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Power Quality Improvement by using a STATCOM Control Scheme for Grid Connected Wind Energy System

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Abstract: ***Renewable electricity assets inclusive of air, solar, water, biomass, and many others. Are crucial for sustainable development and social development, in addition to assembly power wishes through the usage of renewable electricity resources. Complete renewable electricity such as wind strength is needed in the energy device to lessen environmental influences. The project proposes the STATCOM manage plan for grid-connected wind electricity structures to increase strength excellent. The bang-bang controller changed into advanced for STATCOM primarily based at the hysteresis cutting-edge manipulate scheme. STATCOM has been merged with common coupling to reduce electricity excellent problems. The STATCOM manage scheme implemented for the grid related wind strength era machine used to enhance the power quality is simulated the usage of the MATLAB / Simulink inside the electricity device block set. This proposed scheme ensures an increase in energy great in production output.***

Keywords: FACTS devices, Power quality issues, STATCOM, Wind turbine, Point of Common Coupling etc.

I. INTRODUCTION

Attaining supportive development and social development requires renewable power sources such as sun, wind, biomass, hydro, co-generation, and so on. To fulfill strength demand thru the asset strength system, electricity conservation and so on. Renewable electricity. Sources are vital models. Renewable electricity, which includes wind strength, desires to be incorporated into the electricity device to create the potential to reduce the environmental effect on general power plant life [1]. Due to energy call for and environmental issues, wind energy generation is developing rapidly and massive-scale wind flowers around the sector are being connected to strength networks. By means of injecting alternating strength into the software grid the power first-rate is violated due to the character of the air fluctuations. In line with the iec general, electricity satisfactory is determined via wind generator performance. Throughout this paintings power first-rate troubles such as voltage variant, flicker, and harmonics are tested by putting in a wind turbine with a grid. Information equipment can be used to overcome those electricity great problems. The venture proposes the STATCOM control scheme for grid related wind electricity systems to beautify power great. The project pursuits to eliminate harmonic content (flicker, voltage variant, energetic and reactive electricity) the usage of STATCOM with battery electricity storage system (BESS). The simulation takes location within the MATLAB/ Simulink block set. STATCOM has been shown to beautify the electricity fine of strength grids with the aid of connecting primarily based wind flora [2].

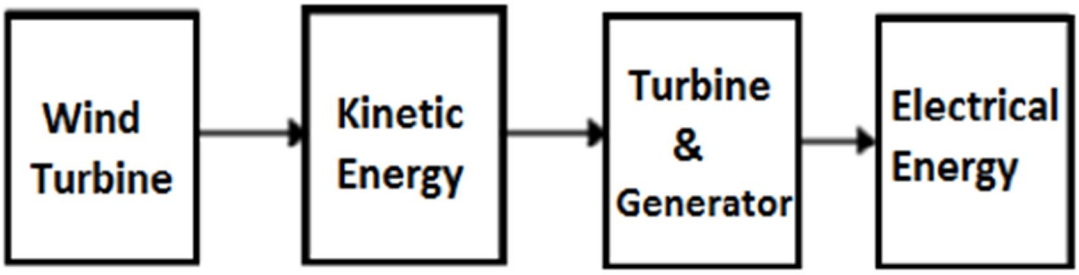

Fig.1 Basic Flow diagram of Wind Power Generation

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II. WIND ENERGY

Wind energy is the usage of wind mills to increase electrical energy, the use of wind power for mechanical energy, and the conversion of wind electricity into useful forms which include air pumps or vessels for water pumping or drainage. Let's pass similarly. Wind shape approach a pair of wind mills within the equal vicinity used to generate strength. A big wind farm consists of numerous hundred individual wind generators and covers an area of masses of rectangular miles, however the land between the turbines may be used for agricultural or other purposes. Wind farm is likewise offshore.

A. Wind Generating System

Many wind generators are jogging correctly round the world. Inside the operation of fixed-velocity wind turbines, all fluctuations in wind pace accelerate mechanical torque fluctuations, grid-aspect strength and massive voltage fluctuations. Energy excellent problems can be visible with air manufacturing, transmission and distribution community concerns including voltage sag, swelling, flicker, harmonics. Non-wind mills introduce disruptions in the distribution community. One of the simplest ways to operate a wind generation device is to use an induction generator (ig) this is without delay related to the grid gadget.

III. OBJECTIVE

Grid-connected wind strength era gadget the usage of STATCOM has the following targets to enhance energy pleasant

A. Unity is the energy thing towards the supply.
B. Wind generator and help for reactive energy from STATCOM for loading.
C. Easy bang-bang controller for STATCOM to lessen overall harmonic distortion.

IV. SYSTEM CONFIGURATION AND PRINCIPLE OF OPERATION

The static synchronous compensator is mostly a control voltage supply inverter (VSI), which injects power into the grid, harmonizes the supply modern and has their desired segment-perspective value relative to the supply voltage. The modern injected from the inverter is the reactive part and the harmonic on-linear load and induction generator can take away a portion of the modern-day, so it improves the strength component and as a result the energy quality. To perform these dreams, the grid voltage is subtracted and synchronized to generate the cutting-edge command for the electric converter. Grid connection structures were reversed to improve strength excellent all through everyday coupling. The grid-connected gadget is proven in fig.2.

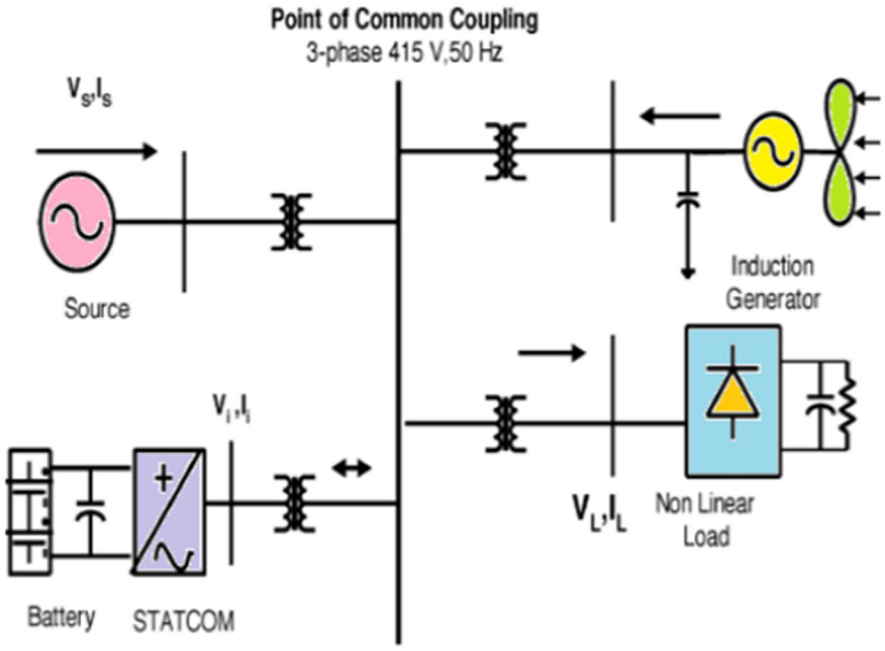

Fig.2 Grid Connected Wind Energy System

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V. PRINCIPLE OF STATCOM

The static synchronous compensator (STATCOM) bendy ac transmission gadget (records) is a completely unique device for the own family, which controls the glide of electricity the use of strength electronics and improves the steadiness of the energy grid. STATCOM controls the voltage at its terminal to control the reactive strength injected or absorbed from the strength tool. While the gadget voltage is low, STATCOM produces reactive electricity (STATCOM capacitive). Whilst the system voltage is high, it absorbs the reactive electricity (STATCOM inductor). In synchronization with the decision for to stabilize the voltage of the capability community.

