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Performance Analysis of Hybrid Solar Module and Wind Turbine Using Matlab

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Abstract- The most popular renewable energy technology is Hybrid Power System consisting of wind and solar energy sources because the system is reliable and complimentary in nature. Wind / PV Hybrid system is commonly used in Distributed Generation (DG). This project proposes a new solution for improved voltage stability with quality power output. In this system voltage output from Wind Energy Conversion System(WECS) and Photo Voltaic Panels are given to separate DC-DC converters are independently controlled and connected to a common DC bus and from there it is inverted. In the proposed controller the voltage stability is obtained with a PI controller. The implementation of the proposed method is done by using MATLAB Simulink platform. The performance of the suggested coordinate control system is analyzed by comparing the computer simulation results with and with out using controllers and it shows that the proposed system is more efficient.

Index Terms- Solar energy,Wind energy,MATLAB Simulink,DC-DC Converter

I. INTRODUCTION

Hybridizing solar and wind power systems capitalizes on their complementary nature, mitigating the limitations of individual technologies and enhancing overall system reliability and efficiency. By integrating multiple renewable energy sources, hybrid systems can better match energy supply with demand profiles, optimize resource utilization, and improve grid stability. Moreover, hybrid systems offer enhanced resilience to fluctuations in weather conditions, ensuring consistent power generation throughout the day and across seasons. Against this backdrop, the investigation into hybrid power systems integrating solar modules and wind turbines assumes paramount importance. Through advanced simulation techniques facilitated by MATLAB, it becomes feasible to explore the dynamic interactions, performance characteristics, and optimization strategies of such hybrid systems under diverse operating conditions. The primary objective of this investigation is to evaluate the performance of hybrid power systems combining solar modules and wind turbines using MATLAB simulations. Specific objectives include characterizing the individual behavior of solar and wind energy sources, investigating the synergistic effects of integrating solar and wind energy sources within a hybrid system, assessing the impact of system configurations on the overall performance and economic feasibility of hybrid power systems, and identifying key challenges, opportunities, and techno-economic considerations associated with the deployment of hybrid solar-wind power systems. The methodology employed in this investigation entails data collection and pre-processing, system modelling and simulation, performance evaluation, sensitivity analysis, and optimization. Data collection involves gathering meteorological data, including solar irradiance, wind speed, and temperature, from reliable sources such as weather stations or databases. Preprocessing involves quality control, filtering, and temporal aggregation to ensure data accuracy and compatibility with simulation requirements.System modelling entails developing mathematical models and algorithms to represent the behaviour of solar PV modules, wind turbines, energy storage systems, and power electronics within the hybrid power system. MATLAB provides a versatile platform for designing, simulating, and analyzing complex energy systems, enabling dynamic simulations under varying environmental and operational conditions. Performance evaluation involves conducting comprehensive assessments to quantify key metrics such as energy yield, capacity factor, system efficiency, and levelized cost of energy. Comparative analyses may involve varying system configurations, control strategies, and geographic locations to identify optimal design parameters and operational regimes. Sensitivity analysis and optimization techniques are employed to assess the sensitivity of system performance to input parameters and optimize system design parameters and control strategies for maximizing energy production, minimizing costs, or achieving other predefined objectives. The findings of this investigation hold significant implications for the advancement and deployment of renewable energy technologies, particularly hybrid solar-wind power systems. By elucidating the performance characteristics, operational dynamics, and techno-economic viability of such systems, this research contributes to informed decision-making by policymakers, energy planners, investors, and stakeholders. The insights gained from MATLAB simulations facilitate the identification of optimal system configurations, deployment strategies, and policy interventions to promote the widespread adoption of hybrid renewable energy solutions. Moreover, the investigation underscores the pivotal role of advanced simulation tools in accelerating innovation, improving system design, and facilitating the transition towards a sustainable energy future. This paper is organized into several sections, each addressing specific aspects of the investigation, including the introduction, literature review, methodology, results and discussion, and conclusion.

II. SOLAR SYSTEM

The continuous increase in the electrical energy with the clean environment needs the decentralized renewable energy production. The increasing energy consumption may overload the distribution grid as well as power station and may cause the negative impact on power availability, security and quality. The only solution to overcome this problem is integrating the utility grid with the renewable energy systems like solar, wind or hydro. The grid can be connected to the renewable energy system as per the availability of renewable energy sources. Recently the solar power generation systems are getting more attention because solar energy is abundantly available, more efficient and more environment friendly as compared to the conventional power generation systems such as fossil fuel, coal or nuclear. The PV systems are still very expensive because of higher manufacturing cost of the PV panels, but the energy that drives them -the light from the sun- is free, available almost everywhere and will still be present for millions of years, even all non-renewable energy sources might be depleted. One of the major advantages of PV technology is that it has no moving parts. Therefore, the PV system is very robust, it has a long lifetime and low maintenance requirements. And, most importantly, it is one solution that offers environmentally friendly power generation.

