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PV FED ZETA-SEPIC based Integrated Converter for Street Light System

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Abstract: This paper proposes an efficient cost-effective PV fed zeta-Sepic integrated converter for street lighting system. Generally, two separate power electronics converters are used for charging and discharging of battery.in proposed system zeta-Sepic converter is used as a single power electronics interface for the complete operation. Fractional order incremental conductance (FO-INC) algorithm is used for MPPT control. The integrated converter has at least components compared to those existing converter which have stepping up and stepping down capability in all modes. The proposed street light system is designed and modeled such that the performance is not affected under dynamic conditions. The suitability of proposed system at practical operation condition is demonstrated through simulation result using MATLAB/Simulink followed by an experimental validation.
Keywords: zeta-sepic integrated converter, charging mode, discharging mode

I. INTRODUCTION

With increase in demand of electricity and limited conventional energy resources solar photovoltaic become a favorable alternative as it is pollution free and easily available and has less maintainable cost. Solar panel is an assembly of photo-voltaic cell mounted in a frame work for installation. It uses sunlight as a source of energy to generate direct current electricity.

The major benefits of street lighting include, it is used for security in urban and rural areas. Street lighting increases the quality of life by increasing the working hours as the day and night are equally important for work now a days. Street lighting also provide safety for riders and drivers. If there is no sufficient light during driving causes majority of accidents. The analysis of road safety says that only 25% of travellers are during night but it provides 40% of total accident rate. Pedestrians and other road users suffer from decreased visibility in the dark too so that the street light system gets much importance in everyday life.

The use of photovoltaic-powered Light Emitting Diode (LED) in street light system is a major consideration since it is highly efficient and provide longer life time. This paper consists of a Zeta-Sepic integrated converter, which is used for managing the LED light, a PV panel, and a battery for storage. The proposed system provides compact efficient and single-stage power conversion.

The output from solar panel is given to an integrated converter. The low energy conversion effectiveness is a disadvantage in PV system in low radiation and temperatures so the MPPT needs to be operated for ideal efficiency and operations. MPPT methods not only enhance the power performance of PV but also increase the operating life of the PV system. In this proposed system fractional order incremental conductance algorithm is used.

A new zeta-sepic integrated converter for charging and discharging of battery in the street lighting application. Zeta-sepic integrated converter which has buck boost capability in each mode of operations. the converter act as a zeta converter during charging of battery and act as a sepic converter during discharging and electronics interface for the complete action.

II. PV FED ZETA-SEPIC BASED INTEGRATED CONVERTER

The block diagram of pv fed zeta-sepic based multifunctional integrated converter for street lighting system is shown in figure 1. the main components of block diagram are solar panel, MPPT control block, zeta- sepic integrated converter, control unit, battery and a load that is street lighting system. The output from solar panel is given to a zeta-sepic integrated converter through a MPPT control unit. The fractional order incremental conductance (FO-INC) algorithm is used. Zeta-sepic multifunctional integrated converter act as a single power electronics interface for charging and discharging. Battery gets charged through integrated converter, integrated converter act as a zeta converter during charging. Load is the lighting system. the battery discharges through the integrated converter when converter act as a sepic converter. The control unit provide gating pulses for the switches to control the modes of operation and also provide feedback from battery and load.

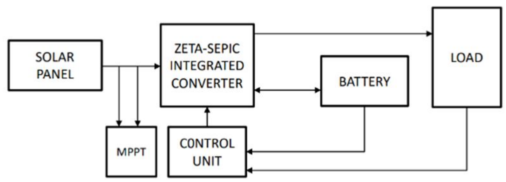

Fig1.block diagram of proposed system subsystem

III. MPPT CONTROL

MPPT method enhances the power performance of pv and also increases the operating life of the pv system. MPPT algorithms are usually used as electronic power convertion devices and the control signal is a duty cycle for peak load energy. To improve dynamic performance, FO-INC based on the nonlinear and fractional order changes of pv voltage and current has been proposed to track the maximum output power.