Normally, STATCOM is established to help the power network with negative strength supply and sometimes terrible voltage control. The most common use of this tool is for voltage balance. Mainly it's miles a voltage source converter (VSC) primarily based device, which is the voltage source in the back of the reactor. The voltage source is designed with a dc capacitor and therefore the tool has low lively power ability. However, if dc energy is connected to the appropriate power garage tool in the capacitor, its energetic ability can be increased.

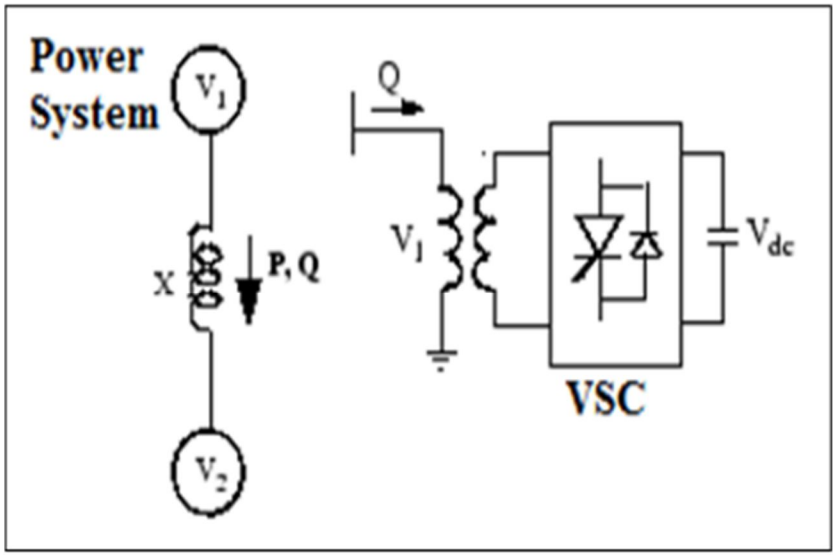

Fig. 3 Single line diagram of the STATCOM

VI. PROBLEM FORMULATION

Putting wind power inside the energy grid affects the first-rate of energy. The performance and power best of the wind turbine are decided based on measurements and the requirements are followed according with the global electro-technical commission widespread, iec-61400. Energy satisfactory measurements related to wind turbine effect inside the grid system - lively electricity, reactive power, variation of voltage, flicker, harmonics and electrical behavior of switching operation and are measured in step with countrywide / worldwide recommendations. The paper look at indicates the power high-quality troubles due to the set up of wind generators along the grid. The static compensator (STATCOM) is included with the commonplace battery electricity storage gadget (BESS) to lessen electricity high-quality troubles in the proposed scheme. Battery power storage has been incorporated to preserve a actual strength supply beneath wind power fluctuations.

VII. EXISTING SYSTEM

The STATCOM manage scheme for a grid related wind power era machine is simulated the use of the MATLAB / Simulink inside the power machine block set to improve electricity fine via the pi controller. The impact of the traditional scheme is to relieve the burden of the principle supply and the reactive strength demand of the induction generator.

VIII. PROPOSED SYSTEM

Fuzzy logic controller is designed to improve the profile of source current in STATCOM. The motive of the proposed scheme is to relate the principle deliver source through the deliver and reactive strength demand of the remarks generator and the discount of THD (total harmonic distortion) within the source waft of the system.

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IX. CONTROL SCHEME

A. Bang-bang Current Controller

The current control scheme is implemented using a pulsating current controller. Under supervision
The scheme, the source current is detected by the current sensor and compared with the reference current to obtain the current error for the hysteresis-based bang-bang controller. Therefore, the on / off switching signals for STATCOM's IGBT are obtained from the hysteresis controller.

The switching function S_A for phase 'a' is expressed as

$$i_{sa} < (i_{sa}^{*} - HB) \rightarrow S_A = 0$$

$$i_{sa} > (i_{sa}^{*} - HB) \rightarrow S_A = 1$$

When HB is a hysteresis current band, the same can be obtained for the switching function
Phase's "b" and "c" [14] [15].

- ***Gird synchronization***

In a three-phase equilibrium system, the RMS voltage is calculated on the source amplitude model
Frequency from source voltage is expressed as frequency () and sample template,
(1) Similar to sample peak voltage.

$$V_{sm} = \sqrt{\{\frac{2}{3}(V_{sa}^2 + V_{sb}^2 + V_{sc}^2)\}} \quad (1)$$

The in-phase unit vectors are taken from the AC source-phase voltage and the RMS value of the unit
Vector u_{sa}, u_{sb}, u_{sc} as shown in (2).

$$u_{sa} = \frac{V_{sa}}{V_{sm}},\ u_{sb} = \frac{V_{sb}}{V_{sm}},\ u_{sc} = \frac{V_{sc}}{V_{sm}} \quad (2)$$

X. SIMULINK MODEL OF WIND TURBINE

The Simulink model of the wind turbine is proven underneath fig. 2.1 this version is derived from the MATLAB/ Simulinlk software program, which has a nominal velocity of (ii) three inputs at (ii) pitch angle (i) generator pace () r_ pu). . Is in ranges and (iii) ms with wind pace. The tip pace ratio is the pulo of pu n_ nom, which is received via dividing the bottom rotation speed by using the rational velocity in line with unit of the pulo wind pace of the bottom wind speed. Torque to the output generator shaft. Nominal power of an electric powered generator pair with a wind turbine in va. Those parameters are used to discover the output torque inside the pu of the nominal torque of the generator. The base fee of wind velocity is in m / s, which is used for the unit device. The common price of the wind pace behind the wind is called the base wind pace. This base wind speed produces mechanical power and its cost is generally less than the nominal strength of the turbine. Simulink model of wind turbine shown in figure 4

