APPLICATION OF STATIC SYNCHRONOUS COMPENSATOR (STATCOM) AS REACTIVE POWER CONTROL IN DFIG WIND FARM AND GRID INTERCONNECTION SYSTEMS

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ABSTRACT

The most difficult aspect of optimizing a wind farm is creating an accurate wind farm model, especially if the farm is connected to the grid. The inconsistency and unpredictability of wind speeds exacerbates this issue. When dealing with wind farms, it is possible that the reactive power addition capabilities of individual wind turbines are insufficient to meet network requirements. This is due to cable losses and line losses between the wind farm and PCC. This study employs a doubly fed induction generator (DFIG) and a Static Synchronous Compensator (STATCOM) compensator to keep the output voltage amplitude more constant. Using two PI controller loops, the STATCOM will generate reactive (capacitive) power if the DFIG voltage is lower. The STATCOM will then absorb reactive (inductive) electricity if the DFIG system voltage is greater. STATCOM's ability to regulate the flow of reactive power can increase the network's stability. By optimizing the network's reactive power, the power factor is increased and stabilized up to 0.99. In addition, the system's harmonics never exceed the 5% limit specified by the IEEE 519-1992 standard.

Keywords: *DFIG, Static Synchronous Compensator, grid interconnection system, wind farm*

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1. INTRODUCTION

Indonesia's electrical energy usage is growing annually. State electricity companies (PLN) efforts to meet the demand for electrical energy rely primarily on fossil fuel generators. Currently, the availability of fossil fuels is diminishing. This circumstance increases the cost of electricity generation and stresses consumers [1]–[6]. In addition, the negative effects of its excessive use, like CO2 gas emissions, might contribute to climate change [7]–[10].

To fulfill the rising demand for electrical energy, it is vital to develop ecologically friendly technology capable of minimizing these harmful effects. In the trend of diversifying the energy industry, wind energy is a fast-expanding sector. However, the wind speed itself presents a challenge for generating electricity with wind power. Wind velocity varies frequently and is difficult to anticipate. This becomes a big impediment if a wind farm or wind turbine system is connected to the network. [7], [11]–[13]). To meet the demand for electrical energy, it is required to optimize the utilization of this energy source.

There are generally three types of wind power generators: the squirrel-cage induction generator, the permanent magnet synchronous generator, and the doubly fed induction generator (DFIG). DFIG is widely employed in the wind energy business nowadays. The primary benefit of using DFIG in wind turbines is that the amplitude and frequency of the output voltage can be kept at a constant value, unaffected by variations in wind speed within the wind-generating turbine. DFIG can be directly connected to the AC power grid and remain constantly synchronized. This includes the capacity to sustain power electronics devices in wind turbines while controlling the power factor [3], [8], [14]–[16]

The most difficult aspect of maximizing a wind farm is creating an accurate model of the wind farm. In addition, a significant number of parameters must be tuned to ensure good and stable interaction between the wind farm and the power grid at the common coupling point (PCC). To ensure system stability in terms of power quality and voltage levels, wind farms are necessary to create reactive power at the power conversion center. Voltage drops, power loss, and system failure may be caused by reactive power oscillations in a system. Therefore, a system capable of controlling the reactive power in the wind power system is required.

When dealing with wind farms, the reactive power addition capabilities of individual wind turbines may be insufficient to meet network requirements. This is because of losses in the conductor cables and the line between the wind farm and the PCC.

Utilizing a Static Synchronous Compensator (STATCOM) is one method for controlling the reactive power in the system. STATCOM is one of the methods used to enhance the power factor and regulate the system voltage. STATCOM operates by creating reactive electricity in accordance with system needs. Utilizing STATCOM in a wind energy system can increase system performance and decrease reactive power fluctuations[3], [16]–[18].

This work uses STATCOM compensators to optimize DFIG on wind farms that are grid-connected. STATCOM will provide reactive (capacitive) power if the system voltage is low and absorb reactive (inductive) power if the system voltage is greater. The voltage source converter (VSC) will control reactive power fluctuations. It is hoped that the employment of this compensator will enhance the performance of the system in the event of a change in wind speed. In addition, it may determine the reactive power regulation on the network-connected wind farm when a disruption occurs. If the system functions well, the need for eco-friendly electrical energy can be met. Background, objectives, problem identification, and research techniques should be implicitly explained in the preliminary content.

2. RESEARCH METHOD

Figure 1 depicts the STATCOM system utilized to enhance the condition of the hybrid power system between the wind farm and the grid. The initial step in collecting data for the simulation is to enter actual field data, such as the quantity of complex power derived from the calculation of active power and reactive power. Several parameters must be evaluated before to performing the simulation, as stated in equation (1).

$$y(n) = \sum_{k=-\infty}^{\infty} x(k)x(n-k) \tag{1}$$

A. Grids

The simulation voltage input on a three-phase programmable voltage source is divided in half. The utilized standard corresponds to the size of the transformer's 500kV/150kV voltage. This voltage input is divided to determine how the STATCOM reacts when the network voltage fluctuates. The input voltage is split between a higher voltage (510kV) and a lower voltage (490kV).

