valuable tool for control and optimization function in compound systems like power networks.

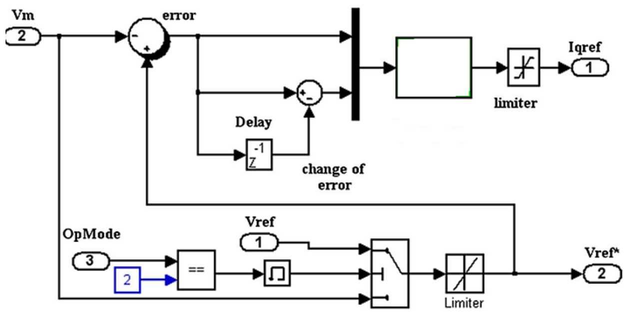

Figure 4. Simulink /MATLAB STATCOM based ANN

3.2 Static VAR Compensators (SVCs) based ANN

Static VAR Compensators (SVCs) and their application in combination with Artificial Neural Networks (ANNs) for voltage control and reactive power compensation electrical systems *figure 5*. SVCs are devices that can produce or engross reactive power to control the voltage in power systems.

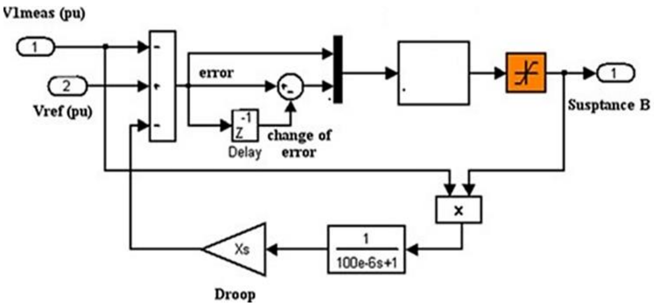

Figure 5. Simulink /MATLAB Svc-based ANN

The key point description is:

1.SVC Configurations: SVCs It can be in different forms, such as thyristor switched reactors (TSR), thyristor control reactors (TCR), thyristor switched capacitors (TSC), or groups of these. The output reactive power is controlled by variable the firing angle of silicon-controlled rectifiers (SCRs).

2. Applications: SVCs are necessity for dynamic voltage control, growing power transfer in low-voltage conditions, and relieve unacceptable fault impacts on generators.

3. Voltage Control: The core function of SVCs is continuing the system voltage at the necessary level. They obtain this by varying the susceptance value built on the control signal provided by a voltage control system.

4. SVC-Based ANN Model: You've integrated an Artificial Neural Network (ANN) into the control system of the SVC. The ANN takes error signals and their variation as inputs and generates control signals for the SVC. These control signals regulate the Pulse Width Modulation (PWM) inverter, which, in turn, regulate the firing angles of SCRs to supply the requisite reactive power.

5. Simulation: You've implemented this control system using MATLAB/Simulink.

This combination of SVCs and ANNs is a sophisticated control strategy for managing the voltage and reactive power in power systems. It enables real-time adjustments based on system conditions, contributing to the stability and reliability of the electrical grid.

4. RESULTS AND DISCUSSION

The present study aims to conduct an analysis and the subsequent debate on the topic at hand of the results findings. The power the distribution shown in *figure 1* of the WSCC included the FACTS - devices, namely SVC and STATCOM, which are controlled by a neural network controller. The model of the researched system is shown in *figure 6*, using MATLAB/Simulink. In order to evaluate the performance of the system, a 3-phase to-ground short circuit fault is introduced at bus (3). This site is chosen to be situated at the junction of the wind farm and the unit of WSCC., Comparison research was conducted to investigate the impact of STATCOM as well as SVC-based ANN on system situation and stability in the presence of disturbances.

