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ANALYSIS AND DESIGN CONTROL OF SMART DC MICROGRID FOR INTEGRATION OF RENEWABLE ENERGY SOURCES

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ABSTRACT

Environmentally friendly solutions are becoming more prominent than ever as a result of concern regarding the state of our deteriorating planet. This paper presents a hybrid battery/photovoltaic energy system. This configuration allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The inherent nature of this Cuk-SEPIC fused converter, additional input filters are not necessary to filter out high frequency harmonics. Harmonic content is detrimental for the generator lifespan, heating issues, and efficiency. Operational analysis of the proposed system will be discussed in this paper. Simulation results are given to highlight the merits of the proposed circuit.

Keywords: Battery Energy Storage System, DC Microgid, DC-DC Converter, MOSFET, Pulse Width Modulation, Solar photovoltaic system.

I. INTRODUCTION

With the increasing increasing threat of global warming and the depletion of fossil fuel reserves many are looking at sustainable energy solution to preserve the for future generation , along with environmental concerns and the emergence of electricity market have attracted interest in large deployment of Renewable Energy Sources (RES).With increasing concern of global warming and the depletion of fossil fuel reserves, many are looking at Sustainable energy solutions to preserve the earth for the future generations. Other than hydro power, photovoltaic energy holds the most potential to meet our energy demand. Similarly, solar energy is present throughout the day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc.

The concept of “Microgrid” is one of the solutions to integrate a mix of RES, which offers advantages of higher flexibility, controllability, efficiency of operation, and bidirectional power flow between utility gridand the microgrid under the grid connected mode of operation . The microgrids are classified as ac microgrid, and dc microgrid. The DC Micro-Grid (DCMG) is preferred over AC microgrid because of the advantages: 1) higher quality of power supply, 2) higher reliability and uninterruptible supply, 3)) due to absence of reactive power, it leads to better utilization and reduced total losses, 4) higher efficiency, and 5) each Distributed Generation (DG) connected to the DCMG can be easily operated as only dc voltage is required to be Controlled .

The Power Electronic (PE) interface is used to integrate any type of Distributed Generation (DG), energy storage system, and ac and dc loads to the DCMG. The sinousidal pulse width modulation based inverter with

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mosfet (metal oxide field effect transistor) switches. The advanatage of using mosfet switches is it provide low loss of power in switching devices.

The proposed system consists of hybrid battery and solar energy systems as shown .The proposed design is a fusion of CUK and SEPIC converters which eliminate the need for separate passive filter and support step up/down operations for renewable energy sources.The fusion of the two converters is achieved by reconfiguring the two existing diode from each converter and the shared utilization of the CUK output inductor by the SEPIC converter. Then the PI controller is being used as the closed loop control.

The DC output voltage is being fed to the load or DCMG . The DCMG is able to supply both the AC and DC power to load simulatenously.so the DC output is being converted to AC by using sinousidal pwm inverter. AC output voltage is being obtained. The proposed control scheme for the DCMG has been implemented in matlab /Simulink environment.

II. PV PANEL CHARACTERISTICS

Solar energy is one of the most important renewable energy sources has been gaining increased attention in recent years. Solar energy is abundant in compared to other energy sources. The radiation of sun falling on earth in one day is sufficient to power the total energy needs of the earth for one year. Solar energy is clean and free of emissions, since it does not produce pollutants or by-products harmful to nature. The conversion of solar energy into electrical energy has many application fields. Residential, vehicular, space and air craft, and naval applications are the main fields of solar energy.A photovoltaic cell converts sunlight into electricity, which is the physical process known as photoelectric effect. Light, which shines on a PV cell, may be reflected, absorbed, or passed through; however, only absorbed light generates electricity. The energy of absorbed light is transferred to electrons in the atoms of the PV cell. With their newfound energy, these electrons escape from their normal positions in the atoms of semiconductor PV material and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell, called “built-in electric field,” provides the force or voltage required to drive the current through an external “load” such as a light bulb.