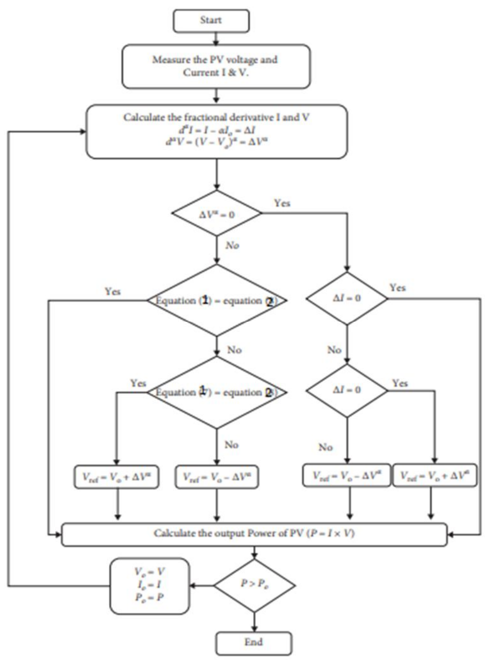

Fig 2.FO-INC algorithm flow chart

The FO-INC MPPT main criteria can be expressed by the equation (1)and(2)

1) dα I/ dVα ≈ I − αIo /(V − Vo)

2) dα/ dVα (− Io/ Vo) = (-1 /V)(Γ(2)/ Γ(2 − α)) (Io)^1- α- Io(Γ(0)/ (Γ(- α))Vo^(1- α)

The control procedure of the FO -INC algorithm can be expressed by the flow chart in fig.3.2.the procedure starts with measuring the PVs voltage and current to determine the MPPT action according to the following conditions

Condition 1.

If (ΔVα ≠ 0&(dα I/dVα) =(dα /dVα) (− I0/V0)) or (ΔVα = 0&ΔI = 0), keep the current duty cycle, fix the duty cycle

Condition 2.

If (ΔVα ≠ 0 & (dα I/dVα) > (dα /dVα) (− I0/V0)) or (ΔVα = 0&ΔI > 0), decrease the duty cycle of the Buck–Boost converter.

Condition 3.

If (ΔVα ≠ 0 & (dα I/dVα) < (dα /dVα) (− I0/V0)) or (ΔVα =0&ΔI < 0), increase the duty cycle of the Buck–Boost converter.

Condition 4.

Calculate Po = Vo × Io and P = V × I. If P > Po ⟶ terminate, otherwise update the voltage Vo = V, current Io = I, and power Po =P

IV. ZETA-SEPIC BASED INTEGRATED CONVERTER

A zeta-sepic based multifunctional integrated converter is a single power electronics interface for the complete operation of pv system. most of the cases two different power electronics converters are used for charging unit and discharging unit. being integrated to a single converter the complications in conversion reduces accordingly. this zeta-sepic integrated converter consist of buck boost stages in each mode of operation. The converter works as a zeta converter during charging of battery which can operate in buck boost modes also the converter works as a sepic converter in discharging to the load where sepic converter mostly a boost converter.

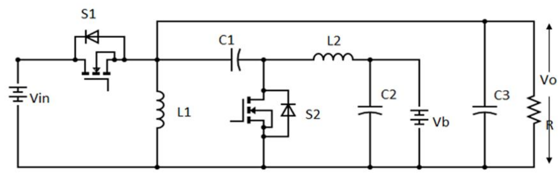

Fig.3.zeta-sepic integrated converter

The circuit diagram consists of two inductor LI, L2, three capacitors, C1, C2, C3, two switches S1, S2, a battery, resistor R is load resistance.in charging state and discharging state consisting of two different modes of operation. Zeta converter consist of switch S1 on and off state and also sepic converter stage consist of switch S2 on and off states.

A. *Charging Stage*

In charging mode, integrated converter act as a zeta converter. here only the charging part is considering for operation. the switch S1 operates for two different modes. switch S2 is off condition

1) Mode 1

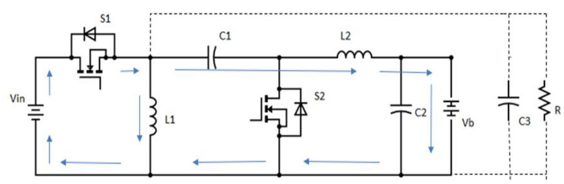

Fig.4. mode 1 operation of charging stage

The fig.4. shows the mode 1 operation of charging stage. In mode 1 operation switch S1 is on. The inductor L1 is charged through the input voltage. The capacitor C1 which is already charged get discharge and inductor L2 charges through C1.the current through L1 and L2 increases.

2) Mode 2

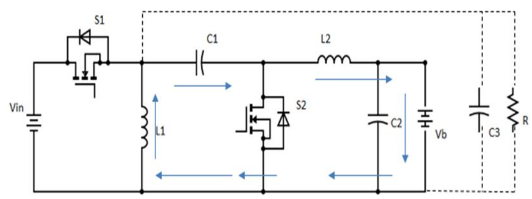

Fig.5.mode 2 operation of charging stage

The figure 5 shows the mode 2 operation of charging state in mode 2, switch S1is off. the previously charged inductors L1 and L2 discharges through the capacitor C1 and C2.the inductor current decreases linearly, Since the switch S1 is off

B. Discharging Stage

In discharging mode, the input from pv panel is not in the operation since the switch S1 is off. Here the battery discharges through the load. Load is the lighting system. the converter act as a sepic converter. Two modes of switch S2 is considering.

