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High Step up Voltage Multiplier Module for a Hybrid Energy Conversion System

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Abstract:

A high step-up converter is proposed for a Hybrid system. A voltage multiplier used here provides high voltage gain without extreme duty cycle. The voltage multiplier is composed of a conventional boost converter and coupled inductors. An extra conventional boost converter is integrated into the first phase to achieve a considerably higher voltage conversion ratio. The two-phase configuration not only reduces the current stress through each power switch, but also constrains the input current ripple, which decreases the conduction losses of metal–oxide–semiconductor field-effect transistors (MOSFETs). It also functions as a clamp circuit which alleviates the voltage spikes across the power switches. So, the low-voltage-rated MOSFETs can be adopted for reductions of conduction losses and cost. Efficiency improves because the energy stored in leakage inductances is recycled to the output terminal.

Index Terms:

Boost–flyback converter, voltage multiplier module, photovoltaic system, Wind system

I.INTRODUCTION:

Energy is essential to our society to ensure our quality of life and to underpin all other elements of our economy. The escalation in cost and environmental concerns involving conventional electrical energy, Sources have increased interest in renewable energy sources. One of the primary needs for socio-economic development in any nation in the world is the provision of reliable electricity supply systems. In Nigeria, the low level of electricity generation in Nigeria from conventional fossil fuel has been the major constraint to rapid socio-economic development especially in rural communities.

Moreso, about sixty-five percent (65%) of 140million Nigeria populace are rural dwellers with majority of them living far-off grid areas [1]. These rural dwellers are mostly farmers whose socio-economic lives can only be improved when provisions are made to preserve their wasting agricultural products and provide energy for their household equipment such as refrigerator, fan, lighting etc. There is also such a need to provide electricity for e-information infrastructures in our rural communities to service school, rural hospital, rural banking and rural e-library. Hence, there is the need to develop an indigenous technology to harness the renewable energies in Sun and Wind to generate electricity.

1.1Importance of Renewable energy:

The global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas. Generators which are often used as an alternative to conventional power supply systems are known to be run only during certain hours of the day, and the cost of fueling them is increasingly becoming difficult if they are to be used for commercial purposes. There is a growing awareness that renewable energy such as photovoltaic system and Wind power have an important role to play in order to save the situation. Figure 1 is the schematic layout of Solar-Wind Hybrid system that can supply either dc or ac energy or both.

II.SOLAR PHOTOVOLTAIC SYSTEM:

The European PV industry Association reported that the total global PV cell production worldwide in 2002 was over 560 MW and has been growing about 30% annually in recent years. The physical of PV cell is very similar to that of the classical diode with a PN junction formed by semiconductor material.

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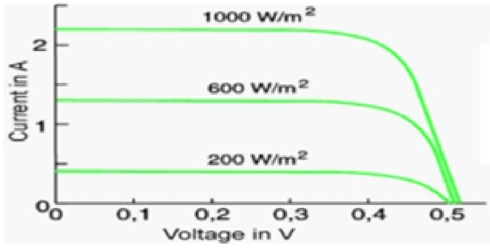
When the junction absorbs light, the energy of absorbed photon is transferred to the electron-proton system of the material, creating charge carriers that are separated at the junction. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field, and circulate as current through an external circuit. The solar cell is the basic building of the PV power system it produces about 1 W of power.

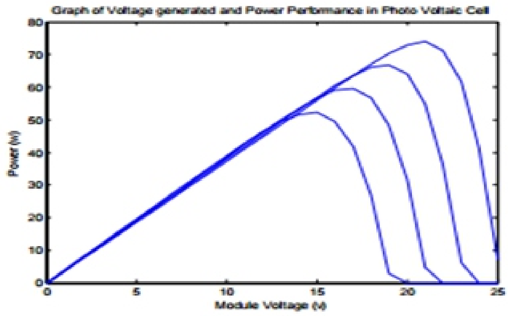
To obtain high power, numerous such cell are connected in series and parallel circuits on a panel (module), the solar array or panel is a group of a several modules electrically connected in series parallel combination to generate the required current and voltage. The electrical characteristics of the PV module are generally represented by the current vs. voltage (I-V) and the current vs. power (P-V) curves. Figs. and show the (IV) and (P-V) characteristics of the used photovoltaic module at different solar illumination intensities. The I– V characteristic of the PV module are:

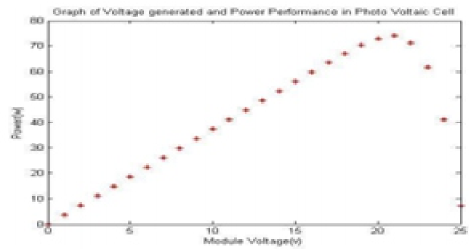
I = IL - I0 (e^q(V +IRS)/nkT _ 1)
Where
IL = photo current
I0 = diode saturation current
RS = series resistance
q = charge of electron
k = constant
T = temperature
N = number of PV module
Power output from the PV array can be obtained by using the equation:
Ppv (t) = Ins (t) * A*Eff(pv).
Where
Ins (t) = insulation data at time t (kw/ m2)
A = area of single PV panel (m2)
Effpv = overall efficiency of the PV panels and dc/dc converters.