The disadvantage of the PV system is that it can supply the load only in sunny days. Therefore, for improving the performance and supplying the power in all day, it is necessary to hybrid the PV system into another power generation systems or to integrate with the utility grid. The integration of the PV system with the utility grid requires the PWM voltage source converter for interfacing the utility grid and results some interface issues. A prototype current-controlled power conditioning system has been developed and tested. This prototype sources 20 kW of power from a photovoltaic array with a maximum power point tracking control. The disadvantage of this system is the need of high bandwidth current measurement transducers (dc to several times the switching frequency), and the need for relatively high precision in the reference signal generation. Hence, this increases the cost of the system. The inverters suitable for the PV system are central inverters, string inverters, Module integrated or module oriented inverters, multi string PV inverter with new trends has been described . If these solar inverters are connected with the grid, the control of these inverters can be provided using the phase locked loop . The need and benefits of the distribution technology has been presented . Single-phase Grid connected PV inverters with the control has been described with its advantages and disadvantages. The three-phase Photovoltaic power conditioning system with line connection has been proposed with the disturbance of the line voltage which is detected using a fast sensing technique. The control of the system is provided through the micro-controller. Power electronic systems can also be used for controlling the solar inverter for interfacing the Solar Power Generation system with the grid. The complete design and modeling of the grid connected PV system has been developed to supply the local loads

World is moving towards the greener sources of energy to make the planet pollution free and environment friendly. The major utilization of these sources with grid integration is the challenging task. It is therefore Distribution Generation (DGs) particularly single phase rooftop PV system are major research area for grid integration, since these sources have huge opportunity of generation near load terminal. The rooftop application involving single phase DG’s fed with PV source can be not only utilized for household use but the excess energy can be transferred to the grid through proper control scheme and adequate hardware. Control scheme based on instantaneous PQ theory has been presented in some litterateurs for single phase system.

Improvements were gradual over the next two decades. The only significant use was in space applications where they offered the best power-to-weight ratio. However, this success was also the reason that costs remained high, because space users were willing to pay for the best possible cells, leaving no reason to invest in lower-cost, less-efficient solutions. The price was determined largely by the semiconductor industry; their move to integrated circuits in the 1960s led to the availability of larger boules at lower relative prices. As their price fell, the price of the resulting cells did as well. These effects lowered 1971 cell costs to some $100 per watt.

DC- DC Converter

A boost converter (step-up converter) is a DC-to-DC power converter steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and atransistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are added to such a converter's output (load-side filter) and input (supply side filter)

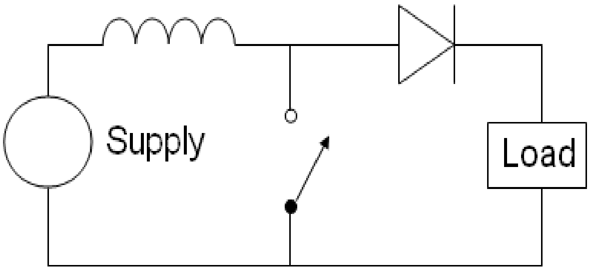


Fig 1 The basic schematic of a boost converter. The switch is typically a MOSFET, IGBT, or BJT.

Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power ( ) must be conserved, the output current is lower than the source current. For high efficiency, the SMPS switch must turn on and off quickly and have low losses. The advent of a commercial semiconductor switch in the 1950s represented a major milestone that made SMPSs such as the boost converter possible. The major DC to DC converters were developed in the early 1960s when semiconductor switches had become available. The aerospace industry's need for small, lightweight, and efficient power converters led to the converter's rapid development.

The NHW20 model Toyota Prius HEV uses a 500 V motor. Without a boost converter, the Prius would need nearly 417 cells to power the motor. However, a Prius actually uses only 168 cells and boosts the battery voltage from 202 V to 500 V. Boost converters also power devices at smaller scale applications, such as portable lighting systems. A white LED typically requires 3.3 V to emit light, and a boost converter can step up the voltage from a single 1.5 V alkaline cell to power the lamp. Boost converters can also produce higher voltages to operate Cold Cathode Fluorescent Tubes (CCFL) in devices such asLCD backlights and some flashlights.

Circuit Analysis

Operating

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure 2.2

(a) When the switch is closed, electrons flow through the inductor in counter-clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

(b) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

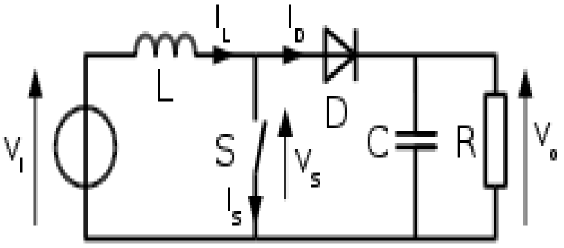


Fig 2: Boost converter schematic

Continuous Mode

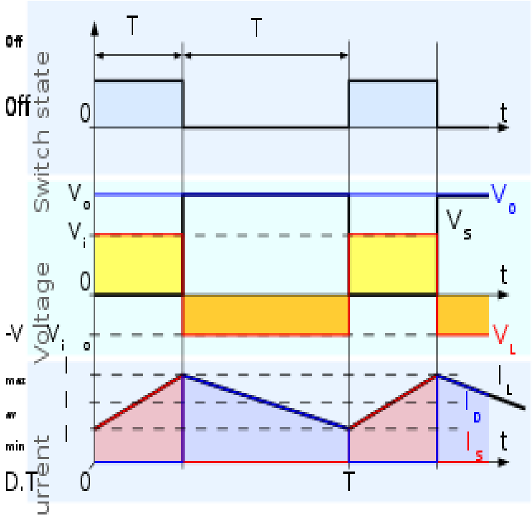


Fig 3 Waveforms of current and voltage in a boost converter operating in continuous mode

During the On-state, the switch S is closed, which makes the input voltage ( ) appear across the inductor, which causes a change in current ( ) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

At the end of the On-state, the increase of IL is therefore:

$$\Delta I_{L_{On}} = \frac{1}{L}\int_0^{DT} V_i dt = \frac{DT}{L} V_i$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore, D ranges between 0 (S is never on) and 1 (S is always on).