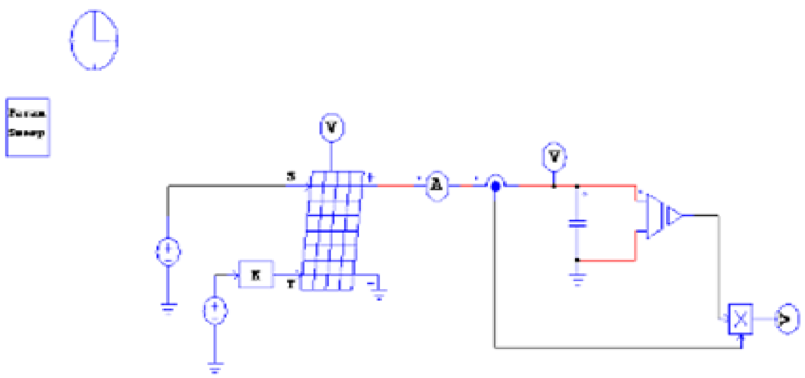

Fig:1 PV panel consists of 36 cells

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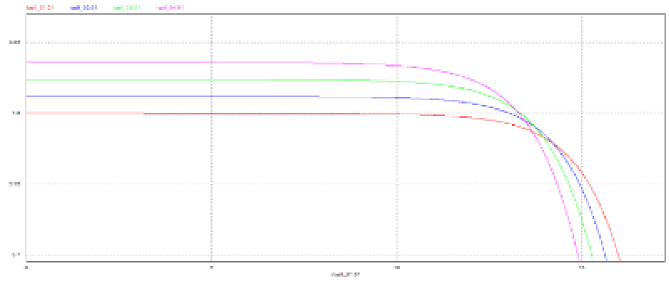

Fig: 2I-V characteristics of solar panel

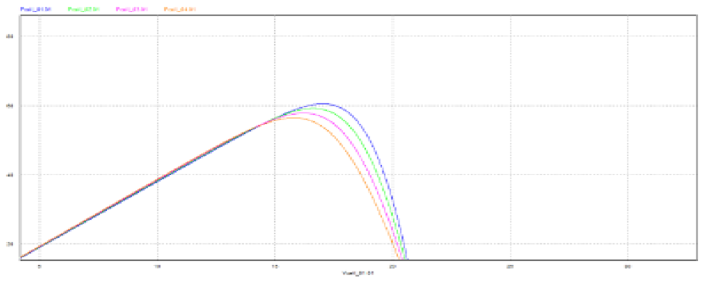

Fig: 3 P-V characteristics of solar cell

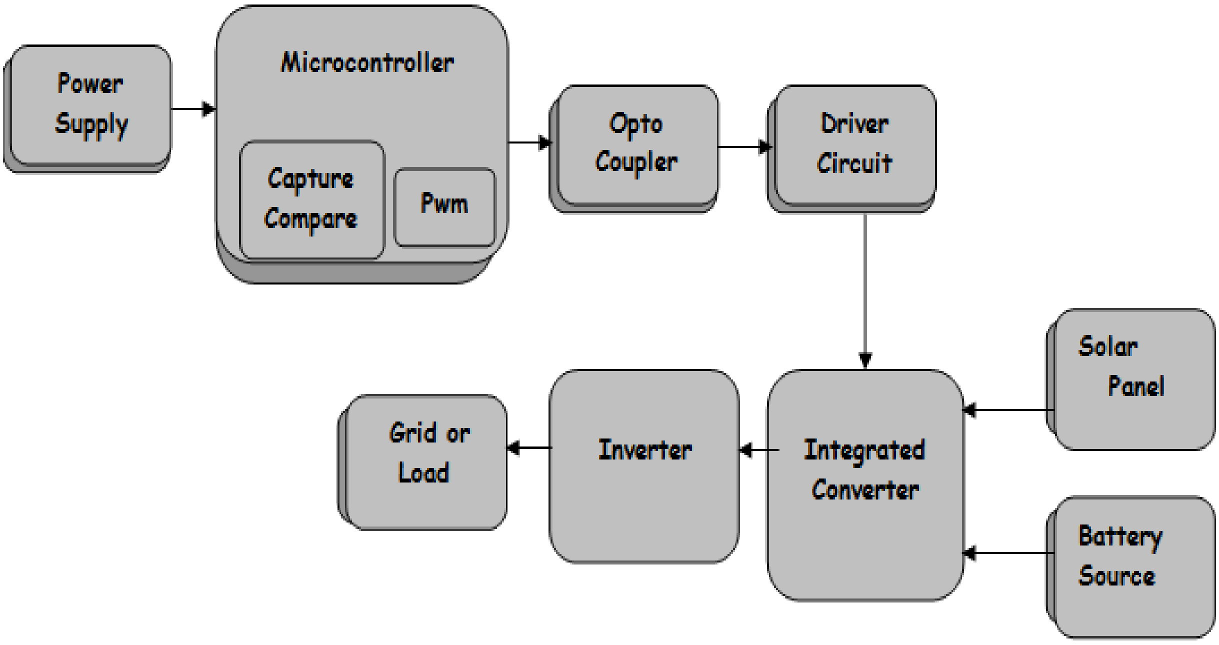

Fig:4 proposed architecture of smart dc microgrid for integration of renewable energy resources

