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POWER QUALITY ENHANCEMENT IN A SOLAR-WIND HYBRID ENERGY GENERATION SYSTEM CONNECTED TO A STANDALONE MICRO-GRID.

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*Abstract-***The present paper highlights several concerns with solar-wind hybrid energy systems that are associated with microgrids as well as potential improvements. In recent years, there have been more renewable energy options available. Alternatives to the present energy sources, such as renewable energy, are very good. The utilization of renewable energy sources like solar and wind power as a consistent energy source is widespread. The focus of this study is on microgrid connected solar-wind hybrid energy system performance analysis and control. In this paper, the harmonics of the system are controlled by passive filters. Additionally, several control topologies based on power electronics control are needed for the micro grid's integration of various energy sources. A power electronics application is used in microgrids that use a variety of renewable energy sources, however some power quality problems frequently arise. The whole microgrid system's voltage management and voltage stability must be maintained, therefore these power quality issues must be fixed or at the very least reduced. An example of a solar-wind hybrid power system simulation using MATLAB is provided in this study. For micro-grid parameter adjustments, PI-PWM control is included into the MATLAB microgrid simulation. The outcomes of the simulation show that the present THD levels in the grid are less than 5%. The energy storage system also serves as a backup power source in this simulation for power variations brought on by irregular solar and wind power generation in the microgrid.**

*Keywords-***Hybrid energy System, PV Array, Wind turbine, Inverter, Backup Energy storage system, Solar-Wind and Inverter Controller, MPPT controllers, Boost converter, PMSG, Bi-directional dc to dc converter, Control of voltage at dc-link, AC microgrid.**

I. INTRODUCTION

We can all agree that humanity cannot progress into the future without a very large and constant energy source, so energy will continue to be a necessity for humanity[1]. Green energy alternatives to fossil fuels are becoming more popular due to rising energy demand and environmental concerns over these fuels. Due to its advantages in terms of the environment and economy, PV is presently utilized widely as a distributed energy resource in standalone mode[2]. Stand-alone or autonomous power systems are a fantastic solution in distant areas where utilities infrastructure, especially transmission lines, are not difficult to run or establish because of their high cost and/or difficult terrain, etc.[3]. To integrate with the micro-grid with this system, power is generated using solar and wind energy. Due to alterations in the environment, power varies when these two sources are combined in hybrid operation Converters based on MPPT, P&O, and PWM are used to integrate renewable energy sources into the grid as a source of backup power. A stand-alone wind or solar power system can give us constant electricity because they are seasonal. Better characteristics can be provided by passive filters for harmonic correction[4]. The proposed work will result in reduction of various grid-integrated renewable energy resource power quality challenges. The grid current has had its total harmonic distortion levels analyzed. Solar-wind hybrid systems have been studied for grid integration of renewable energy sources to improve power quality. The proposed system faces a number of power quality issues including harmonics, power imbalance, transient and flicker, overvoltage and under voltage, and voltage sag-swell[5]. Addressing power quality

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issues is essential for the micro-grid integrated solar-wind hybrid system to function properly. Connecting scattered generation systems to existing micro power grids can lead to problems with power quality and system dependability, among many other problems. Solar, wind and a backup energy storage system are three different energy sources. They are coupled with converters that transform DC and AC energy into DC outputs. In order to transform DC into AC, the inverter uses the output's controlled DC voltage. A closed-loop system is used, using grid parameters to regulate the inverter[6]. A variety of topologies are available for inverters, including ANN, PI, hysteresis, PWM, fuzzy, and others.

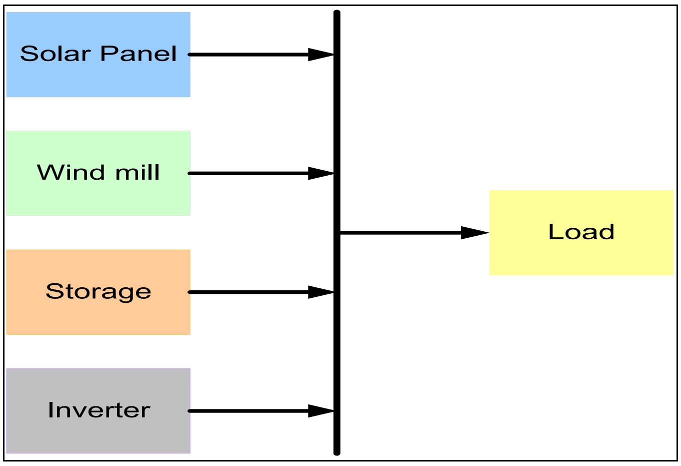

Figure 1.Block diagram of system component.