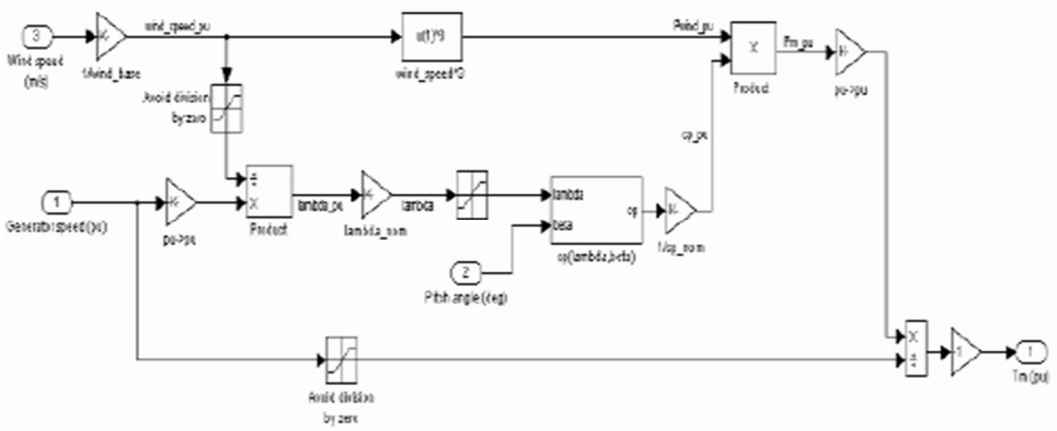

Fig.4 Simulink model of Wind Turbine

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The version relies upon at the constant-state energy characteristics of the turbine. The visibility of the force educate is endless and the friction coupler and inertia of the turbine should be coupled to the ones turbines. The output electricity of the wind turbine is given,

$$P_{m=}\ Cp(\lambda, \beta)\ \frac{\rho A}{2} V^3 \text{wind}$$

Where Pm is Mechanical o/p power of turbine (W), Cp is Performance coefficient of the turbine, P is Air density kg/m3),
A is Turbine swept area (m2), B is Blade Pitch angle (degradation) and A is the ratio of tip speed to wind speed of rotor blade tip speed.

XI. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES

A. *International electro technical commission guidelines*

A directional region unit is supplied to measure the strength pleasant of the turbine. International requirements the international electro-technical commission (iec) technical committee-88 developed the unit of iec fashionable 61400-21, which describes the manner for determining the ability satisfactory traits of a turbine [17]. The same old criteria are specific.

1) *IEC 61400-21:* Wind turbine era device, part-21. Dimension and evaluation of the energy excellent of a grid linked wind turbine.
2) *IEC 61400-13:* Measurement procedure in determining wind turbine-strength behavior.
3) *IEC 61400-three-7:* Emission restrict estimates for fluctuating masses IEC 61400-12: wind turbine performance. The information sheet containing the electric traits of the wind turbine gives the idea for the utility assessment in terms of the grid association.

B. *Voltage Variation*

The voltage variation releases the end result from the air fee and generator torque. Voltage variant is immediately related to actual and reactive energy versions. Voltage variant is normally classified as follows:

1) Voltage sag / volt dips.
2) Inter minor interruption.
3) Voltage swelling.
4) Long-term voltage version.

Voltage flicker hassle describes dynamic adjustments inside the community due to wind generators or variable hundreds. So energy fluctuations from the wind turbine occur at some stage in continuous operation. The amplitude of voltage fluctuations relies upon on the electricity of the grid, community resistance and section angle, and the strength hassle of the wind turbine.

C. *Flicker*

Electric electricity is an critical element for many commercial, industrial and domestic methods. As a product, electric energy must be of an appropriate fine to be able to make sure the proper conduct of the devices connected to the power distribution device. The IEC 610002-1 preferred classifies low-frequency frequency-driven disturbances into the following five businesses: harmonics and inter-harmonics and short-impedance interruptions, voltage immersion, energy frequency versions and voltage fluctuations, voltage imbalance. Voltage fluctuations are underlined as a cyclical exchange in voltages much less than one hundred% of the face cost. Most linked devices do no longer suffer from voltage fluctuations, despite the fact that those fluctuations purpose changes inside the mild depth of the light supply, referred to as flicker.

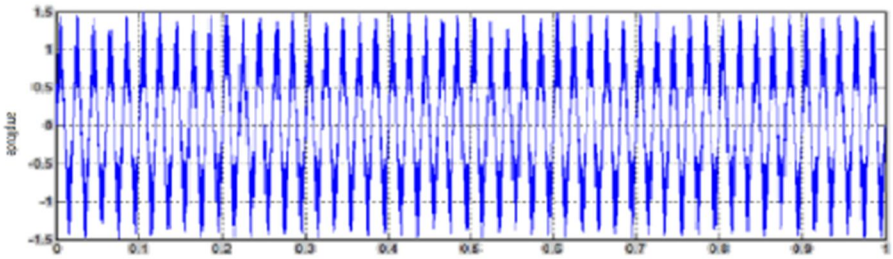

Fig.5. Voltage Flicker

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XII. MATLAB/ SIMULINK MODEL OF BANG-BANG CURRENT CONTROLLER

Bang-bang modern controller is an improvement to the contemporary manipulate scheme. The reference modern-day is generated and the actual sensor is detected by using the usage of the contemporary sensor and subtracted to reap the current errors for hysteresis based totally definitely at the bang-bang controller. Therefore on / off switching signals for STATCOM's IGBT are obtained from the hysteresis controller. Switching function switching for phase a is expressed as follows, wherein HB can reap a hysteresis modern-day-band, as well as the switching feature for phases "b" and "c". Simulink model proven in determine 6.