4.1 Faults located at Wind farm bus 3

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

4.2 Subsection

The identification of the malfunction bus (3) of the WF transport system has been established. A defect to ground occurred in the wind power station system bus (3), manifesting as a three-phase fault. The issue exhibited a duration of 0.1 seconds, commencing on the first, second and being rectified at

Research Article | Volume 12, Issue 1 | Pages 247-252 | e-ISSN: 2347-470X

the subsequent second. *Figure 6* Illustrates the temporal behaviour of active power, reactive power for Static Var Compensator (SVC) and Static Synchronous Compensatorn (STATCOM), together with their respective control signals. The figure demonstrates that both SVC and STATCOM supplied an equivalent quantity of reactive power. The reactive power output of a STATCOM exhibits a higher degree of smoothness and a quicker reaction compared to that of an SVC. Conversely, the output of an SVC is characterized by sharper fluctuations and a greater number of oscillations. The reactive power requirement for STATCOM led to a fast adjustment of the Iq component on the quarter voltage axis, in contrast to the susceptance (β) for SVC. *Figure 7* Presents the dynamic temporal response of voltage, current, active power, and reactive power for generator 1. The system's instability for a brief duration may be seen due to the significant distance between the fault and the bus in question. The steady state of the system is achieved within half of the whole time by using Flexible Alternating Current Transmission System (FACTs) devices. The system is capable of capturing data without the use of FACTs devices. In addition, it should be noted that the absence of Flexible Alternating Current Transmission System (FACTS) devices in the system results in a greater degree of over-shooting. The system is capable of operating without the use of FACTs devices. In addition, it should be noted that the absence of FACTS devices in the system results in a greater degree of overshooting.