The Novelty of Proposed Strategies –

1. Controlling and managing reactive electricity in accordance with the needs of the AC grid.
2. System for storing hybrid energy with a controller.
3. The output of active and reactive power should be improved.
4. Look up the produced current THD.

This paper emphasizes the study of solar-wind hybrid power systems and the necessity of using renewable energy sources to examine and manage each of its component parts. This paper describes a number of issues that arise from poor grid quality and adversely affect hybrid energy systems connected to micro-grids. Harmonics of the system are minimized by passive filter type operation. In addition, the power quality has been improved by using the System Component Controller. Table 1 provides some tabulated references along with a backdrop of the suggested topology and control.

Micro grid element	Method	Main Contribution	Ref.
PV-Diesel Generator-BESS-Load	Control DC Micro-grid	Adaptive Backstopping	[7]
PV-Wind-BESS-Residence	Energy Management	Two Low Complexity FLC	[8]
PV-Wind-BBSS	Energy Management	Super twisting Fractional Order	[9]
PV-Wind-BBSSSOFC-Loads	Coordinated Control	Two feed Back Control Loop and	[10]

		Feed Forward Control Loop	
PV-BBSS-Load	Energy Management	Adaptive droop control	[11]
ELDC+DC Load (House)	Distribution Voltage Control	FLC + Gain scheduling	[12]
Wind-BBSS-SCFOSC	Energy Management + Wind system control	DRPC with FLC + Multilevel Converter + DC Control	[13]
Wind-PV-BESS Loads	Energy Management + System Control	Component Controllers and common DC link + Passive filter	Proposed strategy

Table 1. Analysis of the suggested strategy in comparison to current references.

Needs of Hybrid energy system –

The power plant can produce more power and is better off with less reliance on a single source. The use of solar and wind energy must be maximized because these sources are now receiving the majority of the world's attention. The solar PV panels and wind turbines in this hybrid plant can both produce power and feed it into the grid, much like previous hybrid plants. It is projected that the number of hybrid plants in India would increase with a target of 10GW from such plants by 2022 and support from the national and numerous state governments. It's crucial to comprehend the primary reasons for the necessity of hybrid plants before delving into their technical aspects. Below is a list of its benefits:

<u>Supplemental power generation</u> -This hybrid plant's main benefit is its capacity to provide supplemental electricity. Solar power plants generate electricity during the day, but wind power plants often generate (more) electricity at night and in the evening.

<u>Increased capacity utilization factor</u> -The capacity utilization factor is the ratio of an energy plant's actual production to its maximum output when it is running (24 hours per day, 365 days per year). Due to sun availability restrictions, the CUF of a solar power plant ranges from 16 to 21 percent. Between 20 and 26 percent can be found in the CUF (locational variation of wind at various elevations) of a wind generating facility. This indicates that between 74 and 84 percent of the time, the plant is not producing any energy. However, studies demonstrate that the CUF for hybrid power plants can be achieved in the range of 35% to 50%. (in some cases). By reducing the power plant's LCOE, this suggests that a higher power per watt may be generated, increasing plant productivity (compared to the LCOE of the individual power plant).

<u>Use of transmission capacity increasing</u> -Facilities for producing renewable energy at a utility scale are frequently located rather distant from load Centre's. Accordingly, it follows that enough transmission infrastructure is required to deliver such power to load Centre's. The fact that such transmission infrastructure is underused is readily seen from the individual power generation curves of solar and wind generating installations. A HV transmission substation must be used to the fullest extent possible because it costs tens of lakhs to build one. A solar-wind hybrid plant can be useful in this situation. Due to the complimentary nature of its generation, the hybrid plant may use this infrastructure more effectively than an individual plant.