During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of IL is:

$$V_i - V_o = L\frac{dI_L}{dt}$$

Therefore, the variation of IL during the Off-period is:

$$\Delta I_{L_{Off}} = \int_{DT}^{T} \frac{(V_i - V_o)\,dt}{L} = \frac{(V_i - V_o)(1-D)T}{L}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2} L I_L^2$$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = 0$$

Substituting $\Delta I_{L_{On}}$ and $\Delta I_{L_{Off}}$ by their expressions yields:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = \frac{V_i DT}{L} + \frac{(V_i - V_o)(1-D)T}{L} = 0$$

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

The above equation shows that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a step-up converter.

Rearranging the equation reveals the duty cycle to be:

$$D = 1 - \frac{V_i}{V_o}$$

Discontinuous Mode

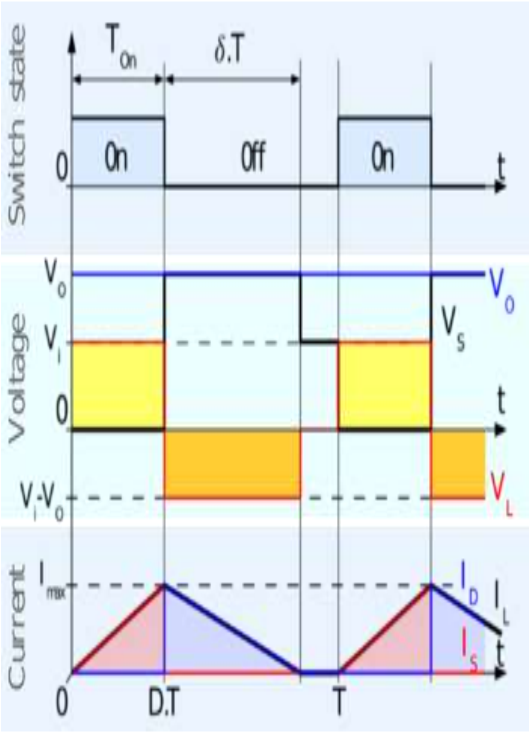


Fig 4 Waveforms of current and voltage in a boost converter operating in discontinuous mode.

As the inductor current at the beginning of the cycle is zero, its maximum value $I_{L_{Max}}$ $t = DT$ (at) is

$$I_{L_{Max}} = \frac{V_i DT}{L}$$

During the off-period, IL falls to zero after δT :

$$I_{L_{Max}} + \frac{(V_i - V_o)\,\delta T}{L} = 0$$

Using the two previous equations, δ is:

$$\delta = \frac{V_i D}{V_o - V_i}$$

The load current Io is equal to the average diode current (ID). As can be seen on figure 2.4, the diode current is equal to the inductor current during the off-state. Therefore, the output current can be written as:

$$I_o = \bar{I_D} = \frac{I_{L_{max}}}{2}\delta$$

Replacing ILmax and δ by their respective expressions yields:

$$I_o = \frac{V_i DT}{2L} \cdot \frac{V_i D}{V_o - V_i} = \frac{V_i^2 D^2 T}{2L\,(V_o - V_i)}$$

Therefore, the output voltage gain can be written as follows:

$$\frac{V_o}{V_i} = 1 + \frac{V_i D^2 T}{2 L I_o}$$

Compared to the expression of the output voltage gain for continuous

III. WIND ENERGY

Wind energy is transformed into mechanical energy by means of a wind turbine that has one or several blades. The turbine is coupled to the generator system by means of a mechanical drive train. It usually includes a gearbox that matches the turbine low speed to the higher speed of the generator. New wind turbine designs use multi pole, low speed generators, usually synchronous with field winding or permanent magnet excitation, in order to eliminate the gearbox. Some turbines include a blade pitch angle control for controlling the amount of power to be transformed. Stall controlled turbines do not allow such control. Wind speed is measured by means of an anemometer. A general scheme of Wind energy conversion system is shown in Fig. 3.1.

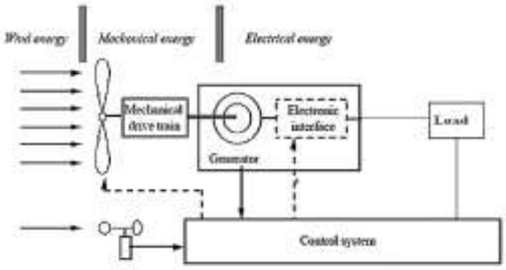


Fig 5 Block Diagram of Wind Energy Conversion System

Types of Wind Turbines

Wind turbines can be separated into two types based on the axis about which the turbine rotates. Turbines that rotate around a horizontal axis are most common where as vertical-axis turbines are less frequently used.