The initial status of the 490kV input voltage is closed, whereas the 510kV is open. Then, it is assembled with a three-phase breaker to adjust the input voltage according to the switching time [0 9 13 17]. When the simulation is started, the incoming voltage from the time interval 0s to 9s is 510kV. The voltage then shifts to 490kV at intervals 9s to 13s, and so on.

B. Loads

The simulation loads are derived from the data at the Jember substation. The 380V distribution area has a load of 40,2MW and 5.6MVAR. The simulation load is divided into three categories: resistive, capacitive, and inductive. Therefore, while retrieving data, the load is set independently and not instantly aggregated into a single total load. This is to determine how varied loads affect the qualities of the outcome.

C. DFIG Wind Farm

DFIG is an induction machine utilized extensively in the modern wind power industry. The primary benefit of using DFIG in wind turbines is that the amplitude and frequency of the output voltage can be kept at a constant value, unaffected by variations in wind speed within the wind-generating turbine.

Consequently, the DFIG can be directly connected to the AC mains and will remain synced with the AC mains around the clock. Other benefits include the capacity to change the power factor (e.g., to maintain the power factor) while keeping the power electronics in the wind turbine intact. Other reasons for employing DFIG in wind turbines include lower mechanical loads, simplified propeller designs, and low output power fluctuations.

The rotor of DFIG is connected to the grid via a variable frequency AC/DC/AC converter (VFC), while the stator is directly connected to the network. DFIG is a two-output (fed) induction generator utilized in variable-speed PLTB. Unlike typical single-fed induction generators, the DFIG's electrical output is speed-independent. Thus, a variable - speed wind generator is realizable by determining the mechanical speed at wind speed and increasing turbine operation at an aerodynamically ideal position for a certain wind speed rating.

The wind turbine equipped with the DFIG system is an induction generator whose stator windings are directly connected to a three-phase network and whose rotor windings are produced by three-phase back-to-back IGBTs coming from the PWM converter.

D. STATCOM Control Techniques

STATCOM receives input through $Qr_{\text{-STATCOM}}$ and step time. In addition, the three-phase current and voltage from the 150 kV line are computed to produce $Q_{\text{-STATCOM}}$ and $IQ_{\text{-STAT-max}}$ as outputs. Assume how many references reactive power will be added to the system ($Qr_{\text{-STATCOM}}$). The control technique on Simulink is shown in Figure 2.

The STATCOM control procedure for a hybrid power system: wind farm-grid can be characterized as follows:

1) Initially, the 3-phase grid voltage and current were capped to the d-q frame using a phase-locked loop (PLL).
2) The DC link voltage is detected on the STATCOM.
3) This hybrid system with STATCOM is managed by two loops; ***the first loop*** involves setting the AC voltage (I_{dref}) based on the inverter's output voltage. The output of this I_{dref} loop controls the flow of active power. This I_{dref} loop is depicted in Figure 3(b).
4) ***The second loop*** includes a DC voltage regulator (I_{qref}) whose output is dependent on the STATCOM DC link voltage. This I_{qref} loop's output is utilized to regulate the flow of reactive power. This picture of the I_{qref} loon is depicted in Figure 3(a).
5) Both loop outputs are coupled to a current controller that regulates the magnitude and phase of the STATCOM output voltage.