<u>Efficient use of land</u> -The solar wind hybrid energy plant is capable of making effective use of the available land area. A utility-scale power plant needs approximately 4-6 acres of land per megawatt. Although the size and power output of a wind turbine can vary, on average it takes up between 10 and 50 acres per MW (source: NREL) (wind turbines occupy only 5 percent of the area). Hybrid plants may save 10 to 30 percent more land per MW than conventional ones. Additionally, other supplemental costs can be decreased by using the same transmission infrastructure that is used to evacuate the power.

II. PROPOSED METHODOLOGY

A. Wind-Solar Hybrid Energy System-

One of the most current techniques for power system integration is the hybrid energy system. A hybrid energy

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system is, according to its definition, "a mix of two or more renewable energy sources utilized together to provide increased system efficiency and greater system balance in the energy system"[14]. Most hybrid energy systems integrate a variety of sources, including solar panels, wind turbines, and other technologies. Due to hybrid operation the load will always get power as well as separate electronics components manage to conduct and store power in hybrid system and converter in hybrid system manages power to grid. The output of a wind turbine powers an impeller synchronous generator. Synchronous generator with permanent magnets the rectifier uses the AC output and transforms it into DC. As a result of solar panels' output being unstable owing to temperature and radiation variations, DC to DC boost converters provide the voltage of the final product. Intended hybrid systems incorporate a solar system coupled with an MPPT controller to enhance power tracking. A buck-boost converter is used to keep the DC voltage steady. The bi-directional buck boost converter mechanism adjusts to charge or discharge the battery based on voltage.

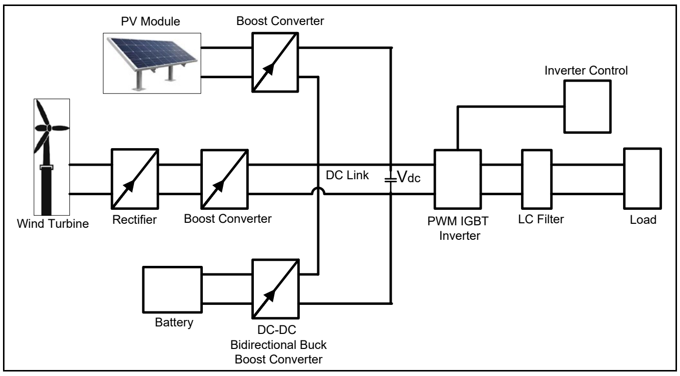

Figure 2.Hybrid solar-wind energy generation system schematic block diagram.

Solar PV array- Solar energy is turned into electrical energy using solar panels[15]. A solar cell is essentially a photovoltaic cell with a p-n junction[16]. PV array modelling has been done using a single PV cell diode[17]. Since a perfect solar cell does not exist, the model also includes a shunt resistance and a serial resistance section to mimic an ideal solar cell working in tandem with a diode[18]. The non-linear current-voltage properties of solar cells are impacted by temperature and solar radiation:

$$I = I_{ph} - I_o\left(e^{\frac{q(V+IR_s)}{nkT}} - 1\right) - \frac{V+IR_s}{R_{sh}} \quad (1)$$

Where,
I_{ph} = Light Generated Current
I_o = Saturation Current
Q = Electron Charge (1.607×10^{-19} in Coulomb)
V=Terminal Voltage of the cell
I_d = Diode Current
Is_h = Shunt Current
K = Constant of Boltzmann (1.3806503×10^{-23} in K / J)
T = Temperature (298.15 in K)
R_s = Series Resistance
R_{sh} = Shunt Resistance

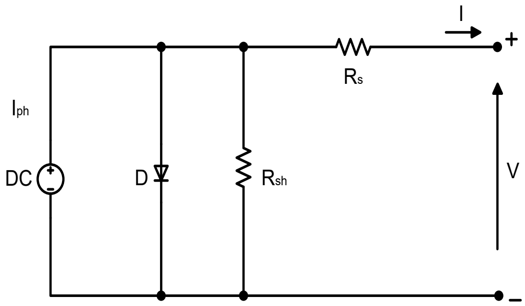

Figure 3.Circuit diagram of PV array.