The Solar Cell Characteristics:

•Isc-short circuit current
•Voc-open circuit voltage
•Peak power The open circuit voltage of a single solar cell is approx 0.5V.
•Much higher voltage is required for practical application.
•Solar cells are connected in series to increase its open circuit voltage.







WIND ENERGY SYSTEM:

Wind power systems convert the kinetic energy of the wind into other forms of energy such as electricity. Although wind energy conversion is relatively simple in concept, turbine design can be quite complex. Most commercially available wind turbine uses a horizontal – axis configuration with two or three blades, a drive train including a gearbox and a generator and a tower to support the rotor. Typical sizes for a wind turbine range from 200-750 KW, with electricity produce within a specific range of wind speed. Capital costs have declined from about $ 2.2/w in early 1980 to less than $ 1/w today. Cooperative research between DOE and manufacturing companies is aimed at increasing the aerodynamics efficiency and structural strength of wind turbine blades, developing variable speed generation and electronic power controls and using taller tower that allow access to the stronger wind found at greater height. An important factor in how much power your wind turbine will produce is the height of its tower. The power available in the wind is proportional to the cube of its speed. This means that if wind speed doubles, the power available to the wind generator increases by a factor of 8 (2 x 2 x 2 = 8) Since wind speed increases with height increases to the tower height

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can mean enormous increases in the amount of electricity generated by a wind turbine. Figure Relationship between wind speed and wind power.

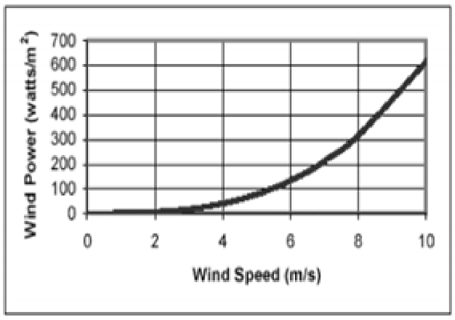

Figure Relationship between wind speed and wind power.

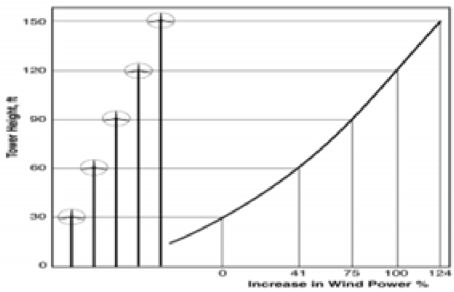

Figure Wind speeds increase with height.

The fundamental equation governing the mechanical power capture of the wind turbine rotor blades, which drives the electrical generator, is given by

Pwin (t) = 1/2 *ℓ*A*V (t) 3 * Cp*Effad

Where

ℓ = air density (kg/m3)

A = area swept of rotor (m2)

V = wind speed (m/s) and

Effad = efficiency of the AC/DC Converter T

he theoretical maximum value of the power coefficient Cp is 0.59 and it is often expressed as function of the rotor tip-speed to wind-speed ratio (TSR). TSR is defined as the linear speed of the rotor to the wind speed.

$$TSR = \omega R/V$$

Where R and w are the turbine radius and the angular speed, respectively. Whatever maximum value is attainableWhere R and with a given wind turbine, it must be maintained constant at that value for the efficient capture of maximum wind power. Power is directly proportional to wind speed, as the wind speed increases the power delivered by a wind turbine also increases.

If wind speed is between the rated wind speed and the furling speed of the wind turbine, the power output will be equal to the rated power of the turbine. Finally, if the wind speed is less than the cut-in speed or greater than the furling speed there will be no output power from the turbine

Power output from practical turbine:

The fraction of power extracted from the power in the wind by a practical wind turbine is usually given the symbol Cp, standing for the coefficient of performance. Using this notation and dropping the subscripts of Eq. the actual mechanical power output can be written as

Pm = Cp (½ ρAu3) = CpPw

II. PROPOSED TOPOLOGY:

In this paper, an asymmetrical interleaved high step-up converter that combines the advantages of the aforementioned converters is proposed, which combined the advantages of both. In the voltage multiplier module of the proposed converter, the turns ratio of coupled inductors can be designed to extend voltage gain, and a voltage-lift capacitor offers an extra voltage conversion ratio.