1) Mode1

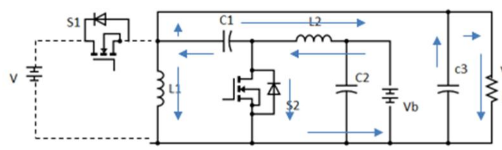

Fig.6.mode 1 operation of discharging stage

Figure.6. shows the mode 1 operation of discharge stage. L2 charges through the battery voltage .C1 is considered to be already charged hence the capacitor C1 gets discharged and inductor L1 get charged. capacitor C3 get charged and there is a voltage across the load resistor.

2) Mode 2

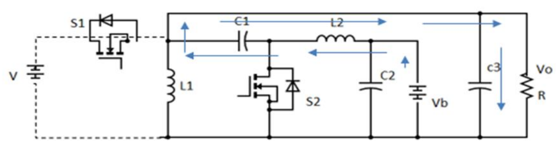

Fig.7.mode 2 operation of discharging mode

Figure.7 shows mode 2 operation of discharging stage. In mode two of discharging stage the switch S2 is off condition. The already charged L1and L2 gets discharged through load resistor and the capacitor C1geta charged. the capacitor C3 also discharges through load

V. SYSTEM DESIGN

A. Design Of PV Panel

The nonlinear equations of the PV system which describe the relationships between the different PV model parameters are developed and solved via MATLAB and Simulink tools where the PV cell electric circuit model is shown in Figure 8. The PV output current IPV can be obtained using equation (1) where Np and Ns are the number of parallel and series cells, respectively:

Ipv = Np × IG − ID – Ish (1)

The nonlinear equation of I-V characteristics of one diode PV model was expressed as follows: Ipv =Np * IG − Ns *Io [e ((q/ηkTk * ((VPV/Ns)+ (I PV/Np Rs)− 1)] − Np/ Rsh *(VPV/ Ns + IPVRs/ N)

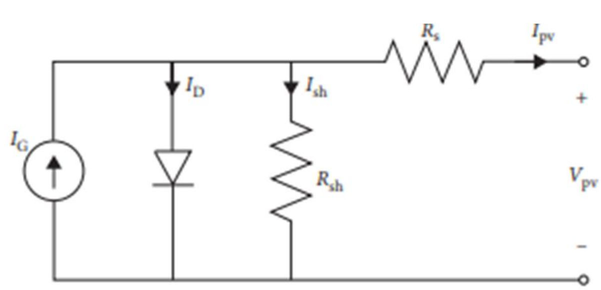

Fig.8 pv cell equivalent circuit model

where Vpv and Ipv are the PV terminal voltage and current, respectively, Rs and Rsh are the series and shunt resistance, respectively, η is the ideality factor, the Boltzmann's constant is k, q is the electron charge, Tk is the temperature degree in Kelvin, IG is photo-generated current, and the diode saturation current is Io.

The number of modules required to connect in series and parallel are shown in equation 4.2 and 4.3

$$Ns = Vm/Vmpp = 2 \quad (4.2)$$

$$Np = Im/Impp = 3 \quad (4.3)$$

The pv panel parameters are given in table below

Peak power Pm(w)	200
Open circuit voltage, Vo(v)	31.7
Voltage at MPP, (v)	26.3
Short circuit current, Is (A)	8.25
Current at MPP, Is(A)	7.66

Table.1.design of solar panel

B. *Design of ZETA-SEPIC Integrated Converter*

The zeta-sepic converter is simulated using MATLAB/Simulink. here the parameter of the converter has been calculated by the equation given below

$$L1 = L2 = 0.5*(Vo*Io)/Vi$$

$$C1 = IL/8*Vo*f$$

$$C2 = Io*D/(Vi*f)$$

D is the duty ratio,

$$D=(Vout-Vin)/Vout)$$

parameters	values
Inductor (L1, L2)	160e-6H
Resistor (R)	50ohms
Capacitor(C1) Capacitor(C2)	10e-6 8000e-6
Switching frequency	20KHZ
Input voltage	24V
Battery voltage	12V

Table 2.design of zeta-sepic integrated converter

VI. CONTROL OF THE SYSTEM

A. *MPPT Control*

In this MPPT block diagram, the duty cycle is generated by first sensing the PV voltage and current using the fractional order Incremental algorithm (FO-INC). MPPT control is used to control the proposed converter. The incremental approach is commonly used to track the maximum power point. A fractional order incremental is introduced in this technique to cause the PV module's power to vary. The PV output power is periodically measured and compared with the previous power.