Wind Turbine - A wind turbine is a specific type of equipment that converts kinetic energy, primarily from wind, into electrical power[19]. An integrated permanent magnet synchronised generator powers the wind energy conversion system. Turbines that generate mechanical energy are propelled by the kinetic energy of the wind[20]. The kinetic energy per unit mass, 1/2 V^3, and the mass flow rate can be multiplied to define the wind power, Pw, which can then be represented as:

$$P_w = 0.15\rho AV^3 \quad (2)$$

Where,
V = Average Wind Velocity (m / s)
A = Area
ρ = Air density (kg / m^3)

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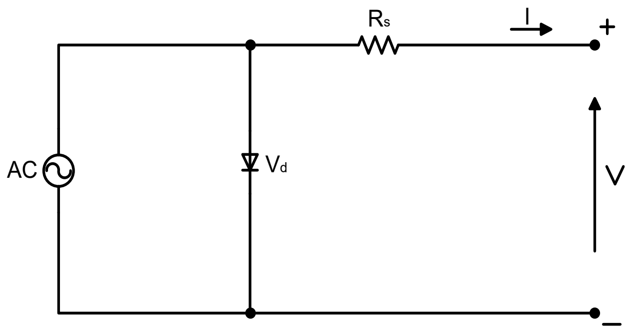

Figure 4.Circuit diagram of Wind Turbine.

Inverter Controlling for Hybrid System- We can convert DC electricity into AC power using an inverter circuit at any desired output voltage and frequency[21]. While other types of controllers are also utilised, the proportional-integral controller and the hysteresis controller are the two that are used in System the most commonly. The PI-controller is used in this modelling. The PI controller maintains the voltage in DC, which serves as the standard value for the DC voltage. The output voltage and currents are controlled by the PI controllers inside the inner control loops as well as the dc voltage controller outside the loop[22]. The error reduces as the output is regulated until it reaches the reference value. An integral plus proportional controller of fractional order is used to integrate the controls for the internal current and external voltage. The concepts proportional action and integral action are included in the controller. The error is multiplied by a constant to generate the controller gain constant, which is then used to determine the proportional term output. Numerous current and voltage harmonics afflict micro-grid connected systems. The use of active power filters, static variable generators, and passive filters can all be used to overcome these issues.

Backup Energy storage System and Electrolizer- Chemical energy is converted into electrical energy, water, and heat in a fuel cell, an electrochemical device[23]. To achieve the necessary nominal voltage, batteries in a hybrid system are interconnected in series[24]. Batteries are a key component of solar-wind hybrid generation systems that use battery energy storage for reducing output fluctuations and improving output quality. The system control also focuses on the battery unit parameters, requiring that they maintain within predetermined limits. The battery controller electrolyzer is used to avoid the battery units from being under, over, or over discharged, which would negatively affect their performance and longevity[25].

Filter- We can make hybrid, passive or active filters. However, the idea of an active filter is not that simple. Therefore for the purposes of this research a passive filter should reduce harmonics. If we just want to build a passive filter, we must first determine the harmonic presence of the circuit using MATLAB's FFT analysis tool, and then we can build a tuned LC filter based on that information. A filter that is parallel to the spot source and resonates at the harmonic frequency is something you can build (or load, depending on where you plan to reduce harmonics). In Simulink's Power System Toolbox in MATLAB, this should be relatively simple. Passive filters can operate without power supply. Since the output of passive filters fluctuates depending on the load, they are unable to increase the gain of the signal.