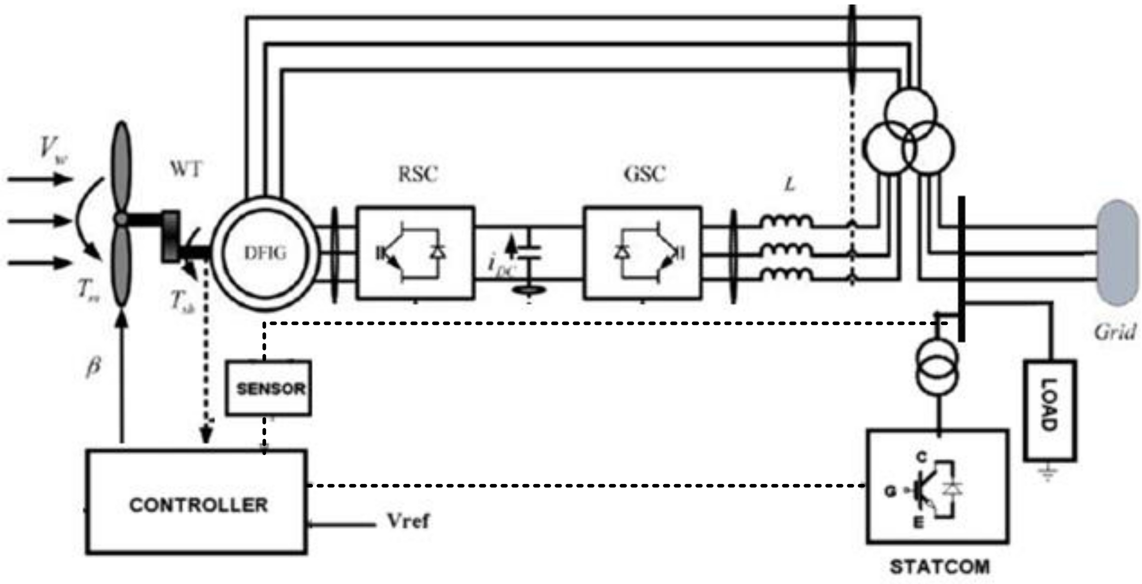


Figure 1. Schematic diagram of the wind generation system

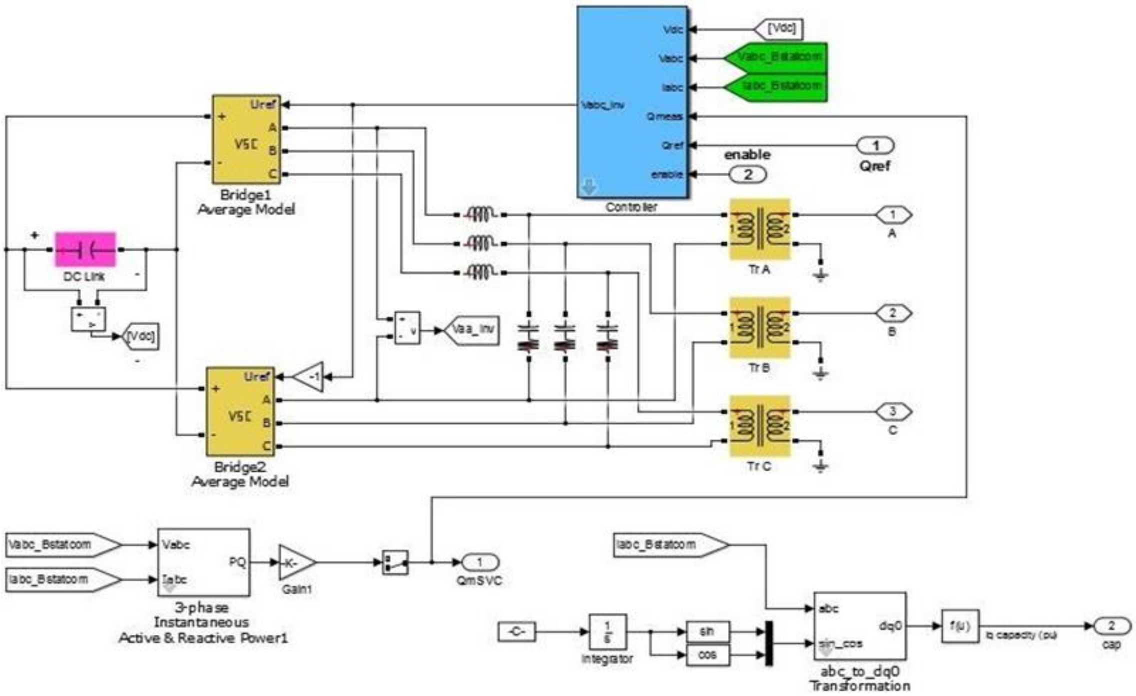


Figure 2. Schematic control of the STATCOM system

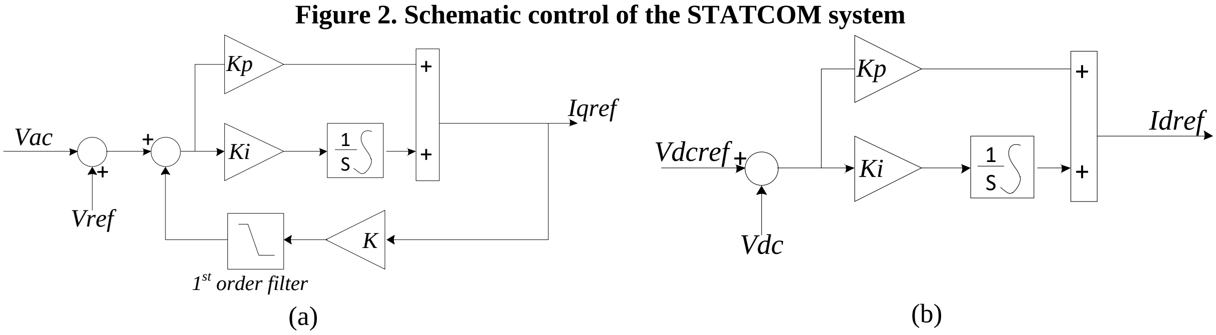


Figure 3. PI Controller of STATCOM system, (a) I_{qref} loop, (b) I_{dref} loop

In this manner of voltage control, the amount of voltage required to be injected into the bus network to compensate for the inverter voltage is determined. The recommended controller's output signal (V_c) is utilized to estimate the ideal IGBT firing angle of the STATCOM compensator.

When operating the STATCOM using a predefined control mechanism, it is known that the PI controller is the basis for the controller. The PI controller is a type of direct controller that can be implemented in a system. The values of K_p and K_i are determined by trial and error under specific operating conditions. Table 1 displays the STATCOM control parameters with a 20-second sample interval.