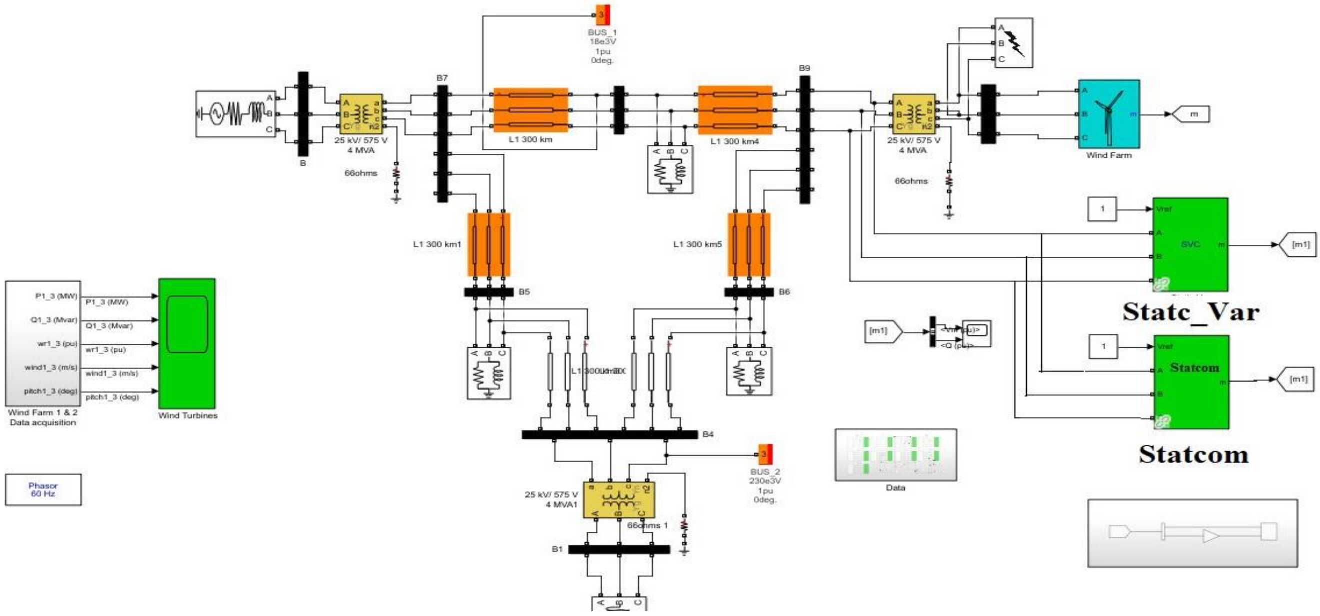

Figure 6. Depicts the Simulink model representing the total system under study

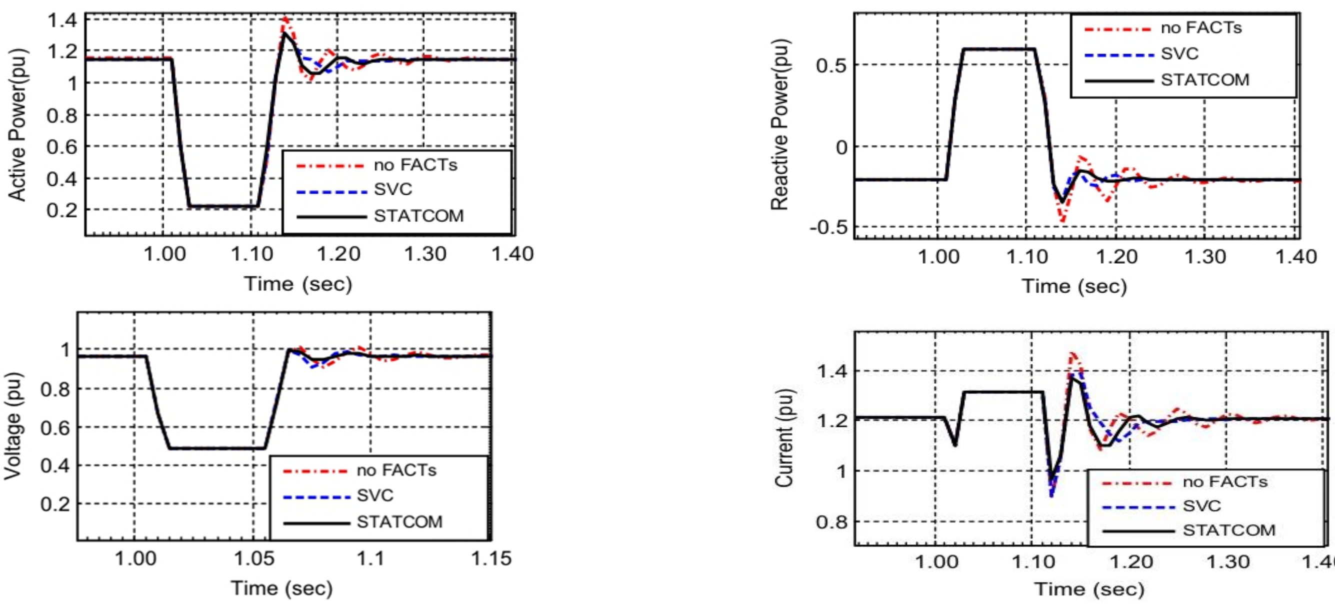

Figure 7. Illustrates the dynamic temporal response of several electrical parameters, including voltage- current - active power and reactive power - pertaining to generator 1. Bass ANN

Table (1) compression the rate of system stability after the fault in the state of (no FACTS, SVC, and STATCOM) related to generator (1) bass ANN

	Voltage (Pu)	Current (Pu)	Active power (Pu)	Reactive power (Pu)
No FACTS	stable at (1.14) sec	stable at (1.4) sec	stable at (1.33) sec	stable at (1.35) sec
SVC	stable at (1.13) sec	stable at (1.28) sec	stable at (1.26) sec	stable at (1.23) sec
STATCOM	stable at (1.1) sec	stable at (1.25)sec	stable at (1.25) sec	stable at (1.23) sec

According to Table 1's findings, when fault takes place, the system recovers to a stable state (Voltage, Current, Active power, Reactive power) more rapidly when used (STATCOM) bass ANN, than when udes (SVC) bass ANN, and the system needs more time to stabilize in case no FACTS.