$$Capacitance\ impedances = \frac{1}{jwc} \quad (3)$$

$$U_0 = \frac{U_i}{R+\frac{1}{jwc}} \cdot \frac{1}{jwc} = \frac{U_i}{1+jwRc} \quad (4)$$

$$A_u = \frac{U_0}{U_i} = \frac{1}{1+jwRc} \quad (5)$$

$$|A_0| = \frac{1}{\sqrt{1+(WRC)^2}} \quad (6)$$

$$\emptyset = -arctanWRC \quad (7)$$

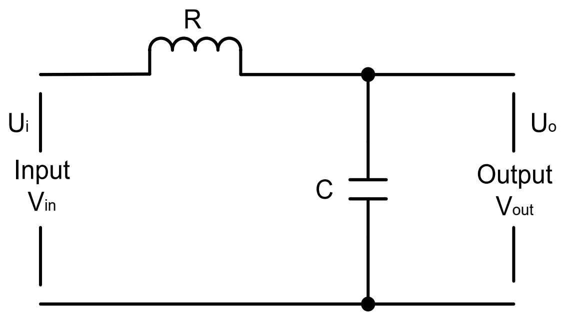

Figure 5.Circuit diagram of Passive Filter.

System Controllers- This system uses the following formula to calculate the 3-phase instantaneous real power and reactive power. Only a balanced, harmonic-free system may use this equation.

$$P = V_a I_a + V_b I_b + V_c I_c \quad (8)$$

$$Q = \frac{1}{sqrt(3)}(V_{bc} I_a + V_{ca} I_b + V_{ab} I_c) \quad (9)$$

Total Harmonics Distortions- This system uses the level of Improve System Current THD is measured as well as Current and Voltage THD.

$$THD = \frac{Uh_{rms}}{U1_{rms}} \quad (10)$$

Where,

Uh_{rms} = rms value of the Harmonics.

$Uh_{rms} = sqrt(U_1^2 + U_2^2 + U_3^2 + \cdots)$

$Uh_{rms} = sqrt(U_{rms}^2 - U_0^2 - U_{1rms}^2)$

U_{1rms} = rms value of the fundamental component.

U_0 = DC Component = mean value.

U_{rms} = True rms value including (harmonics + DC component).

B. System Modification -

Wind, PV, battery based renewable energy sources powered hybrid AC microgrid is implemented in this model. MPPT controller (torque based) of a wind turbine and P&O operated

MPPT of PV are incorporated to achieve their better utilizations. PMSG is used to generate electrical power from wind turbine. By sustaining the charging and discharging of the battery, a bidirectional DC to DC converter is used to control the voltage at the dc-link. The bidirectional dc to dc converter's reference dc-link voltage is produced by the PV system's P&O algorithm, hence the same converter may also serve as the PV system's MPPT converter. The AC microgrid is established by PV, wind and battery, hence the battery can acts as either generation or load according to power difference between generation and load. An inverter controller is developed to regulate voltage at point of common coupling during changes in wind, load, etc. The inverter can also maintain constant or balanced voltages at PCC during unbalanced load.

Role of Controllers - MPPT controllers are used for wind power systems in solar wind hybrid energy systems, which reduce system fluctuations, transients, and ripples. P&O algorithm is used for PV fluctuation reduction. In addition control of the inverter and LC filters are used to reduce system harmonics and maintain power.
All of the power produced from renewable sources must be concentrated on a better condition of electricity without distortion, and the working model relies on a hybrid energy generating technology that combines the solar system and the vertical axis wind turbine system. The system power issue helps us to understand why a variety of topologies have been presented and have successfully improved the power quality.

Fluctuations: Various types of converter topologies are used in these systems to reduce the fluctuations. Such as Rectifier, Buck-Boost Converter, DC-DC Bidirectional Converter.
Transient: The system DC voltage is always taken as 660V and the power transient loss is less than one percent of the period.
Voltage Ripple: The DC to DC converter topology provides a ripple-free output.
Harmonics: Harmonics reduction by LC filter with passive filter using inverter controller.

C. System Configurations -
In the simulation study of the Solar-Wind Hybrid Energy system, the wind turbine and Backup Energy Storage System serve as the Solar System Model's backup energy systems. Every solar panel is coupled to a boost converter and the P&O algorithm. Whatever the time of day or the climate, the boost converter in the system is programmed with the voltage regulation and voltage stability to continuously adjust the PV voltage to create the greatest electricity. A solar system model using P&O algorithm is depicted in using
MATLAB.
In the MATLAB modelling of the wind power plant, the wind generator and PMSG system are depicted. The rectifier converts the PMSG's output voltage from AC to DC. For the output DC voltage to operate as efficiently as possible, the DC to DC converter sets the output DC voltage at 660V. In order to maintain a consistent DC voltage, the output of solar PV and wind turbines is regulated at 660V DC. The DC-DC converter's control system for a wind turbine is used.