Horizontal- and Vertical-Axis Wind Turbines

Wind turbines can be categorized based on the orientation of their spin axis into horizontal-axis wind turbines (HAWT) and vertical-axis wind turbines (VAWT).In horizontal-axis wind turbines, the orientation of the spin axis is parallel to the. The tower elevates the nacelle to provide sufficient space for the rotor blade rotation and to reach better wind conditions. The nacelle supports the rotor hub that holds the rotor blades and also houses the gearbox, generator and, in some designs, power converters. The industry standard HAWT uses a three blade rotor positioned in front of the nacelle, which is known as upwind configuration. However, downwind configurations with the blades at the back can also be found in practical applications. Turbines with one, two or more than three blades can also be seen in wind farms.

In vertical-axis wind turbines, the orientation of the spin axis is perpendicular to the ground. The turbine rotor uses curved vertically mounted airfoils. The generator and gearbox are normally placed in the base of the turbine on the ground. The rotor blades of the VAWT have a variety of designs with different shapes and number of blades. The design given in the figure is one of the popular designs. The VAWT normally needs guide wires to keep the rotor shaft in a fixed position and minimize possible mechanical vibrations. The vertical axis machine has the shape of an egg beater, and is often called the Darrieus rotor after its inventor.

Wind power has been used as long as humans have put sails into the wind. For more than two millennia wind-powered machines have ground grain and pumped water. Wind power was widely available and not confined to the banks of fast-flowing streams, or later, requiring sources of fuel. Wind-powered pumps drained the polders of the Netherlands, and in arid regions such as the American mid-west or the Australian outback, wind pumps provided water for livestock and steam engines.

The first windmill used for the production of electric power was built in Scotland in July 1887 by Prof James Blyth of Anderson's College, Glasgow (the precursor of Strathclyde University). Blyth's 10 metres (33 ft) high, cloth-sailed wind turbine was installed in the garden of his holiday cottage at Marykirkin Kincardineshire and was used to charge accumulators developed by the Frenchman Camille Alphonse Faure, to power the lighting in the cottage, thus making it the first house in the world to have its electric power supplied by wind power. Blyth offered the surplus electric power to the people of Marykirk for lighting the main street, however, they turned down the offer as they thought electric power was "the work of the devil." Although he later built a wind turbine to supply emergency power to the local Lunatic Asylum, Infirmary and Dispensary of Montrose, the invention never really caught on as the technology was not considered to be economically viable.

Generator characteristics and stability

A permanent magnet synchronous generator is a generator where the excitation field is provided by a permanent magnet instead of a coil. The term synchronous refers here to the fact that the rotor and magnetic field rotate with the same speed, because the magnetic field is generated through a shaft mounted permanent magnet mechanism and current is induced into the stationary armature.

Synchronous generators are the majority source of commercial electrical energy. They are commonly used to convert the mechanical power output of steam turbines, gas turbines, reciprocating engines and hydro turbines into electrical power for the grid. Some designs ofWind turbines also use this generator type.

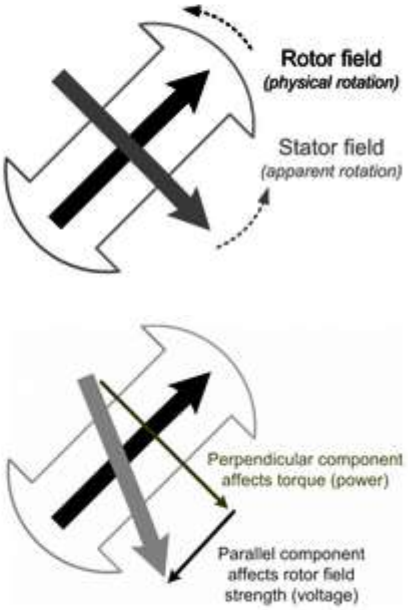


Fig 6Schematic diagrams of rotor field

In the majority of designs the rotating assembly in the center of the generator—the "rotor"—contains the magnet, and the "stator" is the stationary armature that is electrically connected to a load. As shown in the diagram, the perpendicular component of the stator field affects the torque while the parallel component affects the voltage. The load supplied by the generator determines the voltage. If the load is inductive, then the angle between the rotor and stator fields will be greater than 90 degrees which corresponds to an increased generator voltage. This is known as an overexcited generator. The opposite is true for a generator supplying a capacitive load which is known as an underexcited generator. A set of three conductors make up the armature winding in standard utility equipment, constituting three phases of a power circuit—that correspond to the three wires we are accustomed to see on transmission lines. The phases are wound such that they are 120 degrees apart spatially on the stator, providing for a uniform force or torque on the generator rotor. The uniformity of the torque arises because the magnetic fields resulting from the induced currents in the three conductors of the armature winding combine spatially in such a way as to resemble the magnetic field of a single, rotating magnet. This stator magnetic field or "stator field" appears as a steady rotating field and spins at the same frequency as the rotor when the rotor contains a single dipole magnetic field. The two fields move in "synchronicity" and maintain a fixed position relative to each other as they spin.