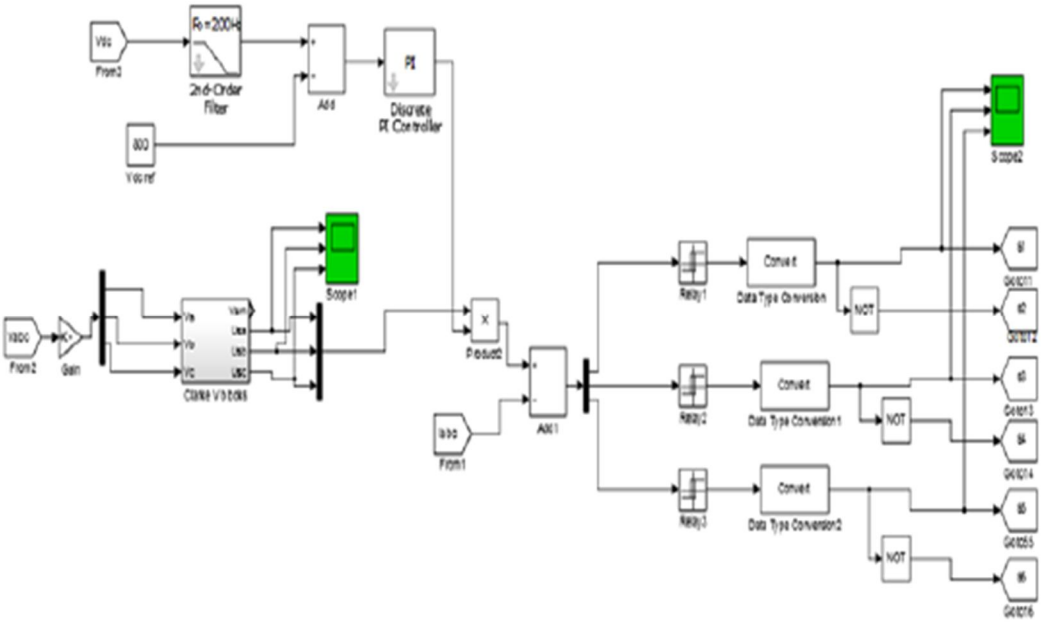

Fig.6. SIMULINK model of the proposed Bang-Bang Controller scheme.

XIII. CONTROL SCHEME AND ITS RESULT

The STATCOM control scheme is based on injecting currents into the grid using a bang-bang controller. The controller makes use of hysteresis present day controlled method. The usage of this technique, the controller continues a manage machine variable among the boundaries of the hysteresis region and gives an appropriate switching signal for STATCOM operation. In reality, the manipulate machine scheme that produces the switching signal in STATCOM is proven in fig.7. This manage set of rules requires the size of various variables which include 3 section source current, dc voltage and inverter present day with the help of sensors. The modern manipulate phase gets the reference modern-day and the center of real present day to prompt the operation of STATCOM inside the modern-day reference mode.

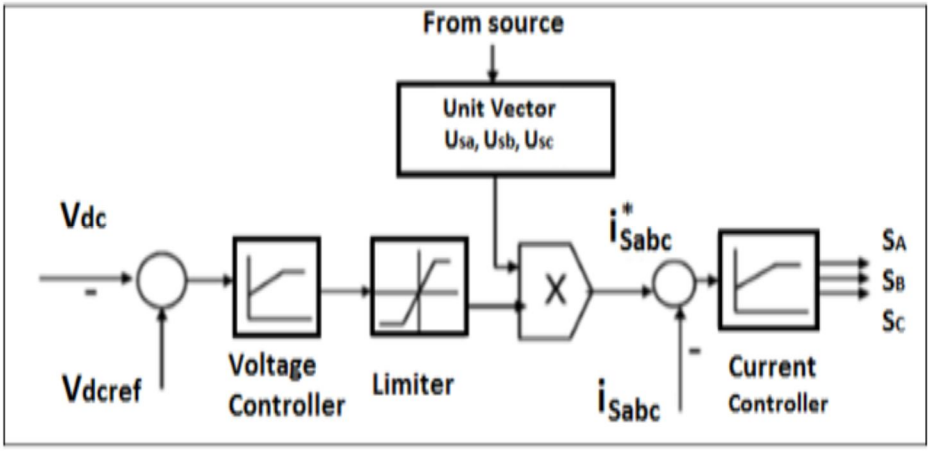

Fig. 7 Control System Scheme

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XIV. GRID SYNCHRONIZATION

In a three-phase equilibrium system, the RMS voltage is calculated from the source frequency phase voltage (Vsabc) at the source amplitude sample frequency and is expressed as the sample template VSM, sample peak voltage.

$$V_{sm} = \left\{\frac{2}{3}\left(V_{sa}^2 + V_{sb}^2 + V_{sc}^2\right)\right\}^{1/2} \quad (1)$$

The unit vectors in the phase use the AC source phase voltage and the RMS value of the unit vector as shown below.

$$u_{sa} = \frac{V_{sa}}{V_{sm}}, u_{sb} = \frac{V_{sb}}{V_{sm}}, u_{sc} = \frac{V_{sc}}{V_{sm}} \quad (2)$$

The reference currents generated as shown below are taken using the in-phase unit voltage template,

$$i_{sa}^* = I.u_{sa}\ , i_{sb}^* = I.u_{sb}\ , i_{sc}^* = I.u_{sc} \quad (3)$$

Here i is proportional to the value of the filtered source voltage for the corresponding phases. This makes it safe that the source current is sinusoidal controlled. Unit vectors implement important performance over grid connections for synchronization for STATCOM.

The reference circulation is generated as inside the above equation and the actual present day float is detected from the sensor and subtracted to acquire the modern error for the hysteresis-based totally current controller. Therefore, the on / off switching indicators generated for STATCOM IGBT are taken from the hysteresis controller. The switching characteristic for step "sa" is “a” expressed below,

When ia< (i*a - HB), SA = 0
When ia> (i*b - HB), SA = 1

Here HB can get a hysteresis current band, as well as the switching function for SB, SC phase b & c.

XV. SIMULATIONS AND RESULTS

The proposed operation and control scheme is simulated in the power system block set using Simulink,