Table 1 Control Parameters on STATCOM

Parameter	
AC Voltage Setpoint V_{ref} (pu)	1.015
Manual Mode: Q_{ref} (pu)	0
DC Voltage Setpoint (volt)	2400
Vac Regulator Gains [Kp Ki]	[0.55 2500]
Vdc Regulator Gains [Kp Ki]	[0.001 0.15]
Sample Time (s)	20

3. RESULT AND DISCUSSION

After collecting the necessary data, the next step is to generate a simulation. When the simulation is complete, testing is the following stage. There are four of testing, including STATCOM voltage level testing, reactive power flow, harmonics, and the power factor.

The four of testing involve installing loads of varying natures. There are resistive, capacitive, and inductive loads among these. The four of testing are conducted both with and without the utilization of STATCOM. The collected findings will be compared to establish the features of each load application. 40,2 MW of loading is utilized for resistive loads. In the meantime, both the inductive and capacitive loads are equal at 5.6 MVAR.

3.1 Research Results

A. Testing of reactive power flow

The testing of reactive power flow determines how STATCOM influences power quality. In this instance, the reactive power at the wind turbine output is of uncertain quality. In addition, the effect on harmonics and power factor was determined. One may claim that the findings of other tests are compared to this one.

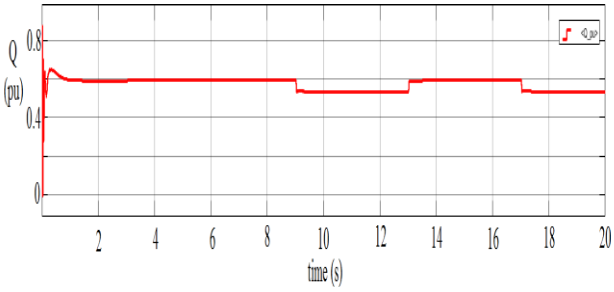
During the test with a voltage of 510kV, the reactive power created with a resistive load is greater than the reactive power flow with a voltage of 490kV. With a voltage of 510 kV, the average resultant value is 0.59690219 pu, but for a voltage of 490 kV, the average resultant value is 0.5342pu. Because there is no STATCOM to act as reactive power compensation in this instance when the input voltage varies, so does the output reactive power. It is shown in Table 2 and Figure 4.

Table 2 Comparison of Reactive Power at resistive loads

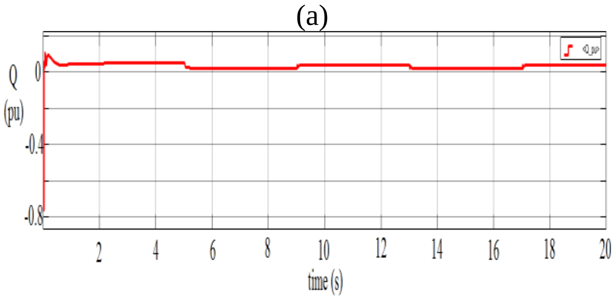
Time (s)	Q Without STATCOM		Q Using STATCOM	
	490kV	510kV	490kV	510kV
1	0.5357	0.5982	0.0597	0.0466
2	0.5317	0.5942	0.0647	0.0517
3	0.5320	0.5946	0.0680	0.0550
4	0.5328	0.5954	0.0700	0.0570
5	0.5333	0.5959	0.0710	0.0580
6	0.5337	0.5963	0.0413	0.0263
7	0.5339	0.5966	0.0414	0.0263
8	0.5341	0.5968	0.0414	0.0263
9	0.5343	0.5970	0.0414	0.0263
10	0.5344	0.5972	0.0414	0.0263
11	0.5345	0.5973	0.0414	0.0263
12	0.5346	0.5974	0.0413	0.0263
13	0.5347	0.5975	0.0413	0.0263
14	0.5348	0.5975	0.0413	0.0263
15	0.5348	0.5976	0.0413	0.0263
16	0.5349	0.5976	0.0413	0.0263
17	0.5349	0.5977	0.0413	0.0263
18	0.5349	0.5977	0.0413	0.0263
19	0.5349	0.5977	0.0413	0.0263
20	0.5350	0.5977	0.0413	0.0263

In contrast to when the system uses STATCOM, the system's reactive power flow can attain a stable value near zero from the first to the final second despite variable values. The difference between testing with 490kV and 510kV voltage is negligible. With a voltage of 490kV, the average value of reactive power is 0.0476 pu, while at a voltage of 510kV, it is 0.0331 pu.
The characteristics of the reactive power flow generated during an inductive load test without STATCOM are greater at a voltage of 510kV than at a value of 490kV. With a voltage of 510 kV, the average resultant value is 0.6520 pu, but at a voltage

of 490 kV, the average resultant value is 0.5844 pu. As there is no adjustment for the reactive power when the input voltage varies, so does the generated reactive power. It is shown in Table 3 and Figure 5.