Capacity Factor

Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. Typical capacity factors are 15–50%; values at the upper end of the range are achieved in favourable sites and are due to wind turbine design improvements.

Online data is available for some locations, and the capacity factor can be calculated from the yearly output. For example, the German nationwide average wind power capacity factor over all of 2012 was just under 17.5% (45,867 GW•h/yr / (29.9 GW × 24 × 366) = 0.1746), and the capacity factor for Scottish wind farms averaged 24% between 2008 and 2010.

Unlike fueled generating plants, the capacity factor is affected by several parameters, including the variability of the wind at the site and the size of the generator relative to the turbine's swept area. A small generator would be cheaper and achieve a higher capacity factor but would produce less electric power (and thus less profit) in high winds. Conversely, a large generator would cost more but generate little extra power and, depending on the type, may stall out at low wind speed. Thus an optimum capacity factor of around 40–50% would be aimed for.

A 2008 study released by the U.S. Department of Energy noted that the capacity factor of new wind installations was increasing as the technology improves, and projected further improvements for future capacity factors. In 2010, the department estimated the capacity factor of new wind turbines in 2010 to be 45%. The annual average capacity factor for wind generation in the US has varied between 29.8% and 34% during the period 2010–2015.

Wind energy penetration is the fraction of energy produced by wind compared with the total generation. The wind power penetration in world electric power generation in 2015 was 3.5%.

There is no generally accepted maximum level of wind penetration. The limit for a particular grid will depend on the existing generating plants, pricing mechanisms, capacity for energy storage, demand management and other factors. An interconnected electric power grid will already include reserve generating and transmission capacity to allow for equipment failures. This reserve capacity can also serve to compensate for the varying power generation produced by wind stations. Studies have indicated that 20% of the total annual electrical energy consumption may be incorporated with minimal difficulty. These studies have been for locations with geographically dispersed wind farms, some degree of dispatch able energy or hydropower with storage capacity, demand management, and interconnected to a large grid area enabling the export of electric power when needed. Beyond the 20% level, there are few technical limits, but the economic implications become more significant. Electrical utilities continue to study the effects of large scale penetration of wind generation on system stability and economics.

Capacity Credit, Fuel Savings and Energy Payback

The capacity credit of wind is estimated by determining the capacity of conventional plants displaced by wind power, whilst maintaining the same degree of system security. According to the American Wind Energy Association, production of wind power in the United States in 2015 avoided consumption of 73 billion gallons of water and reduced CO2 emissions by 132 million metric tons, while providing USD 7.3 bn in public health savings.

The energy needed to build a wind farm divided into the total output over its life, Energy Return on Energy Invested, of wind power varies but averages about 20–25. Thus, the energy payback time is typically around a year.

Wind turbines reached grid parity (the point at which the cost of wind power matches traditional sources) in some areas of Europe in the mid-2000s, and in the US around the same time. Falling prices continue to drive the levelized cost down and it has been suggested that it has reached general grid parity in Europe in 2010, and will reach the same point in the US around 2016 due to an expected reduction in capital costs of about 12%.

IV. PULSE WIDTH MODULATION

- Cheap to make.
- Little heat whilst working.
- Low power consumption.
- Can utilize very high frequencies (40-100 Khz is not uncommon.)
- Very energy-efficient when used to convert voltages or to dim light bulbs.
- High power handling capability
- Efficiency up to 90%

A modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers, the other being MPPT.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

Fig 4.1 wave for combined positive and negative pulse

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform $f(t)$, with period T, low value , a high value and a duty cycle D (see figure 1), the average value of the waveform is given by:

$$\bar{y} = \frac{1}{T}\int_0^T f(t)\,dt.$$

As $f(t)$ is a pulsewave, its value is y_{max} for $0 < t < D \cdot T$ and y_{min} for . $D \cdot T < t < T$ The above expression then becomes:

$$\begin{aligned}\bar{y} &= \frac{1}{T}\left(\int_0^{DT} y_{max}\,dt + \int_{DT}^{T} y_{min}\,dt\right)\\ &= \frac{D \cdot T \cdot y_{max} + T\,(1-D)\,y_{min}}{T}\\ &= D \cdot y_{max} + (1-D)\,y_{min}.\end{aligned}$$

This latter expression can be fairly simplified in many cases where $y_{min} = 0$ as . $\bar{y} = D \cdot y_{max}$ From this, it is obvious that the average value of the signal ($\bar{y}$) is directly dependent on the duty cycle D.

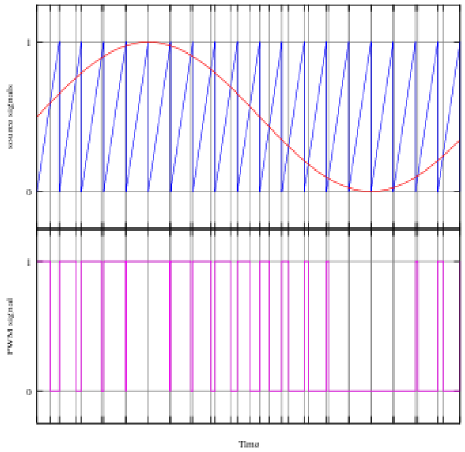


Fig 7 A simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM: the signal (here the red sinewave) is compared with a sawtooth waveform (blue). When the latter is less than the former, the PWM signal (magenta) is in high state (1). Otherwise it is in the low state (0).