A. Simulation Without STATCOM

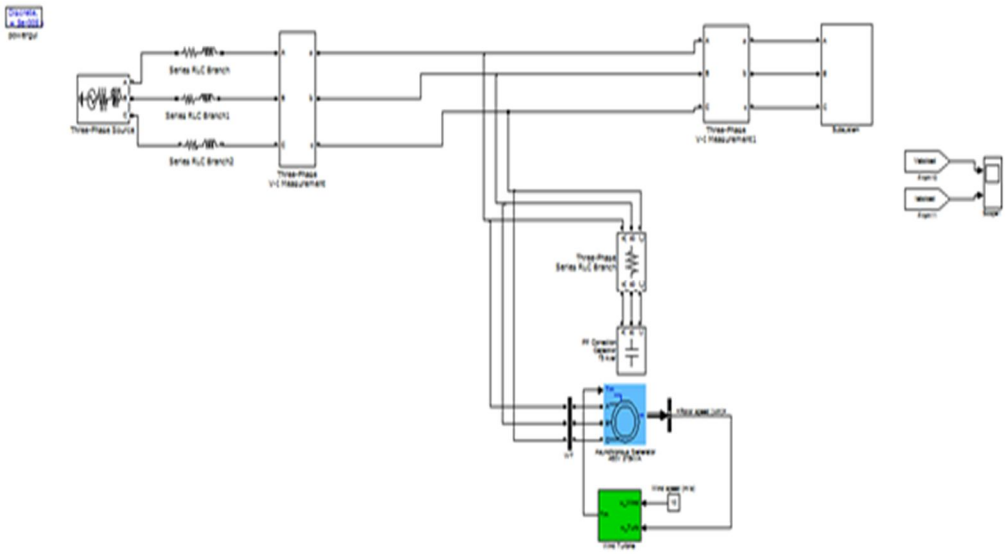

Fig.8 Simulation Without STATCOM

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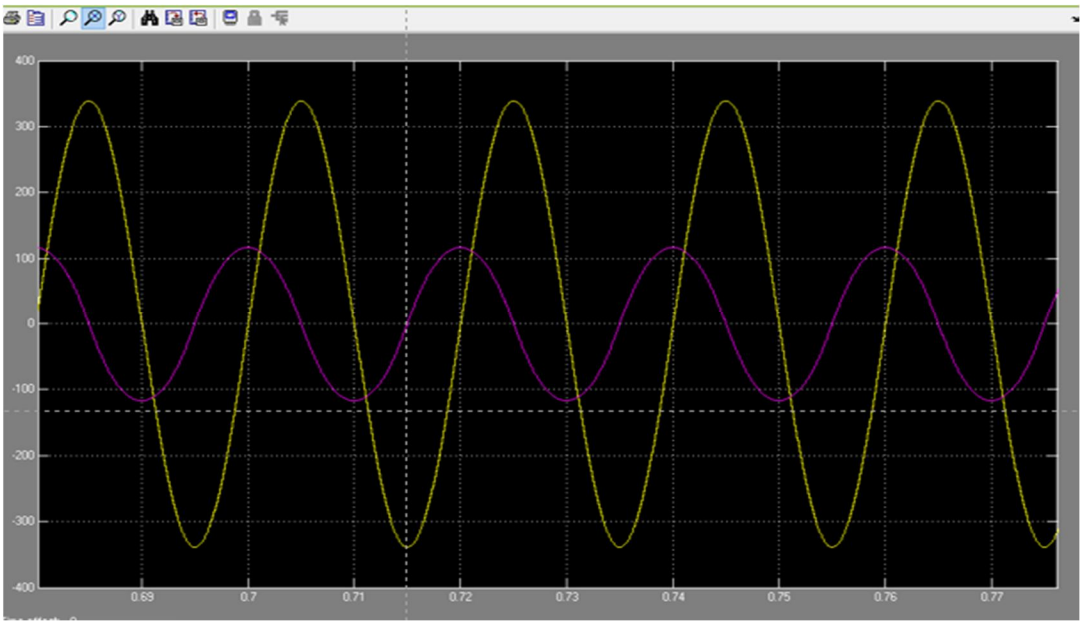

Fig.9 Voltage & Current waveform without STATCOM

B. Block Diagram With STATCOM

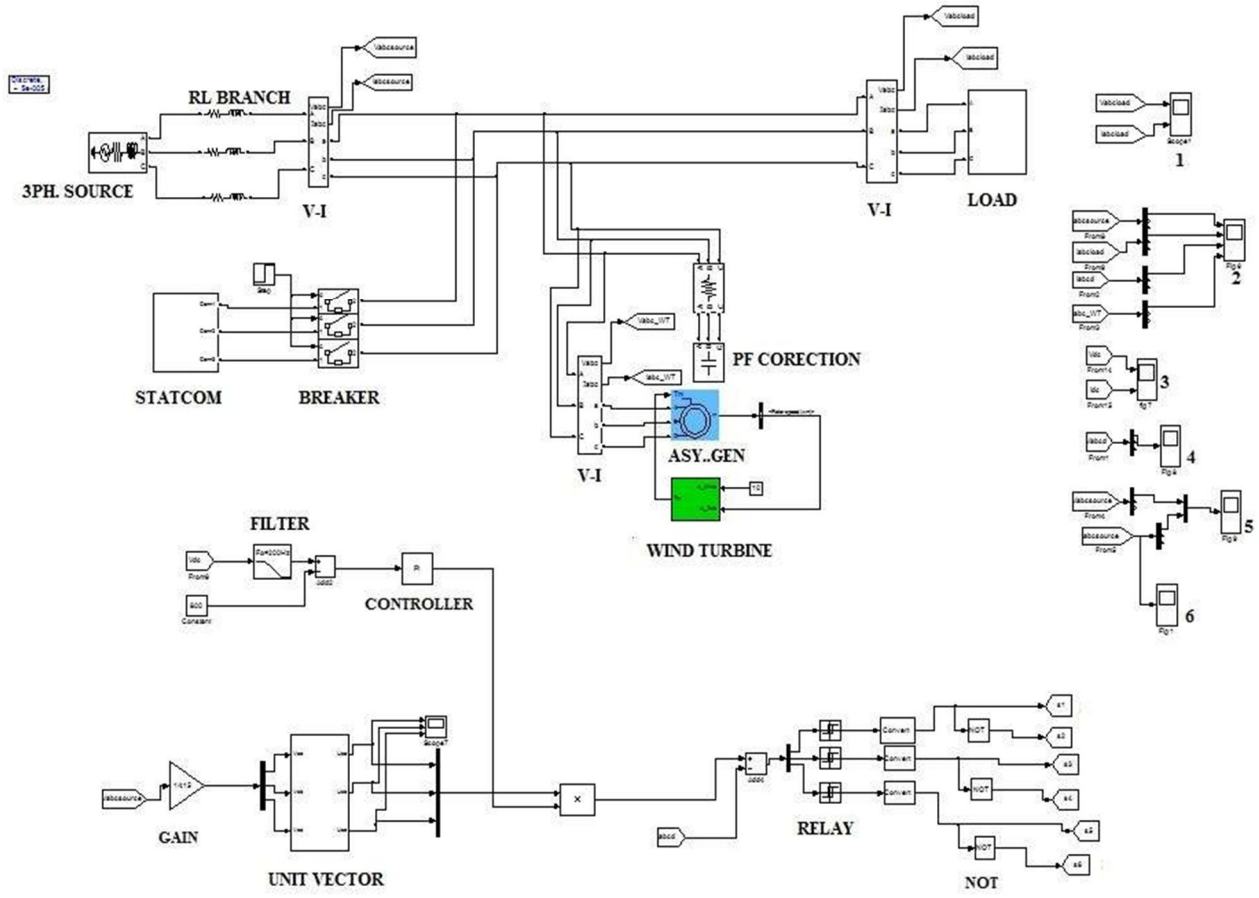

Fig.10 SIMULINK model of the proposed operational scheme.

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C. System Performance

The proposed manipulate scheme is simulated in the power machine block set the use of Simulink. The machine parameters for a given gadget are given in table 1. The device overall performance of the proposed gadget in dynamic situation is likewise displayed.

1) Voltage Source Current Control—Inverter Operation

The three-phase injected contemporary from STATCOM into the grid removes the non-linear load and distortion generated by way of the wind generator. The IGBT-based totally three-segment inverter is connected to the grid through a transformer. The technology of indicators switching from the reference current is simulated within the hysteresis band of 0.08. The slim hysteresis band switching alternative inside the device improves the present day first-class. Manipulate signal of the switching frequency in its working band zero.08 as proven in fig.11. The choice of cutting-edge band depends at the running voltage and the interfacing transformer impedance. Repayment for non-linear load and reactive electricity is furnished by means of the cutting-edge inverter. The controller of this inverter also helps the actual strength transfer from the battery. The 3-segment inverter injected cutting-edge is proven in figure 12.