(a)



(b)

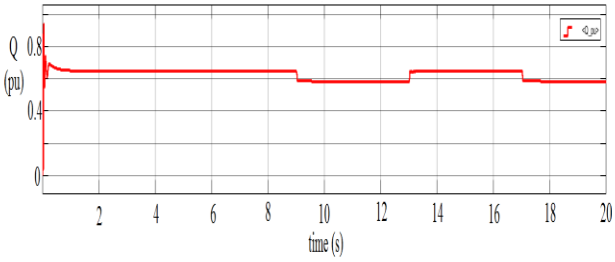
Figure 4. Reactive power flow with resistive load (a) without STATCOM and, (b) using STATCOM

Table 3 Comparison of Reactive Power at inductive loads

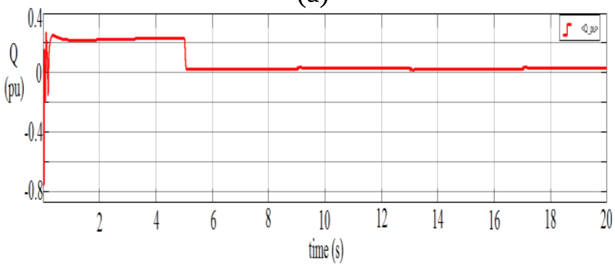
Time (s)	Q Without STATCOM		Q Using STATCOM	
	490kV	510kV	490kV	510kV
1	0.5861	0.6534	0.2120	0.2196
2	0.5818	0.6491	0.2213	0.2243
3	0.5818	0.6492	0.2276	0.2297
4	0.5827	0.6502	0.2308	0.2325
5	0.5833	0.6508	0.2323	0.2338
6	0.5838	0.6513	0.0351	0.0286
7	0.5841	0.6517	0.0351	0.0286
8	0.5844	0.6520	0.0351	0.0286
9	0.5846	0.6522	0.0351	0.0286
10	0.5848	0.6524	0.0351	0.0286
11	0.5849	0.6525	0.0351	0.0286
12	0.5850	0.6527	0.0351	0.0286
13	0.5851	0.6528	0.0351	0.0286
14	0.5852	0.6528	0.0351	0.0286
15	0.5853	0.6529	0.0351	0.0286
16	0.5853	0.6530	0.0351	0.0286
17	0.5854	0.6530	0.0351	0.0286
18	0.5854	0.6531	0.0351	0.0286
19	0.5854	0.6531	0.0351	0.0286
20	0.5854	0.6531	0.0351	0.0286

Table 4 Comparison of Reactive Power at capacitive loads

Time (s)	Q Without STATCOM		Q Using STATCOM	
	490kV	510kV	490kV	510kV
1	0.7155	0.7950	-0.1790	-0.2201
2	0.7113	0.7909	-0.1862	-0.2275
3	0.7115	0.7911	-0.1910	-0.2319
4	0.7125	0.7922	-0.1936	-0.2343
5	0.7132	0.7930	-0.1949	-0.2355
6	0.7137	0.7935	0.0148	0.0011
7	0.7141	0.7939	0.0148	0.0001
8	0.7144	0.7942	0.0148	0.0000
9	0.7146	0.7945	0.0148	0.0000
10	0.7148	0.7947	0.0148	0.0000
11	0.7150	0.7949	0.0148	0.0000
12	0.7151	0.7951	0.0148	0.0000
13	0.7152	0.7952	0.0148	0.0000
14	0.7153	0.7953	0.0148	0.0000
15	0.7154	0.7953	0.0148	0.0000
16	0.7154	0.7954	0.0148	0.0000
17	0.7155	0.7955	0.0148	0.0000
18	0.7155	0.7955	0.0148	0.0000
19	0.7156	0.7955	0.0148	0.0000
20	0.7156	0.7956	0.0148	0.0000



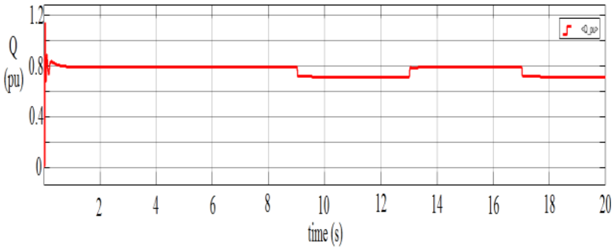
(a)



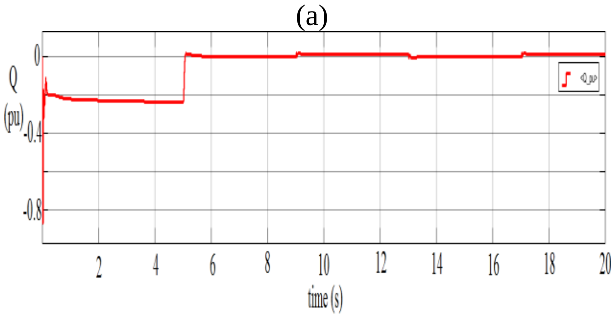
(b)

Figure 5. Reactive power flow with inductive load (a) without STATCOM and (b) using STATCOM

In the first to fifth second, when STATCOM is applied to a system with an inductive load, the reactive power created by the two input voltages at 490kV and 510kV is around 0.22 pu. Both parties were then able to reduce reactive power to near zero. This is displayed in Figure 5 (b). The oscillations that occur to attain stability occur in the same period as the switching time, or [0 9 13 17].