The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator. When the value of the reference signal (the red sine wave in figure 2) is more than the modulation waveform (blue), the PWM signal (magenta) is in the high state, otherwise it is in the low state.

The PWM is a technique which is used to drive the inertial loads since a very long time.The simple example of an inertial load is a motor. Apply the power to a motor for a very short period of time and then turn off the power: it can be observed that the motor is still running even after the power has been cut off from it. This is due to the inertia of the motor and the significance of this factor is that the continuous power is not required for that kind of devices to operate. A burst power can save the total power supplied to the load while achieving the same performance from the device as it runs on continuous power.

Description

The Pulse Width Modulation is a technique in which the ON time or OFF time of a pulse is varied according to the amplitude of the modulating signal, keeping it.

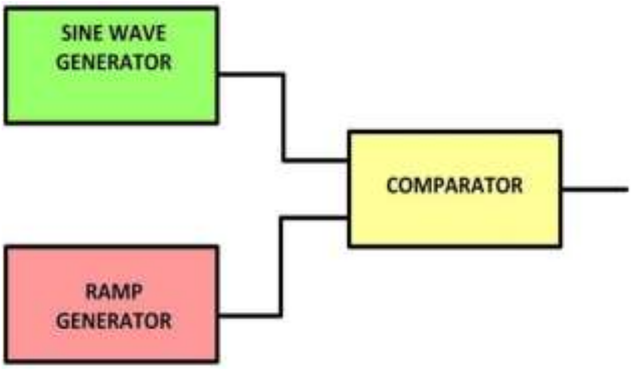


Fig 8 SPWM block diagram

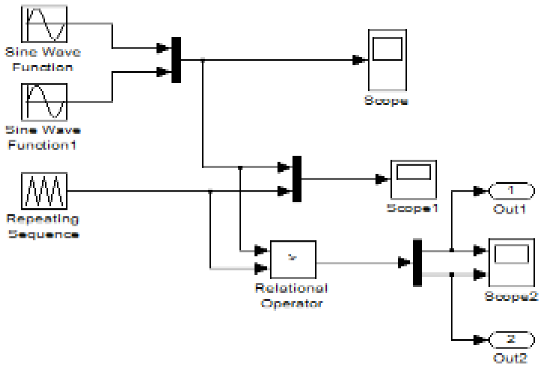


Fig .9 Spwm Simulation Diagram

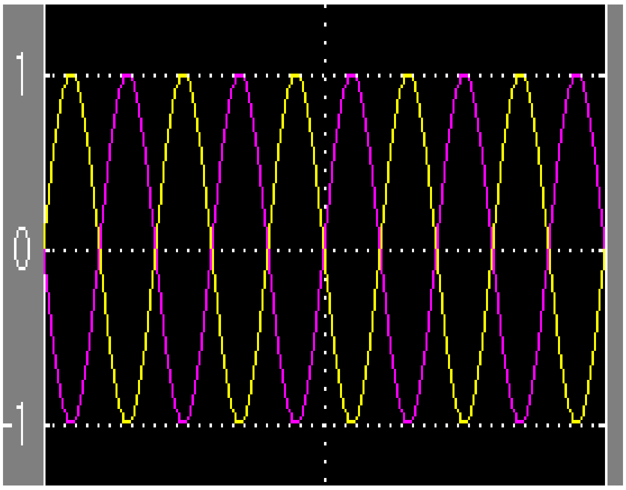


Fig 10 SCOPE view

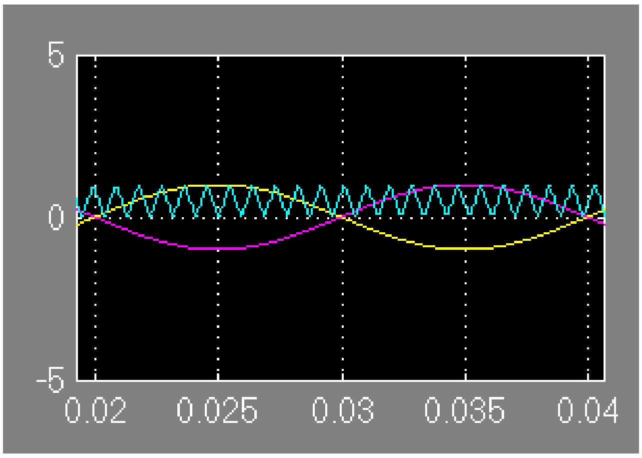


Fig 11 SCOPE 1 view

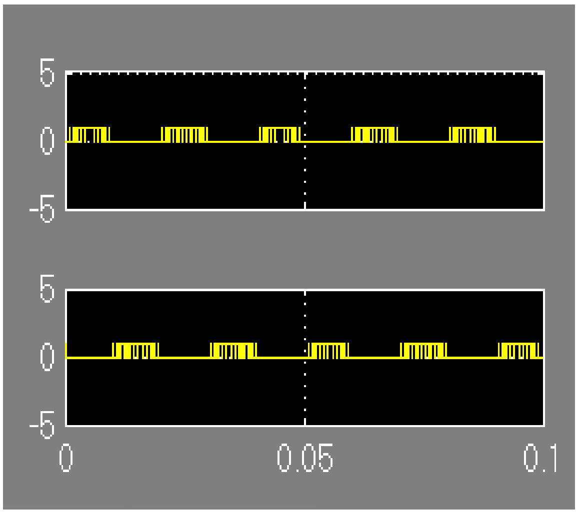


Fig 12 SCOPE 2 view

The (ON time + OFF time) time of the pulse as constant. The (ON time + OFF time) of a pulse is called 'Period' of the pulse, and the ratio of the ON time or OFF time with the Period is called the 'Duty Cycle'. Hence the PWM is a kind of modulation which keeps the Period of pulses constant but varying their duty cycle according to the amplitude of the modulating signal.