The advantages of the proposed converter are as follows:

1) The converter is characterized by a low input current ripple and low conduction losses, making it suitable for high power applications;

2) The converter achieves the high step-up voltage gain that renewable energy systems require;

3) Leakage energy is recycled and sent to the output terminal, and alleviates large voltage spikes on the main switch;

4) The main switch voltage stress of the converter is substantially lower than that of the output voltage;

5) Low cost and high efficiency are achieved.

A. Circuit Description:

The proposed high step-up converter with voltage multiplier module is shown in Fig. 3(a). A conventional boost converter and two coupled

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inductors are located in the voltage multiplier module, which is stacked on a boost converter to form an asymmetrical interleaved structure. Primary windings of the coupled inductors with Np turns are employed to decrease input current ripple, and secondary windings of the coupled inductors with Ns turns are connected in series to extend voltage gain. The turns ratios of the coupled inductors are the same. The coupling references of the inductors are denoted by "." and "*".

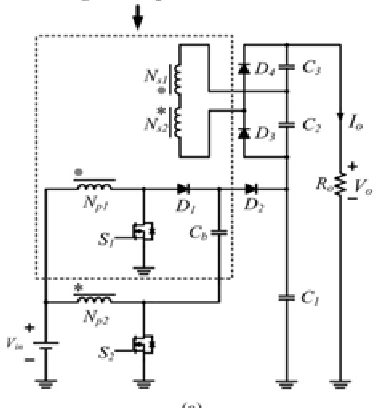

Figure 3(a): Proposed high step-up converter with a voltage multiplier module.

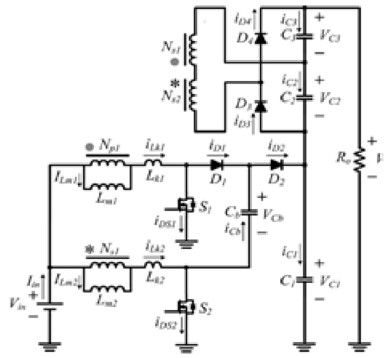

Figure 3(b): Equivalent Circuit III.

The equivalent circuit of the proposed converter is shown in Figure. 3(b), where Lm1 and Lm2 are the magnetizing inductors, Lk1 and Lk2 represent the leakage inductors, S1 and S2 denote the power switches, Cb is the voltage-lift capacitor, and n is defined as a turns ratio Ns /Np.

III.MODAL ANALYSIS:

The proposed converter operates in continuous conduction mode (CCM), and the duty cycles of the power switches during steady operation are interleaved with a 180◦ phase shift and the duty cycles are greater than 0.5. The key steady waveforms in one switching period of the proposed converter contain six modes.

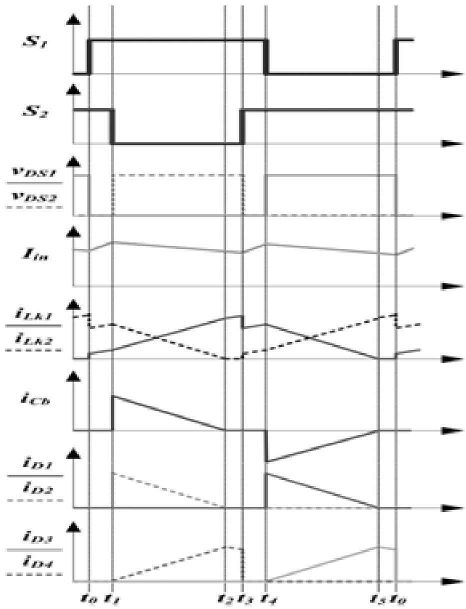

Figure 4: Steady waveforms of the proposed converter

Mode 1 [t0, t1]: At t=t0 , the power switches S1 and S2 are both turned ON. All of the diodes are reversed-biased. Magnetizing inductors Lm1 and Lm2 as well as leakage inductors Lk1 and Lk2 are linearly charged by the input voltage source Vin.