TABLE I
SYSTEM PARAMETERS

S.N.	Parameters	Ratings
1	Grid Voltage	3-phase ,415V,50 Hz
2	Induction Motor/Generator	3.35 kVA,415V, 50 Hz, P = 4, Speed = 1440 rpm, Rs = 0.01Ω, Rr=0.015Ω,Ls =0.06H,Lr=0.06H
3	Line Series Inductance	0.05mH
4	Inverter Parameters	DC Link Voltage = 800V, DC link Capacitance = 100 µF. Switching frequency = 2 kHz,
5	IGBT Rating	Collector Voltage =1200V, Forward Current =50A,Gate voltage =20V, Power dissipation = 310W
6	Load Parameter	Non-linear Load 25kW.

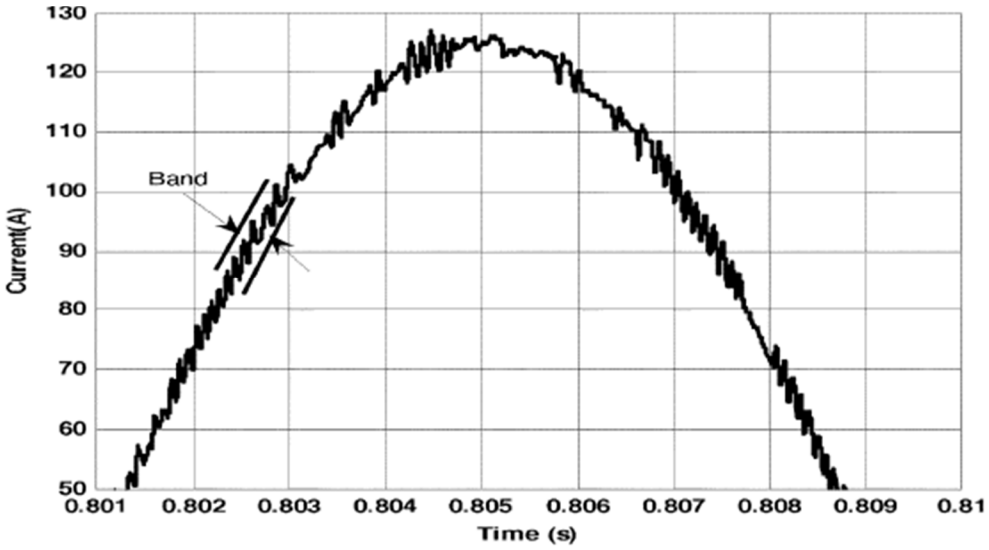

Figure 11. Switching signal and control hysteresis band.

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2) STATCOM—Performance Under Load Variations

The wind power technology device is connected to a linear load bearing grid. System overall performance is measured with the aid of changing the STATCOM to tool time and the manner STATCOM responds to the step exchange command to increase the greater load at 1.0 s. When the STATCOM controller is became on, it begins reducing the reactive demand in addition to the harmonic modern, without converting the parameters of the alternative load circumstance.

Dynamic performance is also finished by way of a step change in load when carried out for 1.Zero seconds. This additional call for is met by the STATCOM compensator. Therefore, STATCOM can control the real electricity to be had from the supply. The result of the supply cutting-edge and the load current are proven in figure 13 (a) and (b) respectively. The result of the cutting-edge injected from the STATCOM is shown in figs. The strength generated from the wind generator at thirteen (c) and percent is proven in discern 13 (d).

The dc hyperlink voltage controls the supply modern-day inside the grid device, so the dc hyperlink voltage is maintained constant across the capacitor as proven in parent 14 (a). The dc link indicates the modern charging and discharge operation with the aid of the capacitor as proven in fig. 14 (b)

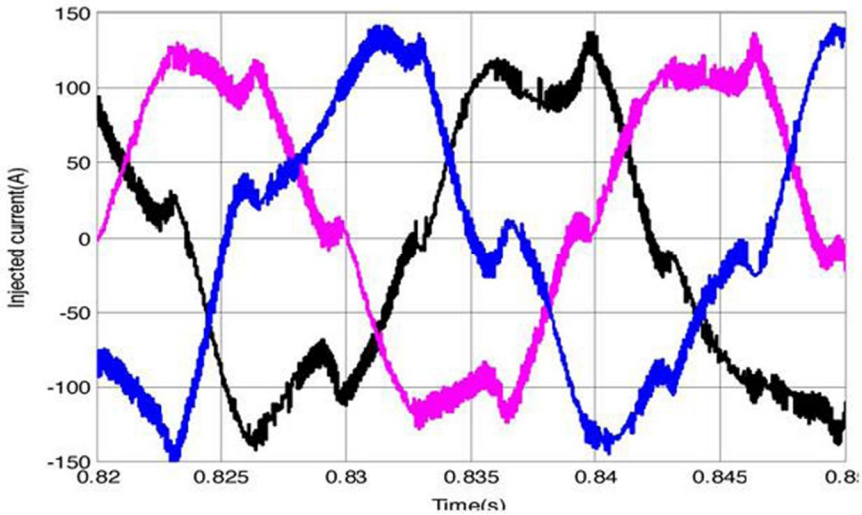

Fig. 12. Three phase injected inverter Current.

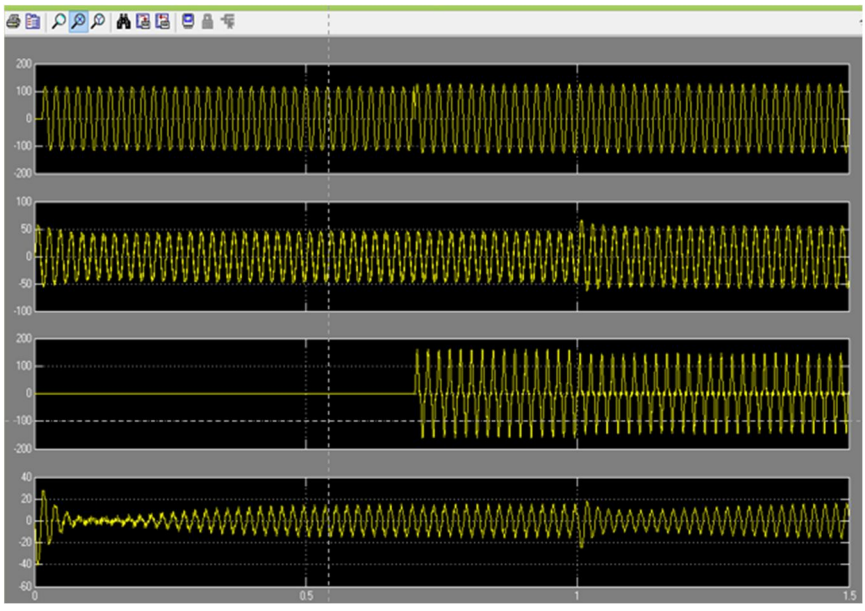

Fig. 13 (a) Source Current. (b) Load Current. (c) Inverter Injected Current. (d) Wind generator (Induction generator) current.