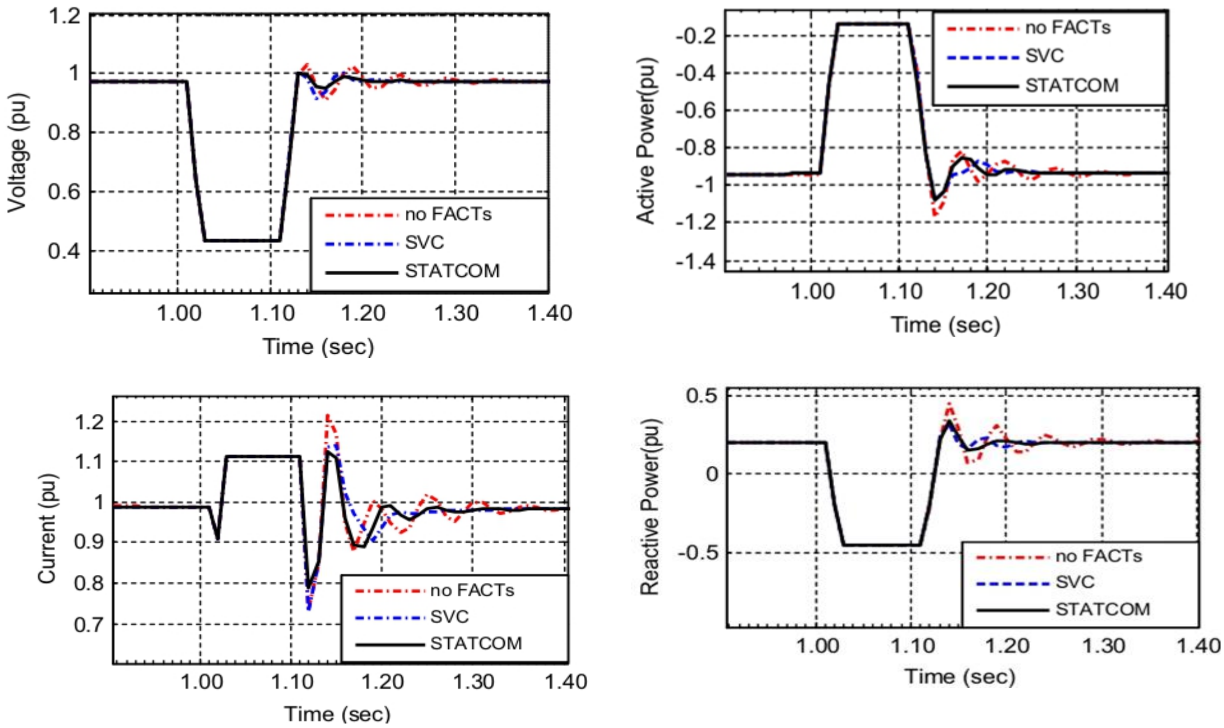

Figure 8. Illustrates the dynamic temporal response of voltage - current - active power and reactive power for Generator 2 based ANN

Table (2) compression the rate of system stability after the fault in the state of (no FACTS, SVC, and STATCOM) related to generator (2) bass ANN

	Voltage (Pu)	Current (Pu)	Active power (Pu)	Reactive power (Pu)
No FACTS	stable at (1.35) sec	stable at (1.4) sec	stable at (1.35) sec	stable at (1.3) sec
SVC	stable at (1.21) sec	stable at (1.32) sec	stable at (1.26) sec	stable at (1.23) sec
STATCOM	stable at (1.2) sec	stable at (1.3)sec	stable at (1.25) sec	stable at (1.23) sec

According to Table 2's findings, when fault takes place, the system recovers to a stable state (Voltage, Current, Active power, Reactive power) more rapidly when used (STATCOM) bass ANN, than when udes (SVC) bass ANN, and the system needs more time to stabilize in case no FACTS.

5. CONCLUSION

The operational efficiency of a wind farm using a doubly-fed induction generator (DFIG) in conjunction with the Western System Coordinating unit (WSCC) multi-machine power system. The system under investigation had severe three-phase-to-ground faults the operational efficiency of a wind farm using a doubly-fed induction generator (DFIG) in conjunction with the Western System Coordinating unit (WSCC) multi-machine power system. The system below implementing had hard three-phase-to-ground fault at bus (3). This site has been chosen to be strategically positioned at the interface between the wind farm and the WSCC system. The use of a neural network has been performed for the control of the wind farm is provide with an integrated Static Var Compensator (SVC) and Static

Research Article | Volume 12, Issue 1 | Pages 247-252 | e-ISSN: 2347-470X

Synchronous Compensator (STATCOM). A comparative analysis was conducted to examine the differences between SVC and STATCOM. The findings of the study show that Artificial Neural Networks (ANN) exhibit superior production in terms of decreased overshoot through transient faults. Both the Static Var Compensator (SVC) and the Static Synchronous Compensator (STATCOM) serve the purpose of supplying reactive power to the power system in the event of faulty situation. The ANN controller provides enhanced damping of oscillations, performing in a reduced settling time and a rapid and seamless response even in the existence of faults. Additionally, both SVC and STATCOM provide for fast restoration of terminal voltage after the clearing of faults. In conclusion, it can be said that STATCOM exhibits superior performance compared to SVC, particularly when these devices are controlled using fractional-order-based ANN control. The incorporation of resilience in ANN and the use of fractional-order precision would contribute to the improvement of the overall system performance when compared to traditional methods.

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