III. SYSTEM CONFIGURATION AND MODELING:

The proposed architecture of "smart dc microgrid " for integration of renewable energy sources in fig:4. The spv generation comprises of pi controller to obtain more accurate results. In the positive-slope region (dP/dVpv > 0), the operation voltage is increased. On the other hand, in the negative-slope region (dP/dVpv <0), the operation voltage is decreased. The SPV generates the dc power at lower voltage than DCMG voltage and therefore a fused sepic and cuk converter is required when circuit needs to boost as well as buck the output

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voltage to DCMG voltage level, and also used for establishing the constant dc voltage .Therefore fused sepic and cuk converter is needed to:1) cuk provide continuous input current 2) cuk provide continuous output current 3)sepic conveter act as low noise buck converter.

The equivalent circuit of a SPV array is shown inFig. 3. The SPV array output current is given as,

$$I_{pv} = n_p I_{ph} - n_p I_{sat}\left[\exp\left\{q\left(V_{pv}+I\left(n_s R_{se}/n_p\right)\right)/n_s k T_{cell} A\right\}-1\right] - \left\{\left(n_p V/n_s\right)+IR_{se}\right\}/R_{sh}$$

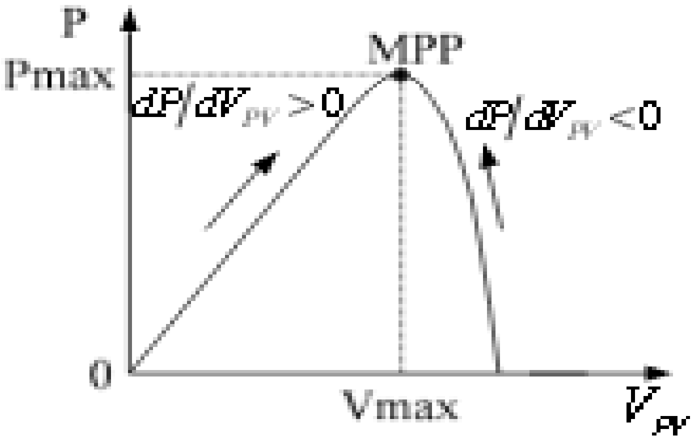

Fig:5 p-v characteristics of spv array

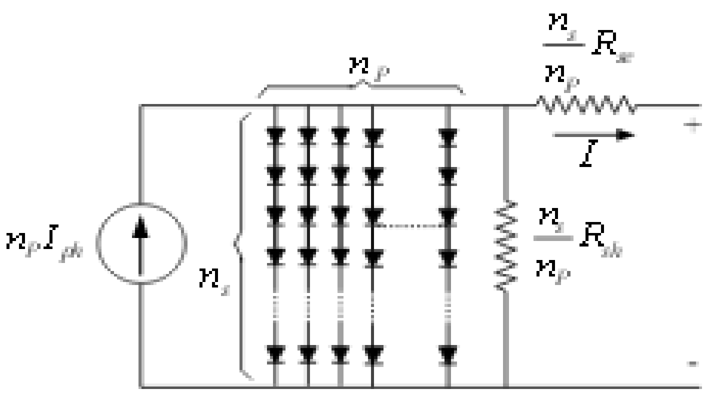

Fig:6 Equivalent circuit of spv array

where Ipv is the SPV array output current (A), Vpv is the SPV array output voltage (V), ns is the number of SPV cells connected in series, nP is the number of modules connected in parallel, q (=1.6×10-19C) is the charge of an electron, k(=1.38×10-23J/K) is Boltzmann's constant, A is the p-n junction ideality factor,Tcell is the cell operating temperature (K), Isat is the cell's saturation current, Rse is series resistance, and Rsh is the shunt resistance. The photo-current depends on the Solar Irradiation (SI) and cell operating temperature, and is expressed as,

$$I_{ph} = \left[I_{sc} + \sigma_{i_{sc}}\left(T_{cell}-T_{ref}\right)\right]\cdot\left(\frac{S}{1000}\right)$$