The conventional method of generating a PWM modulated wave is to compare the message signal with a ramp waveform using a comparator. The block diagram required for the generation of a simple PWM is shown.

V. PROPOSED VOLTAGE SOURCE INVERTER

The thyristors can only be turned on (not off) by control action, and rely on the external AC system to effect the turn-off process, the control system only has one degree of freedom – when to turn on the thyristor. This limits the usefulness of HVDC in some circumstances because it means that the AC system to which the HVDC converter is connected must always contain synchronous machines in order to provide the commutating voltage – the HVDC converter cannot feed power into a passive system. With some other types of semiconductor device such as the insulated-gate bipolar transistor (IGBT), both turn-on and turn-off can be controlled, giving a second degree of freedom. As a result, IGBTs can be used to make self-commutated converters. In such converters, the polarity of DC voltage is usually fixed and the DC voltage, being smoothed by a large capacitance, can be considered constant. For this reason, an HVDC converter using IGBTs is usually referred to as a voltage-source converter (or voltage-sourced converter). The additional controllability gives many advantages, notably the ability to switch the IGBTs on and off many times per cycle in order to improve the harmonic performance, and the fact that (being self-commutated) the converter no longer relies on synchronous machines in the AC system for its operation. A voltage-sourced converter can therefore feed power to an AC network consisting only of passive loads, something which is impossible with LCC HVDC. Voltage-source converters are also considerably more compact than line-commutated converters (mainly because much less harmonic filtering is needed) and are preferable to line-commutated converters in locations where space is at a premium, for example on offshore platforms.

Two-Level Converter

From the very first VSC-HVDC scheme installed (the Hellsjön experimental link commissioned in Sweden in 1997) until 2012, most of the VSC HVDC systems built were based on the two level converter. The two-level converter is the simplest type of three-phase voltage-source converter and can be thought of as a six pulse bridge in which the thyristors have been replaced by IGBTs with inverse-parallel diodes, and the DC smoothing reactors have been replaced by DC smoothing capacitors. Such converters derive their name from the fact that the voltage at the AC output of each phase is switched between two discrete voltage levels, corresponding to the electrical potentials of the positive and negative DC terminals. When the upper of the two valves in a phase is turned on, the AC output terminal is connected to the positive DC terminal, resulting in an output voltage of +½ U_d with respect to the midpoint potential of the converter. Conversely when the lower valve in a phase is turned on, the AC output terminal is connected to the negative DC terminal, resulting in an output voltage of -½ U_d. The two valves corresponding to one phase must never be turned on simultaneously, as this would result in an uncontrolled discharge of the DC capacitor, risking severe damage to the converter equipment

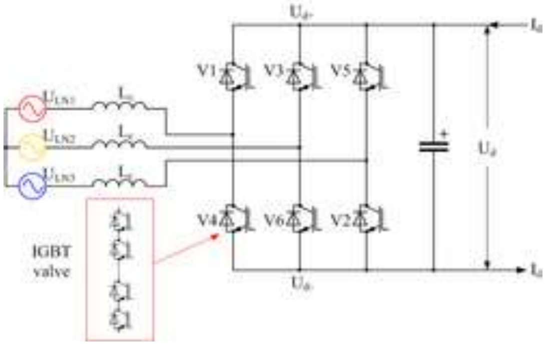


Fig 13 Three-phase, two-level voltage-source converter

VI. PROPOSED SIMULATION RESULTS

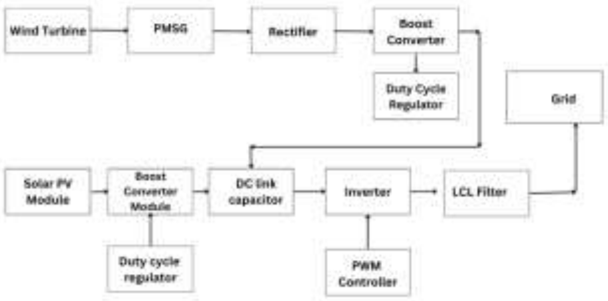
Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Proposed System Configuration

The proposed circuit configuration aims to investigate the hybrid power performance achieved by integrating a solar module and a wind turbine with a three-phase grid. This integration represents a novel approach to harnessing renewable energy sources and maximizing power generation efficiency

Block Diagram



At the heart of the circuit configuration lies the hybrid power generation system, which comprises a solar module, a wind turbine, and associated power electronics. The solar module consists of photovoltaic (PV) panels that convert solar energy into electrical power, while the wind turbine harnesses wind energy to generate electricity. Both sources feed their generated power into a common power conversion system for integration with the grid.