(a)



(b)

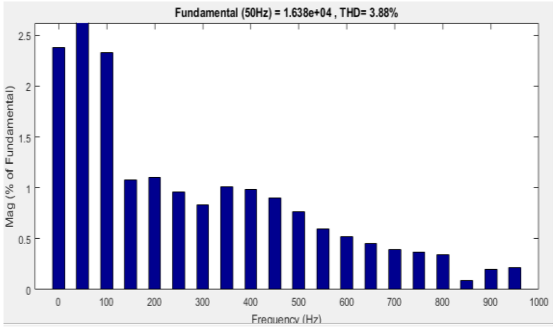
Figure 6. Reactive power flow with capacitive load (a) without STATCOM and (b) using STATCOM

While testing with a voltage of 510kV and a capacitive load, the reactive power flow features developed are bigger than the reactive power flow with a voltage of 490kV when the system is not using STATCOM. With a voltage of 510 kV, the average resultant value is 0.7943 pu, whereas the average resultant value for a voltage of 490 kV is 0.7144 pu. As there is no reactive power correction, when the input voltage swings, the output reactive power also fluctuates. These conditions are shown in Table 4 and Figure 6.

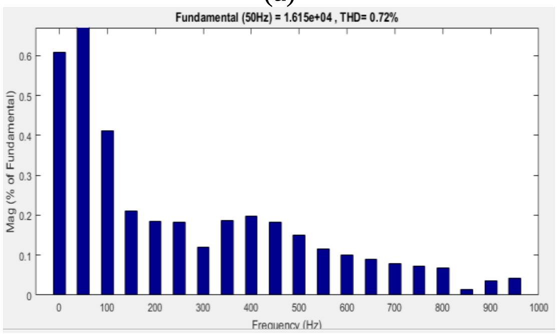
Following five seconds of the system's installation, the STATCOM compensation answer displays. This occurred in both tests with 490kV and 510kV input voltages. When the input voltage is 490kV, the reactive power produced between the first and fifth seconds is approximately -0.19 pu. When the input voltage is 510kV, the reactive power produced is around -0.23 pu. Both parties were then able to reduce reactive power to near zero.

B. Testing of Harmonics

To determine the efficacy difference between systems with and without STATCOM, harmonic testing on the three loads will be directly compared. The resultant resistive load THD: (a) 3.88 % without STATCOM and (b) 0.72 % with STATCOM. According to the IEEE 519-1992 standard, the two test results remain within the 5% tolerance.

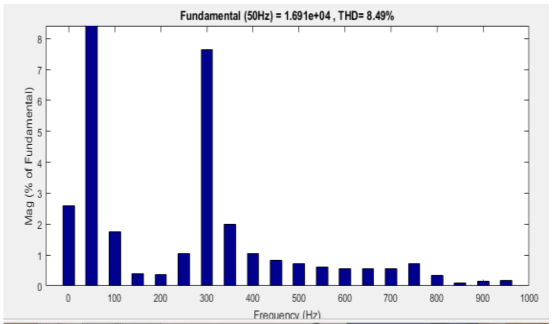


(a)

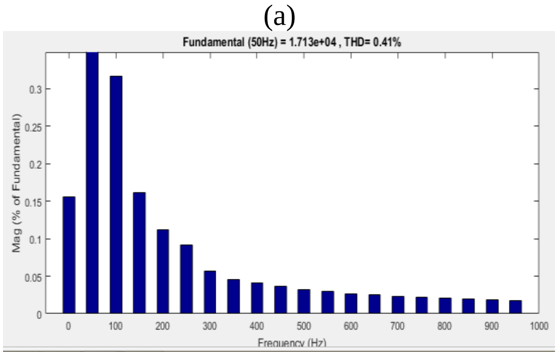


(b)

Figure 7. THD of resistive load (a) without STATCOM and (b) using STATCOM



(a)

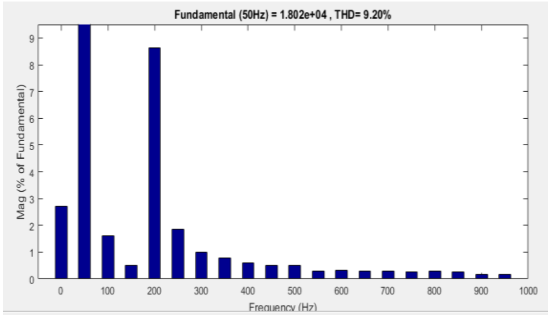


(b)

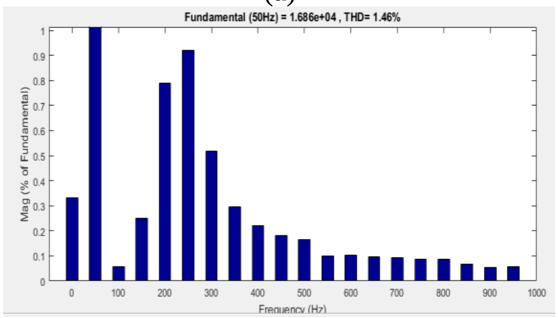
Figure 8. THD of inductive load (a) without STATCOM and (b) using STATCOM

Inductive load THD generated by the system without and using STATCOM respectively: (a) 8.49% and (b) 0.41%. When the system is loaded with a capacitive load, the THD value provided by STATCOM is 1.46%, although it is still 9.20 % before usage. The THD of both inductive and capacitive loads surpasses the IEEE standard of 5%.