The SPVcell's saturation current varies with the cell operating temperature, and is expressed as,

$$I_{sat} = I_{rs}\left(T_{cell}/T_{ref}\right)^{3}\exp\left[qE_G\left(1/T_{ref}-1/T_{cell}\right)/kA\right]$$

The reverse saturation current at reference temperature is given as,

$$I_{rs} = I_{sc} \Big/ \left[\exp\left(qV_{oc} / N_S kAT_{cell}\right) - 1\right]$$

where ISC is the SPV cell's short-circuit current at standard test condition (STC) i.e. 25°C and 1kW/m2, σisc is the cell's temperature coefficient of short-circuit current, Trefis the reference temperature, and S is the solar irradiation (kW/m2), EG is the band-gap energy of the semiconductor used in the SPV cell (eV). Since normally Iph >> Isat and ignoring the small diode and ground-leakage currents under zero-terminal voltage, short-circuit current Isc is approximately equal to the photocurrent Iph.

The dynamic model of lead acid battery with an assumption of neglecting the difference between the charge and discharge resistances is shown . Battery is an electrical storage device, which has been considered equivalent to a capacitor (Cb).The capacitance (Cb) of the battery is modeled as a controlled voltage source in MATLAB, which is controlled relative to the state of charge of the battery [16, 17]. The expressions of battery voltage for charge and discharge are given as:

$$V_{batt} = V_0 - R_1 i - k\frac{Q}{it - 0.1Q}\cdot i^* - k\frac{Q}{Q - it}\cdot it + Exp(t)$$

$$\begin{cases} V_{batt} = V_0 - R_1 i - k\frac{Q}{Q - it}\cdot\left(it + i^*\right) + Exp(t) \\ \text{where } Exp(t) = B\cdot\left|i(t)\right|\cdot\left(-Exp + A\cdot u(t)\right) \end{cases}$$

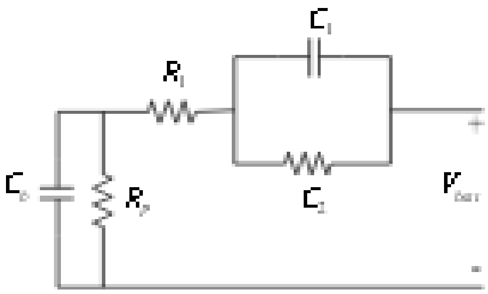

Fig:7Dynamic model of battery

where Vbatt is battery voltage (V), V0 is battery convoltage (V), k is polarization constant (V/Ah) or polarization resistance (Ω), Q is battery capacity (Ah), it id(t) is actual battery charge (Ah), A is exponential zone amplitude (V), B is exponential zone time constant inverse (Ah), i is battery current (A), i* is filtered current (A), R1 is battery resistance, Exp(t) is exponential zone voltage (V), i(t) is battery current (A), u(t) is charge or discharge mode, Rp is self-discharge resistance, R2 is over voltage resistance

IV.CONVERTERS

4.1 CUK CONVETER

CUK is essentially a boostconverter followed by a buck converter with a capacitor to couple the energy.The main applications of this circuit are in regulated dc power supplies, where a negative polarity output may be desired with respect to the common terminals of the input voltage and the average output is either higher or

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lower than the dc input voltage.The cuk converters have low switching losses and the highest efficiency. It can provide better output current characteristics due to the inductor on the output stage.