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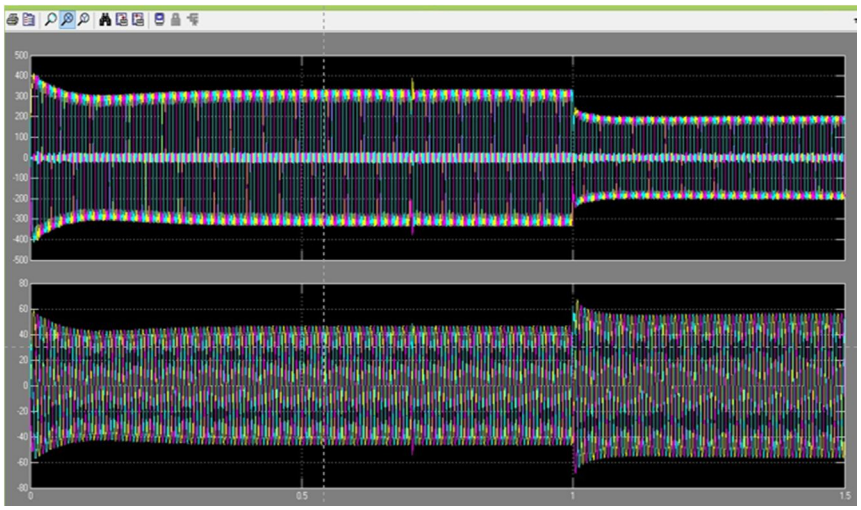

Fig. 14. (a) DC link voltage. (b) Current through Capacitor.

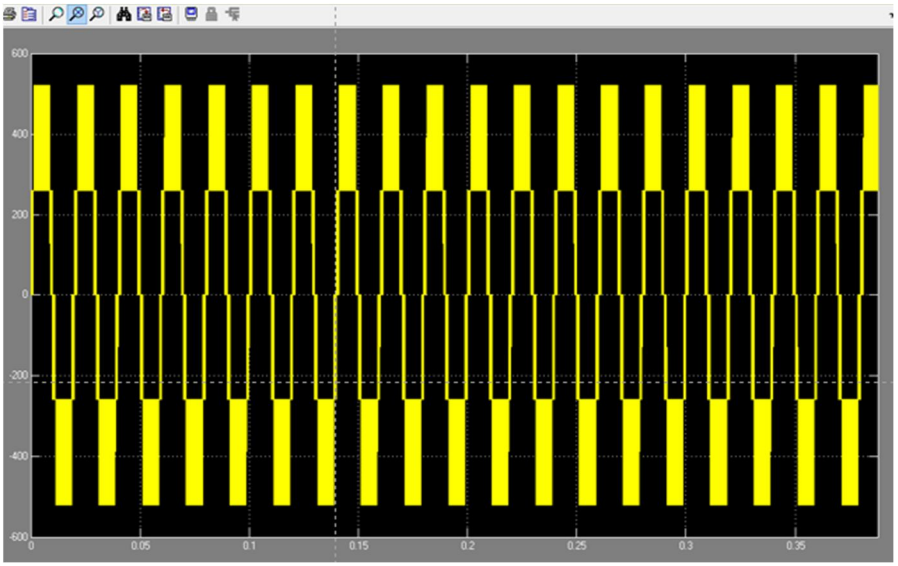

Fig. 8. STATCOM output voltage.

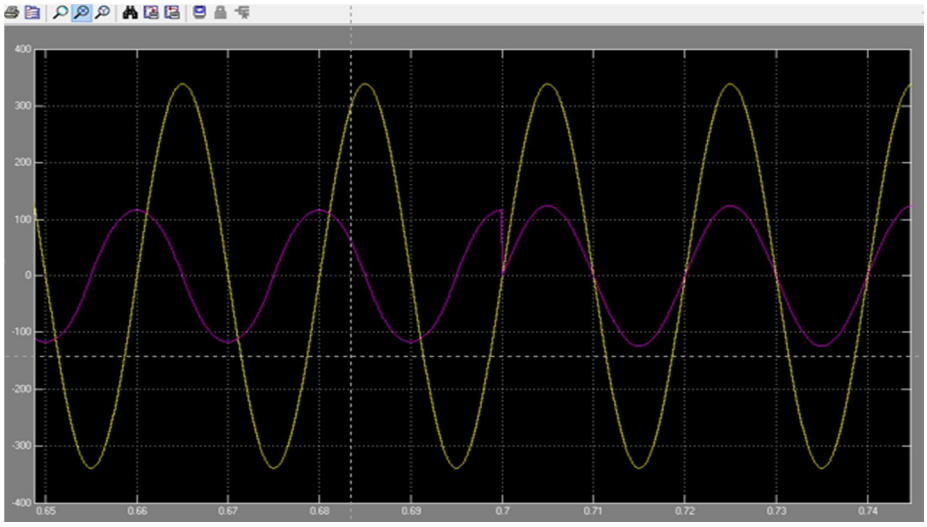

Fig. 9. Supply Voltage and Current at PCC.

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D. Power Quality Improvement

It has been observed that the origin of the supply in the grid is affected by the outcomes of the nelier load and the wind generator, thereby losing the accuracy of the wave on both aspects of the system. The inverter output voltage beneath statcom operation with load version is proven in fig. 15. Dynamic load impacts the inverter output voltage. The present day source with and without statcom operation is shown in fig. 16. While it turns on statcom, it shows that the supply power has a team spirit electricity element. The current waveform became analyzed before and after the STATCOM operation.

The Fourier analysis of this waveform is expressed and the THD of this supply contemporary at p.C without STATCOM is 4.71 %, as proven in fig. 17. The electricity nice development is observed at factor of common coupling, when the controller is in on circumstance. STATCOM is placed into operation at zero.7 s and the modern waveform with its FFT is shown in fig. 18. THD turned into located to be drastically improved and become inside the standards of the usual. The above exams with the proposed scheme will not simplest have better strength first-class, but additionally the capacity to guide load with electricity storage with the aid of batteries.

XVI. CONCLUSION

Paper provides STATCOM -based totally control scheme with progressed energy satisfactory and non-linear load on grid connected wind producing systems. Its outcomes on power first-class and patron and energy consumption are displayed.