This is illustrated in Figures 8 (a) and 9 (a). When STATCOM is applied to these two loads, however, the THD fulfills the criteria.



(a)



(b)

Figure 9. THD of capacitive load (a) without STATCOM and (b) using STATCOM

C. Power Factor (PF) Analysis

According to the power triangle hypothesis, the complex power increases with the amount of reactive power exchanged. As a result, a network's power factor drops. Likewise, the complex power decreases as the reactive power increases. Consequently, the power factor rises.

Table 5 Comparison of Power Factor at resistive loads

Time (s)	PF Without STATCOM		PF Using STATCOM	
	490kV	510kV	490kV	510kV
1	0.8333	0.8145	0.9925	0.9901
2	0.8313	0.8122	0.9943	0.9933
3	0.8105	0.7899	0.9969	0.9962
4	0.7898	0.7679	0.9923	0.9916
5	0.7746	0.7519	0.9997	0.9991
6	0.7622	0.7388	0.9995	0.9999
7	0.7517	0.7278	0.9995	0.9999
8	0.7427	0.7185	0.9995	0.9999
9	0.8333	0.8145	0.9925	1.0000
10	0.8313	0.8122	0.9993	1.0000

Without STATCOM, according to the Table 5, the power factor on resistive loads was initially capable of reaching values of 0.83 and 0.81. The power factor eventually falls to 0.70 and 0.67, however. When the system employs STATCOM, however, the power factor is much different and remains consistent at an average value of 0.99.

Table 6 Comparison of Power Factor at inductive loads

Time (s)	PF Without STATCOM		PF Using STATCOM	
	490kV	510kV	490kV	510kV
1	0.8178	0.7983	0.9969	0.9981
2	0.8158	0.7960	0.9958	0.9973
3	0.7940	0.7727	0.9949	0.9967
4	0.7722	0.7498	0.9943	0.9962
5	0.7563	0.7332	0.9939	0.9959
6	0.7434	0.7197	0.9979	0.9991
7	0.7325	0.7083	0.9979	0.9991
8	0.7232	0.6987	0.9979	0.9991
9	0.8178	0.7983	0.9969	0.9981
10	0.8158	0.7960	0.9958	0.9973

An inductive load without STATCOM has essentially identical power factor characteristics as testing with a resistive load. It was able to achieve values of 0.81 and 0.79 in the first second. The power factor eventually falls to 0.68 and 0.65, however. The resulting power factor, in contrast to the findings when the system employs STATCOM, is consistent at an average value of 0.98. It is shown in Table 6.

Table 7 Comparison of Power Factor at capacitive loads

Time (s)	PF Without STATCOM		PF Using STATCOM	
	490kV	510kV	490kV	510kV
1	0.7813	0.7606	0.9730	0.9601
2	0.7786	0.7575	0.9671	0.9521
3	0.7542	0.7319	0.9618	0.9652
4	0.7304	0.7072	0.9584	0.9508
5	0.7132	0.6895	0.9565	0.9683
6	0.6993	0.6752	0.9697	0.9654
7	0.6876	0.6632	0.9797	0.9766
8	0.6778	0.6531	0.9797	0.9797
9	0.7813	0.7606	0.9730	0.9601
10	0.7786	0.7575	0.9671	0.9521

When testing with capacitive loads instead of resistive and inductive ones, the power factor characteristics are nearly the same. Shown in Table 7, it was able to attain values of 0.78 and 0.76 in the first second. The power factor eventually falls to 0.63 and 0.60, however. When the system employs STATCOM, however, the power factor is much different, remaining steady between 0.99 and 0.98 on average. The appendix contains a list of the active power and reactive power statistics needed for power factor calculations.

3.2 Discussion

A. Testing of Reactive Power Flow

When a STATCOM is applied in a DFIG Wind Farm and Grid Interconnection Systems, it can regulate the voltage and reactive power of the system. This can be achieved by controlling the output current of the STATCOM, which can either absorb or generate reactive power.

In a DFIG system, the stator is directly connected to the grid, while the rotor is connected through power electronic converters. The converters can control the active and reactive power flow between the rotor and the grid. However, the control of reactive power flow is more challenging as it depends on the rotor voltage and the grid voltage.

The STATCOM can help to regulate the voltage and reactive power flow by injecting or absorbing reactive power from the grid. The STATCOM control algorithm can be designed to regulate the reactive power flow based on the difference between the rotor voltage and the grid voltage.