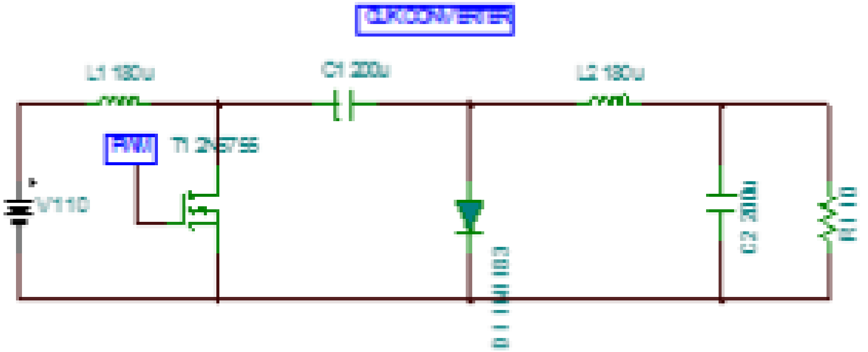

Fig. 8 cuk converter

Output voltage given by : $\frac{Vo}{Vi} = \frac{-D}{1-D}$

V. SEPIC CONVETER

SEPIC stands forSingle Ended Primary Inductor Converter is a type of converter, similar to a traditional buck-boost converter.Working of the SEPIC converter, When the MOSFET is closed, the capacitor and inductor charges. When theMOSFET opens, the capacitor discharges, boosting the output voltage. Based on the values inductor capacitor, the characteristics of SEPIC converter would be either bucktype or boost type. SEPIC converterhas advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown. However,it suffers a disadvantage of fairly hefty transient dump of charge before it delivers a constant output.

V.MICROCONTROLLER and PWM INVERTER

5.1. PI Controller

Pi controller is for the closed loop c system by which system will produce more accurate results, noise can be reduced .By varying ramp cycles in pi controller the output voltage can be varied.It is low cost ,used for wide range of application ,high quality and easily available.

5.2. Sine Wave PWM Inverter

Sine wave inverter represent the latest inverter technology. The wave form produced by these inverters is the same as or better than the power delivered by the utility. Harmonics are virtually eliminated and all appliances operate properly with this type of inverter. Pwm converter message into pulsing signal.

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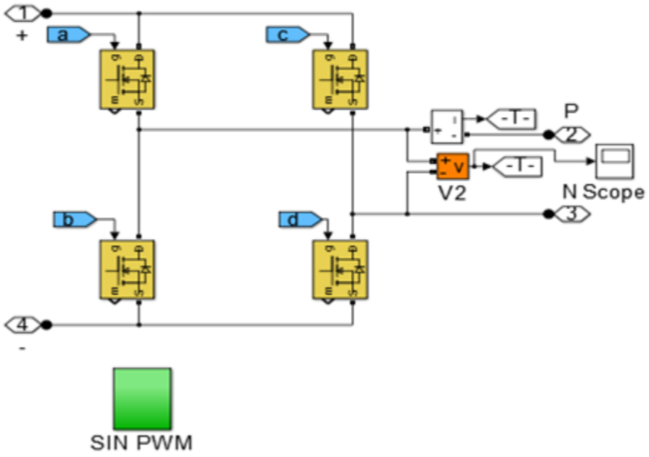

Fig :9 sine wave pwm inverter

VI. PROPOSED CONTROL STRATEGY

This paper focus on design , modeling and operational analysis integrated (Cuk & Sepic) converter, solar panel, Battery and power supply unit with the closed loop control. D.C voltage is generated from the solar panel and Battery. It will be given to integrated converter. Integrated converter is one of the SMPS topologies. SMPS circuit consists of the power circuit and the control circuit. The power stage performs the basic power conversion from the input voltage to the output voltage and includes switches and the output filter. All the converter output connecter to common grid. MICROCONTROLLER is programmed to generate PWM. Switching pulse to the boost converter, it is generated from PWM Controller. DC supply is applied to converter circuit from single-phase DC supply. The PWM pulses are given to input of Optocoupler. is used to isolate between Control circuit and driver circuit. Optocoupler output signal is inverted from original PWM input signal. Optocoupler output is given to driver circuit through NOT gate (NOT gate outputsignal same as the original input signal) finally we get AC signal and Load is connected to across the output terminal. The proposed control system for DCMG been implemented in MATLAB/Simulink environment.