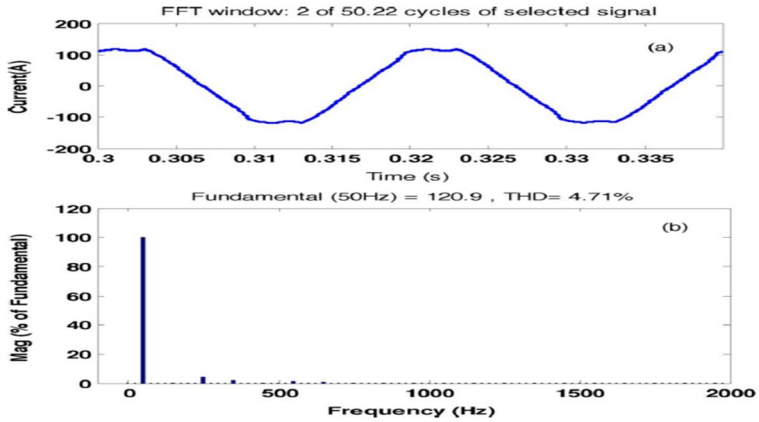

Fig. 17. (a) Source Current. (b) FFT of source current.

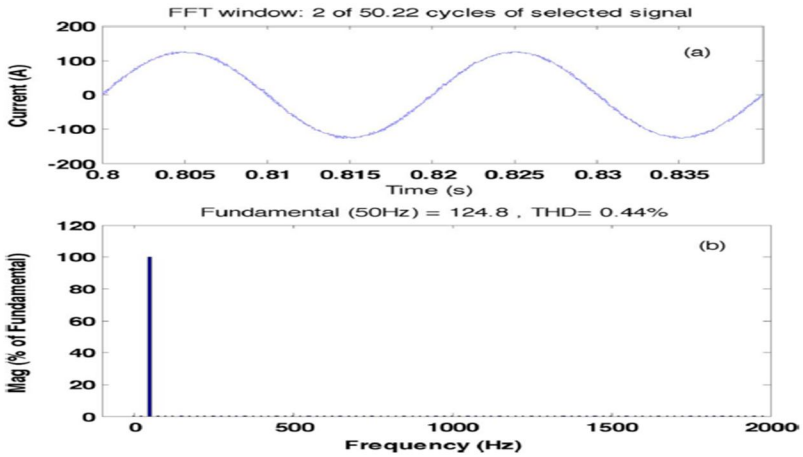

Fig. 18. (a) Source Current. (b) FFT of source current.

The operation of manipulate machine evolved for STATCOM -BESS on MATLAB / Simulink to protect power satisfactory. It has the ability to cancel the harmonic components of the load glide. It maintains the supply voltage and cutting-edge section and helps the reactive power call for the wind generator and load on the computer inside the grid system, consequently giving it the opportunity to boom the transmission line consumption element. Integrated wind technology with BESS and STATCOM showed super performance. Therefore, the proposed scheme inside the grid-connection machine satisfies the energy pleasant.

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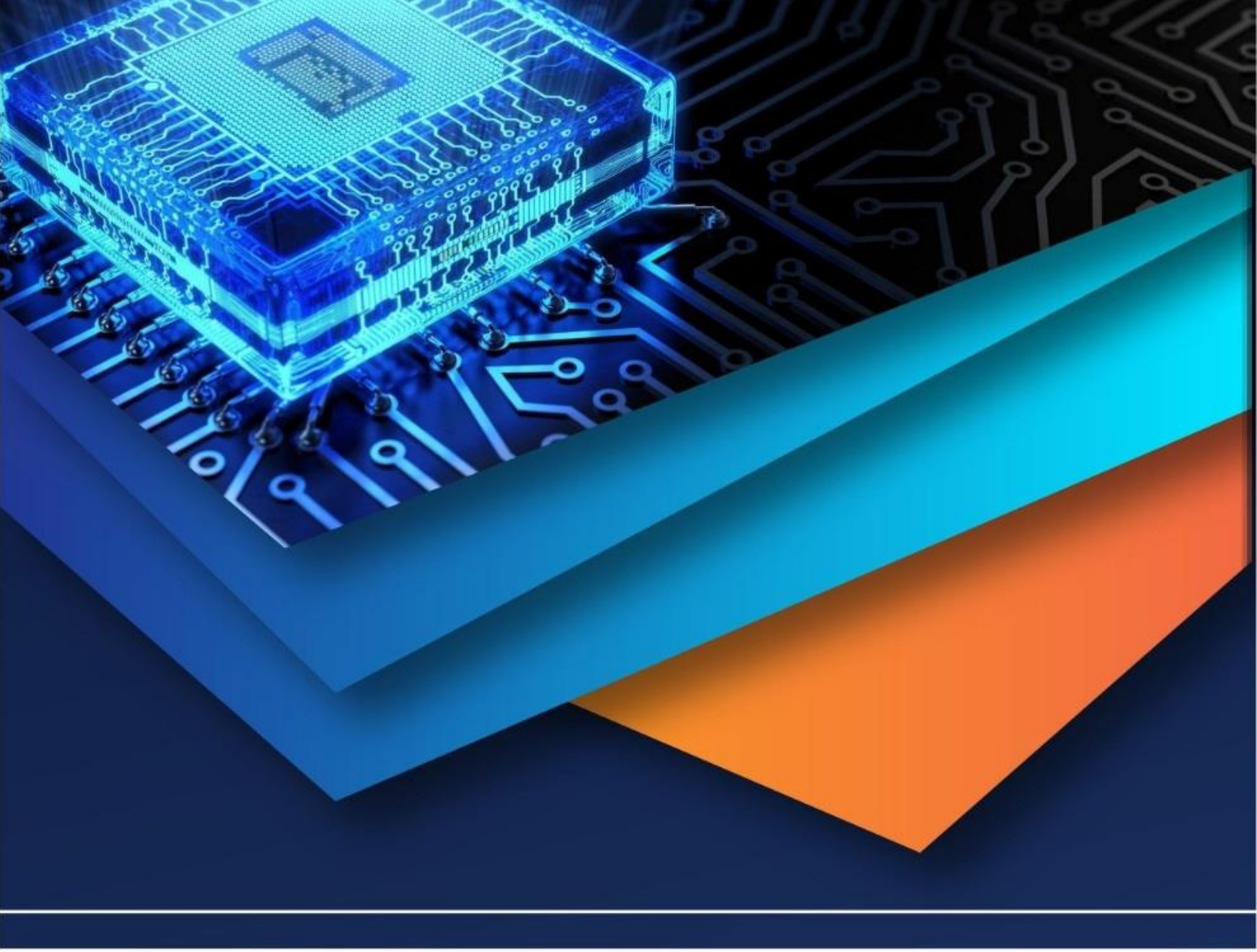

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