STATCOM can improve the voltage profile and decrease reactive power flow in DFIG systems, according to research. Likewise, [7] found that STATCOM can enhance voltage stability and decrease reactive power flow during DFIG fluctuation. Similarly, a study conducted by [11] demonstrated that STATCOM can enhance voltage management and decrease reactive power flow in DFIG systems.

In a ***resistive load***, the reactive power flow is minimal as the load only consumes active power. The STATCOM can still provide reactive power to compensate for the reactive losses in the system, but the amount of reactive power required is low. Similar to the results obtained [7], STATCOM can boost voltage to compensate for the voltage loss induced by resistive loads.

In an ***inductive load,*** the reactive power flow is positive as the load consumes both active and reactive power. The STATCOM can inject reactive power into the system to compensate for the reactive power consumed by the load. STATCOM can control the voltage and reactive power flow to maintain the system's power factor within the intended range, consistent with the findings of this study, which are identical to those reported in [17].

In a ***capacitive load***, the reactive power flow is negative as the load generates reactive power. The STATCOM can absorb the excess reactive power generated by the load and maintain the voltage level of the system. According to [12], STATCOM can regulate the reactive power flow to balance the reactive power demand and supply in the system.

B. Testing of Harmonics

A STATCOM can improve the voltage stability and power quality in electric power systems. When applied in a DFIG Wind Farm and Grid Interconnection System, the STATCOM can reduce the Total Harmonic Distortion (THD) in the system. The effect of STATCOM on THD depends on the type of load connected to the system. In general, STATCOM reduces THD by supplying reactive power to the system and reducing voltage fluctuations. The following is a brief overview of the effect of STATCOM on THD in different load conditions, along with relevant citations.

By providing reactive power and boosting voltage stability, STATCOM can reduce THD in systems with ***resistive loads***. This study revealed that the use of STATCOM in a DFIG wind farm with a resistive load reduced THD by up to 81.44 %.

STATCOM can reduce THD in systems with ***inductive loads*** by supplying reactive power and enhancing voltage stability. This study demonstrated that employing STATCOM in a DFIG wind farm with an inductive load reduced THD by up to 95.17 %.

By supplying excessive reactive power to a system with a ***capacitive load***, the STATCOM can enhance the total harmonic distortion (THD). Using STATCOM in a DFIG wind farm enhanced THD in a system with a capacitive load, as determined by simulation. Adjusting the STATCOM control parameters helps lessen the influence of STATCOM on THD under capacitive load conditions.

The THD in a STATCOM-based DFIG wind farm can vary depending on the load type, with inductive loads generally resulting in higher THD compared to resistive and capacitive loads. However, the THD levels in all cases are generally within the limits set by IEEE Standard 519.

C. Power Factor Analysis

Power factor analysis is an important consideration in wind farm and grid interconnection systems, particularly when using a STATCOM to manage power quality. The STATCOM can be used to improve power factor, which is a measure of how effectively the electrical power is being used in a system. The power factor is defined as the ratio of the real power to the apparent power in a circuit.

To improve the power factor in a wind farm and grid interconnection system with a STATCOM, the device can be used to inject reactive power into the system, which can offset the reactive power generated by inductive loads and improve the power factor. The amount of reactive power required will depend on the specific system configuration and the characteristics of the loads.

In this study, the authors use STATCOM to improve power quality and reduce the impact of grid disturbances on a DFIG-based wind farm. The results show that STATCOM is effective in improving the power factor and reducing harmonic distortion in the system.

When a STATCOM is applied in a DFIG Wind Farm and Grid Interconnection System, it can help improve the power factor under different load conditions such as resistive, inductive, and capacitive loads.

In the case of a ***resistive load***, the power factor can be improved by adjusting the reactive power output of the STATCOM. This helps to maintain a unity power factor which is desirable for efficient power transfer.

Under ***inductive loads***, STATCOM can supply reactive power which compensates for the reactive power required by the load. This improves the power factor and minimizes the impact of the load on the system's stability.

In ***capacitive loads***, STATCOM can absorb excess reactive power and maintain a stable voltage across the system. This helps to prevent overvoltage issues and reduces the strain on the system.

Overall, power factor analysis is an important consideration in wind farm and grid interconnection systems, particularly when using STATCOM to manage power quality. By injecting reactive power into the system, a STATCOM can improve the power factor and reduce the impact of inductive loads, capacitive loads, and other sources of reactive power.

4. CONCLUSION

This article describes a hybrid system between grid integrated DFIG Wind farms. For voltage regulation in the power grid, this system uses a STATCOM-based reactive power controller. In this study, two PI-controller loops are utilized. To validate the suggested controllers, two types of voltage variations generated by DFIG at various speeds are employed. Power factor, reactive power flow, and harmonics are tested parameters. These three parameters are evaluated using loads with distinct resistive, inductive, and capacitive properties. In voltage regulation, the simulation results have validated and validated the use of the recommended STATCOM-based controller.

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