S. No.	Parameter	Value
1.	Solar Panel	
	Short Circuit Current	8.01
	Open Circuit Current	36.90
	Current at Pmax.	30.3
	No. of modules connected in series	22
2.	Wind Turbine	
	Nominal mechanical output power	8.5e3
	Base power of the electrical generator	8.5e3/0.9
	Base wind speed	12

	Max. power at base wind speed	0.8
	Base rotational speed	1
	Pitch angle beta to Display Wind turbine power characteristic	0
3.	Inverter	
	Snubber Resistance	500
	Snubber Capacitance	0.8
	Ron	1e-3
	Forward Voltages	0
4.	LC Filter	
	Inductance	40e-4
	Capacitance	9.49e-6
5.	Load	
	L1	500
	L2	5e3
	L3	7e3

Table 2.Fixed parameter configuration for MATLAB Simulation model.

Pulses trigger for charging and discharging the converter are included in the Backup Energy Storage System simulation control. When there is excess power generated, the converter's primary function for battery storage is to charge the backup energy storage system. When battery power is needed, the converter operates in discharging mode.
Three Different Kind of Loads- Initially about 500w load is added to this solar-wind micro grid connected hybrid energy system, the effect is that a small current of electricity flows through the load. This gives poor quality of voltage as the filter is performing very little current. After about 0.5 second 5kw load is connected then in that case system generation is more and also after about 1 second 7kw load is connected then in that case system generation is little more.

Table 3.Applied System Load Comparisons.

Parameter	Load 1	Load 2	Load 3
Nominal phase to phase voltage	400	400	400
Nominal Frequency	50	50	50
Active power	500	5e3	7e3
Inductive reactive power	0	0	0
Capacitive reactive power	0	0	0

III. RESULT ANALYSIS& DISCUSSION

Power-The PV and Windpower Capacity 4.73KW, 6.5KW respectively. For more voltage Increase more PV module and more power rating it can making in parallel connection. Didn't used any MPPT Controller but used P&O algorithm. Due to the variable loads of 500W, 5KW, and 7KW, the output power of the solar-wind hybrid power system in this instance is higher than the reference power, 660V.

Table 4.Hybrid solar wind energy system power generating.

Parameter	Case1	Case2	Case3
Wind	6400	6400	6400
PV	4700	4700	4700
Battery	$-1*10^4$	-5000	2000
Load	500	5000	2000

Direct Current-The DC voltage of the solar and wind hybrid energy system is completely dependent on the fixed parameter with the power generation is-

Table 5.Solar-wind hybrid system DC output.

Parameter	Input(Reference power)	Output
Wind	500	400
PV	250	660
Battery	320	320

Active Current- Hybrid power system output is higher than the AC reference power. It depends on the differential load given to it-

Table 6.Solar-wind hybrid system AC output.

Parameter	Input (Reference Power)	Output
Voltage phase	1	1
Voltage Load to Load	660	560
Voltage phase rms	320	230

The current part contains the conclusions drawn from the system's simulation results. The simulation's findings indicate that both the solar PV and wind converter's DC output voltages are set at 660V DC. The simulation result displays the DC output voltage that is constantly adjusting for the 660V DC voltage. This section also illustrates the micro-grid side AC output voltage.

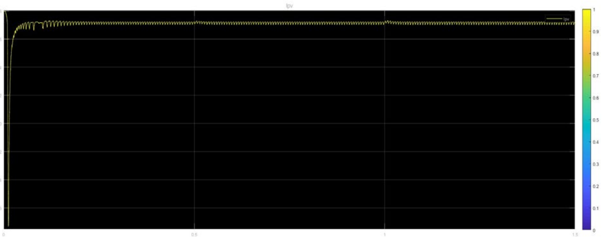

Figure 6.Solar Energy Current DC output.