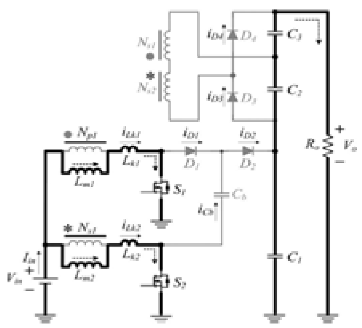

Figure 5(a): Mode 1

Mode 2 [t1, t2]: At t=t1, the power switch S2 is switched OFF, thereby turning ON diodes D2 and D4. The energy that magnetizing inductor Lm2 has stored is transferred to the secondary side charging the output filter capacitor C3. The input voltage source, magnetizing inductor Lm2, leakage inductor Lk2, and voltage-lift capacitor Cb release energy to the output filter capacitor C1 via diode D2, there by extending the voltage on C1.

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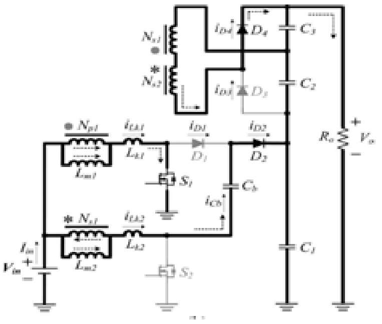

Figure 5(b): Mode 2

Mode 3 [t2, t3]: At t=t2, diode D2 automatically switches OFF because the total energy of leakage inductor Lk2 has been completely released to the output filter capacitor C1. Magnetizing inductor Lm2 transfers energy to the secondary side charging the output filter capacitor C3 via diode D4 until t3.

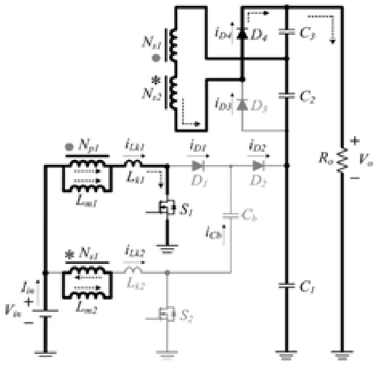

Figure 5(c): Mode 3.

Mode 4 [t3, t4]: At t=t3, the power switch S2 is switched ON and all the diodes are turned OFF. The operating states of modes 1 and 4 are similar.

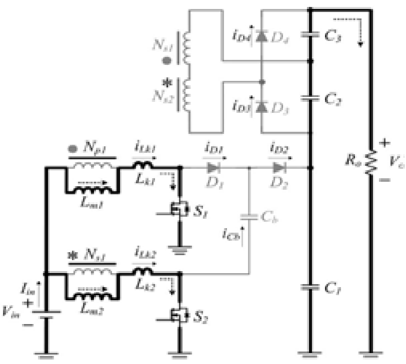

Figure 5(d): Mode 4

Mode 5: Mode 5 [t4, t5]: At t=t4, the power switch S1 is switched OFF, which turns ON diodes D1 and D3. The energy stored in magnetizing inductor Lm1 is transferred to the secondary side charging the output filter capacitor C2.

The input voltage source and magnetizing inductor Lm1 release energy to voltage-lift capacitor Cb via diode D1, which stores extra energy in Cb.

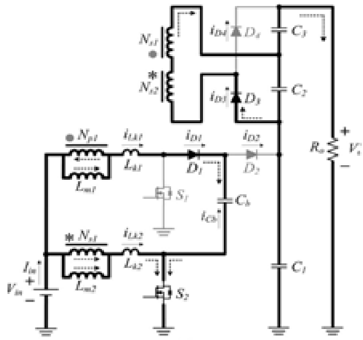

Figure 5(e): Mode 5

Mode 6 [t5, t0]: At t=t5 , diode D1 is automatically turned OFF because the total energy of leakage inductor Lk1 has been completely released to voltage-lift capacitor Cb. Magnetizing inductor Lm1 transfers energy to the secondary side charging the output filter capacitor C2 via diode D3 until t0.

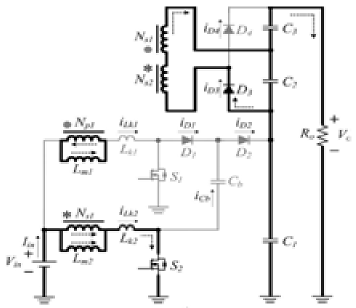

Figure 5(f): Mode 6

IV. SIMULATION RESULTS:

Simulation is performed using MATLAB/SIMULINK software. Simulink liabrary files include inbuilt models of many electrical and electronics components and devices such as diodes, MOSFETS, capacitors, inductors, motors, power supplies and so on. The circuit components are connected as per design without error, parameters of all components are configured as per requirement and simulation is performed