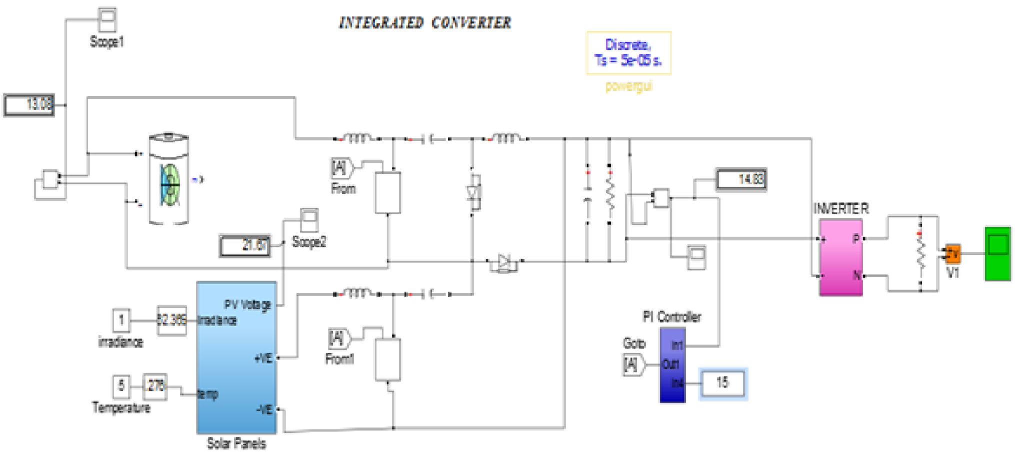

Fig : 11showing simulation in matlab

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VII. SIMULATION RESULTS

The hybrid solar and battery energy systems using CUK-SEPIC fused converter is studied and simulated. The simulation results is obtained by closed loop control and results are shown.closed loop PI controller with suitable and values to adjust the duty cycle of SEPIC and cuk converter.Results of includes PV array voltage, battery energy storage system , DC link voltage and load voltage.

A.Simulation 1 shows the results of battery energy storage system.wave form showing amount of energy stored in battery.

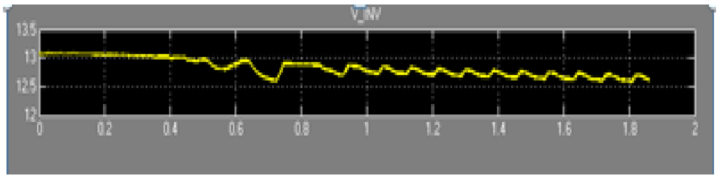

Fig: 12simulation result 1

B.Simulation 2 shows the result of pv cell. Wave form shows the result of pv panel before boosting:

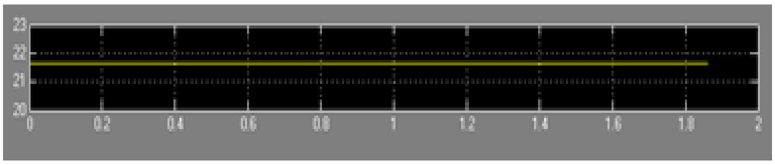

Fig:13 simulation result 2

C.Simulation 3shows the results of DC output voltage .

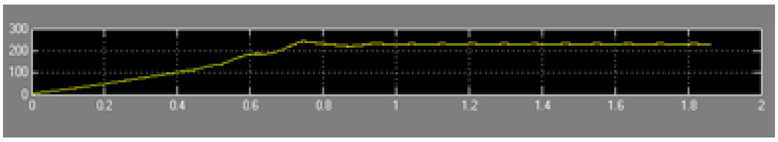

Fig: 14 simulation result 3

D. Simulation 4 shows the result of AC output voltage.

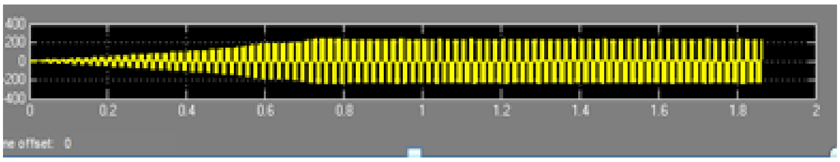

Fig: 15 simulation result 4

In this paper the CUK-SEPIC converter has been proposed for hybrid battery and solar energy system instead of conventional multiple boost converters. The system has following advantages compared to traditional approach:

1) Two boost converters are replaced by single CUK-SEPIC fused converter.

2) Additional input filters are not required to filter out high frequency harmonics because of inherent input filter.

3) Energy storage and transfer depends on capacitors of converter.

4) Both renewable energy sources can be stepped up/downby using converter andwhich supports wide range of PV

5) It supports both individual and simultaneous operation of sources

VIII. CONCLUSION

The proposed "smart dc microgrid "with fused sepic and cuk converter with integrated renewable energy allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The inherent nature of this Cuk-SEPIC fused converter, additional input filters are not necessary to filter out high frequency harmonics. The smart DCMG operates satisfactorily both under the transient and steady state condition.

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