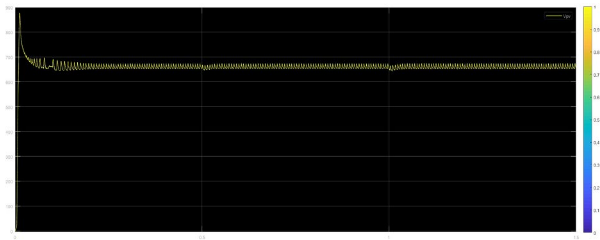

Figure 7.Solar Energy Voltage DC output.

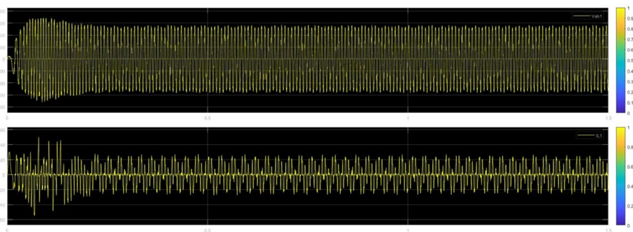

Figure 8.Wind Energy Voltage-Current DC output.

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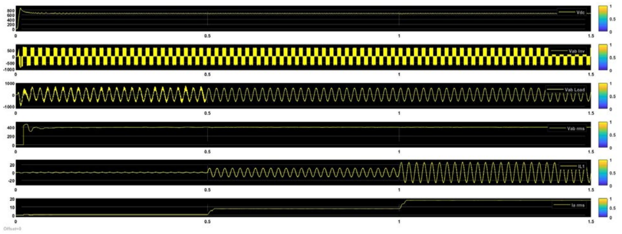

Figure 9.Grid Side Output AC voltage.

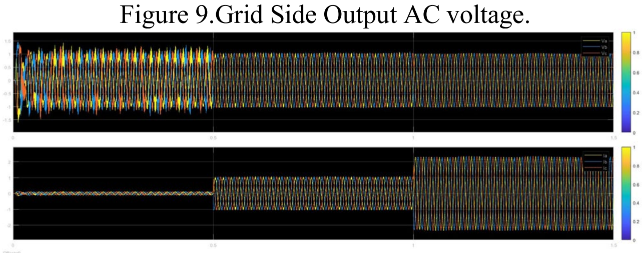

Figure 10.Solar-wind Hybrid Energy system Current-Voltage Power Unit.

THD measurement - The value of THD is determined via FFT analysis from the simulated output waveform of current and voltage. The outcomes of the simulation show that grid current's THD values 4.90% respectively.

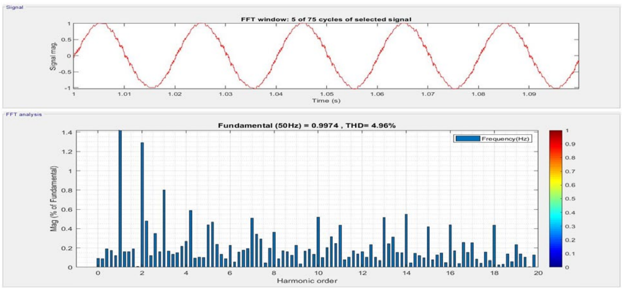

Figure 11.THD measurement for micro grid current.

ANALYSIS-

Wind Output: Voltage Ripple

According to the wind output power the voltage ripple is after initial time period reduced and constant with the load increasing.

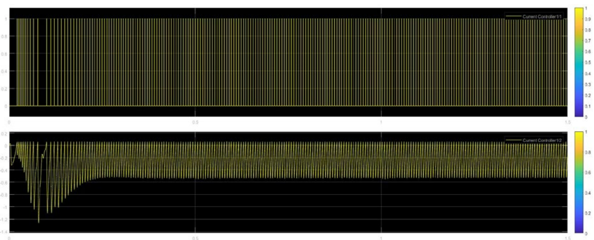

Figure 12.Voltage ripple reduction in Wind DC output.