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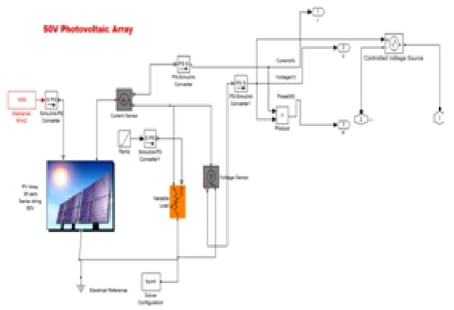
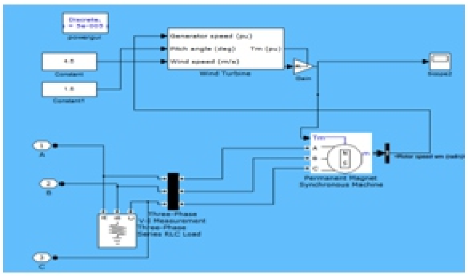
SIMULATION CIRCUIT DIAGRAM:

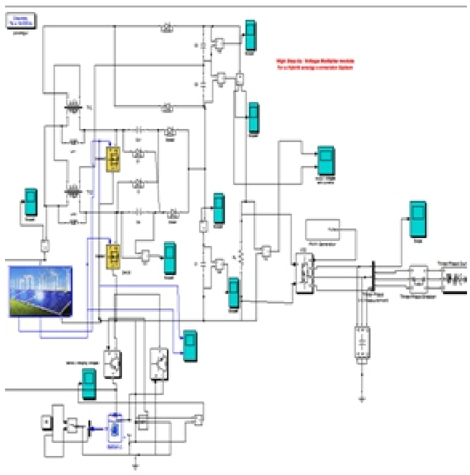
a)PV model:



b)Wind model:

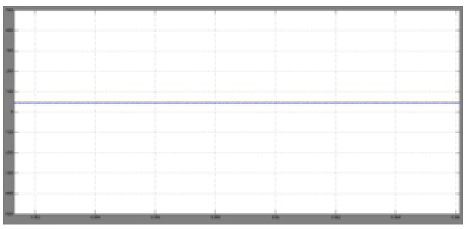


c)Interleaved converter:

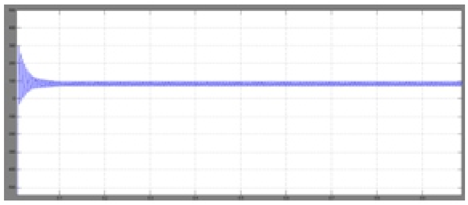


WAVEFORMS:

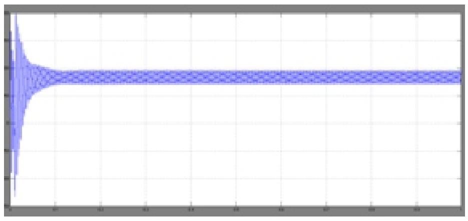
a)Combined DC voltage from hybrid system



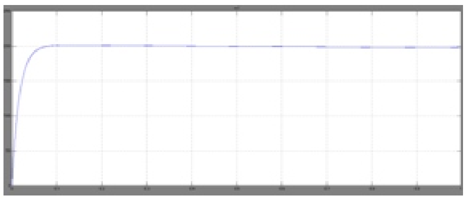
b)VC3



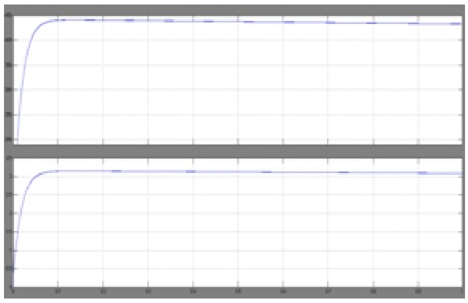
c)VC2



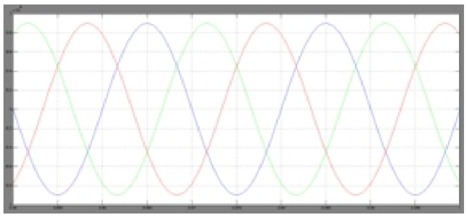
d)VC1



e)Output voltage & Currrents



f)Grid side voltage



V. CONCLUSION:

This paper presents a Hybrid system, the topological principles, steady state analysis, results for a proposed converter.

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The proposed converter has been successfully implemented in an efficiently high step-up conversion without an extreme duty ratio and a number of turns ratios through the voltage multiplier module and voltage clamp feature.

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