Simulation

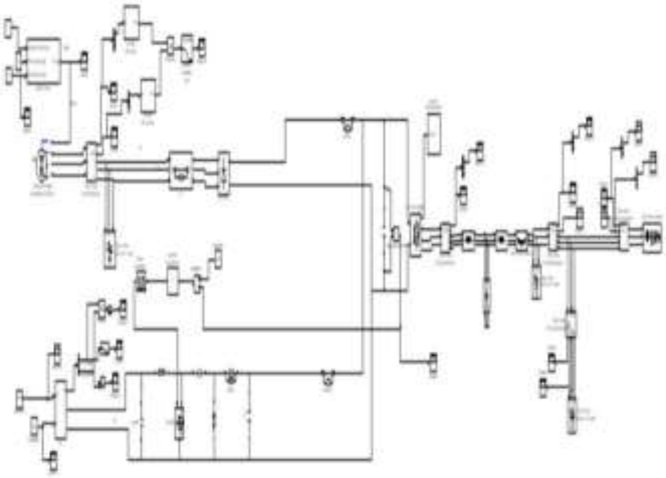


Fig 14 Simulation Setup

Fig 15 DC Link voltage vs time

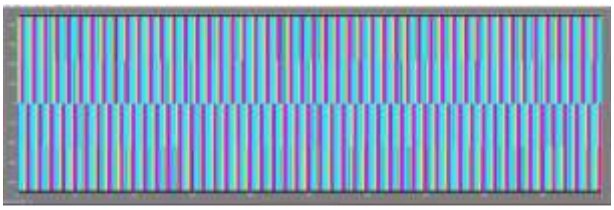


Fig 16: Voltage brfore lcl filter vs time

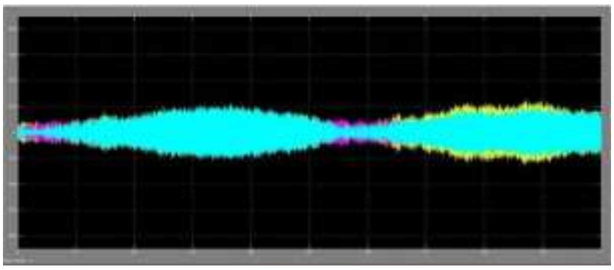


Fig 17: Current before lcl filter vs time

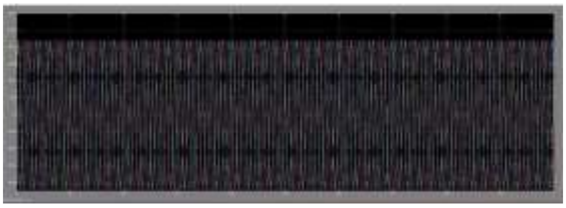


Fig 18: Grid voltage vs time

Fig 19: Grid current vs time

VII. CONCLUSION

The findings derived from the simulated data in MATLAB reveal promising insights into the feasibility of a hybrid power generation system. Notably, the comparison between the power generated by varying wind turbine pitch angles and solar irradiance levels showcases minimal differences, amounting to just 5%. Through our demonstration Simulink model, we have systematically gathered data across diverse weather conditions, enabling a comprehensive analysis of efficiency variations.This analysis underscores the practical viability of our model, indicating its efficacy in delivering efficient outcomes under real-world circumstances. Given the global imperative to curtail greenhouse gas emissions, the transition towards renewable energy sources like wind and solar power is imperative. Unlike conventional fossil fuel-based energy production, renewable sources offer emission-free alternatives that are both sustainable and readily available.Our model is expressly designed to harness green energy across diverse environmental contexts, thereby facilitating a shift towards a more sustainable energy landscape. As nations worldwide, including Bangladesh, endeavor to bolster green energy initiatives, our hybrid power generation system holds promise in alleviating reliance on finite fossil fuel resources. In doing so, it contributes significantly to mitigating the looming fossil fuel crisis while advancing environmental conservation efforts.

Future Scope

Development of new materials that enhance the efficiency and durability of solar panels and wind turbines, making them more cost-effective and robust. Integration of hybrid systems with smart grids to optimize energy distribution and balance supply and demand more efficiently. Use of AI and machine learning to predict weather patterns and optimize the performance of hybrid systems in real-time. Improvements in battery technology and other energy storage solutions to store excess energy generated by hybrid systems for later use. Development of scalable hybrid systems that can be easily adapted for different energy needs, from small households to large industrial complexes. Government incentives and policies promoting the adoption of hybrid systems, which could accelerate their deployment and integration into existing infrastructure. Design of hybrid systems that can be seamlessly integrated into urban environments, including on rooftops and in public spaces. Implementation of remote monitoring and control systems to manage hybrid installations in remote or hard-to-reach areas. Continuous research to minimize the environmental footprint of hybrid systems, including recycling and sustainable manufacturing processes. Increased collaboration between research institutions, industry, and governments to drive innovation and deployment of hybrid energy solutions. Development of educational programs and training initiatives to build a skilled workforce capable of designing, installing, and maintaining hybrid systems. Global partnerships to share knowledge, technology, and resources, promoting the adoption of hybrid systems in developing countries.

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