SOLAR OUTPUT: VOLTAGE FLUCTUATION

According to the solar generation, the fluctuation disturbance occurs only when the load is added and after some time the fluctuation stabilizes with the same load.

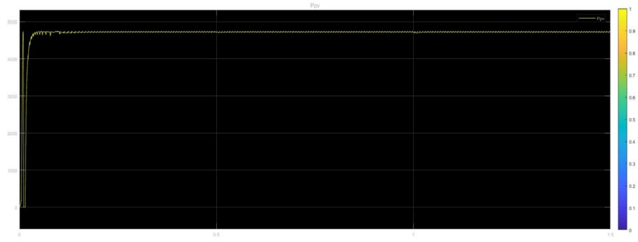

Figure 13.Voltage Fluctuation reducing in Solar DC output.

BATTERY OUTPUT: CHARGING AND DISCHARGING

A bi-directional DC-DC converter is used to power the battery; it has two switches, one of which is used for charging and the other for discharging. With the different Loads 500W, 5KW, 7KW respectively battery is discharging.

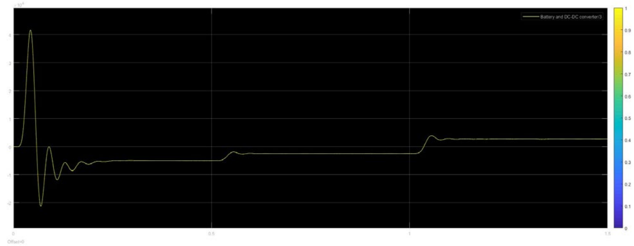

Figure 14.Battery discharging in DC Bidirectional output.

INVERTER OUTPUT: HARMONIC REDUCTION

According to Inverter output increasing the load makes the output power harmonic free and with increasing the load we need more power, so increasing the load causes the battery to discharge.

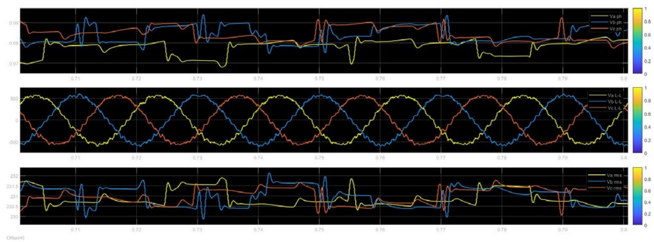

Figure 15.Harmonic Reduction in Inverter AC output.

IV. CONCLUSION

Studying the demand for solar-wind hybrid power systems is the goal of this Research. This study has focused on the control of the system and its many parts. This Research paper explains a number of issues that arise from poor grid quality and adversely affect hybrid energy systems connected to micro-grids. The harmonics of the system are minimized by passive filter type operation. Also, the power quality has been improved by using the system component controller. The suggested hybrid power system with micro-grid integration has been studied using MATLAB simulation. The simulation results demonstrate that the current THD values for the grid are 4.90%, respectively, and which are well within the limits of international standards. Grid side regulating parameters can be used to measure how well the hybrid system is working. FACTS devices can be used in this research as a new approach to address a variety of power quality issues.

NOMENCLATURES

I_{ph} Light Generated Current
I_o Saturation Current
Q Electron Charge (1.607×10^{-19}in Coulomb)
V Terminal Voltage of the cell
I_d Diode Current
I_{sh} Shunt Current
K Constant of Boltzmann (1.3806503×10^{-23}in K / J)
T Temperature (298.15 in K)
R_s Series Resistance
R_{sh} Shunt Resistance
V Average Wind Velocity (m / s)
A Area
ρ Air density (kg / m^3)
Uh_{rms} rms value of the Harmonics.
Uh_{rms} $\mathrm{sqrt}(U_1^2+U_2^2+U_3^2+\cdots)$
Uh_{rms} $\mathrm{sqrt}(U_{rms}^2-U_0^2-U_{1rms}^2)$
U_{1rms} rms value of the fundamental component.
U_0 DC Component = mean value.
U_{rms} True rms value including harmonics and DC component.

V. REFERENCES

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