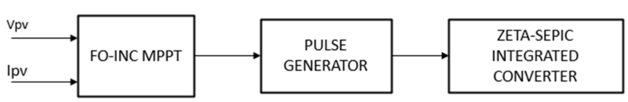

Fig.9. MPPT control block diagram

B. Closed Loop Control Of Zeta-Sepic Integrated Converter

The open loop operation is insensitive to load battery voltage variations it is preferable to go for closed loop control of zeta-sepic based integrated converter. The closed loop control uses a comparator which compares the desired value of voltage to the feedback signal from the system. The generated error signal can be processed to control the converter in order to reduce the error. The output voltage or battery voltage compared with a reference value and thus generate a error signal. The error signal thus produced has been compared with the high frequency carrier signal in order to generate the gate pulse.

VII. SIMULATION DIAGRAMS AND RESULTS

Simulink is a MATLAB-based graphical programming environment for simulating ,modeling and analyzing multidomain dynamical systems. The simulation environment of SIMULINK has high flexibility and expandability which allows a detailed analysis of a electrical system.

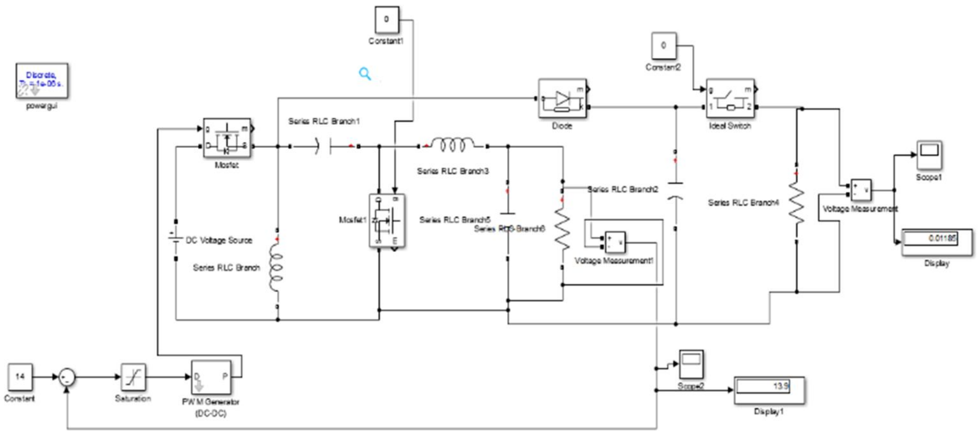

Fig. 10 simulation diagram of integrated converter in Charging mode

A closed loop operation of zeta-sepic converter is done at designed rating. The figure 10 shows the charging mode simulation diagram. Here the charging voltage is analyzing so that the battery is substituted with a resistance R1 and the value is measured. the switching frequency is 20khz when a input of 24 v is given the integrated converter buck the voltage and output voltage at voltage side is obtained as 12V.

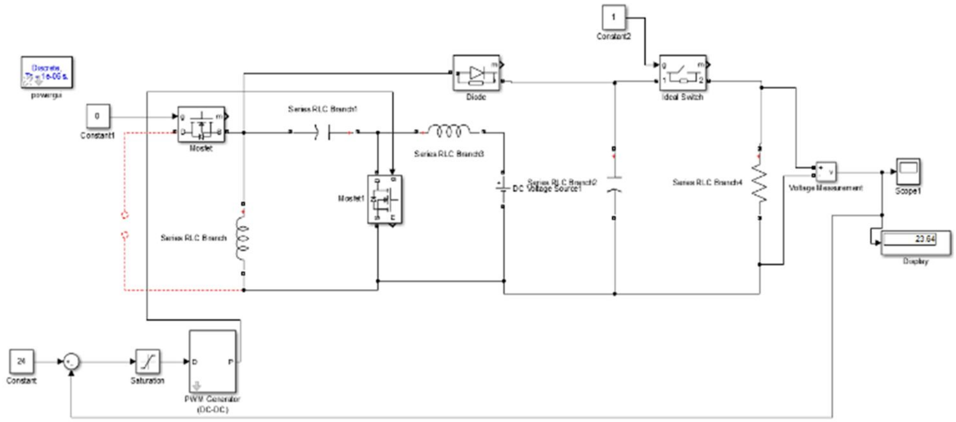

Fig.11. simulation of integrated converter in Discharging mode

Simulation of the discharging mode of the zeta-sepic integrated converter is given in figure.11.Here the feedback is given to the load side so that the 12V from the battery is discharged through the integrated converter the converter act as a sepic converter and sepic converter is generally a boost converter .so the output voltage is 24 V. the load resistance is 50ohms.

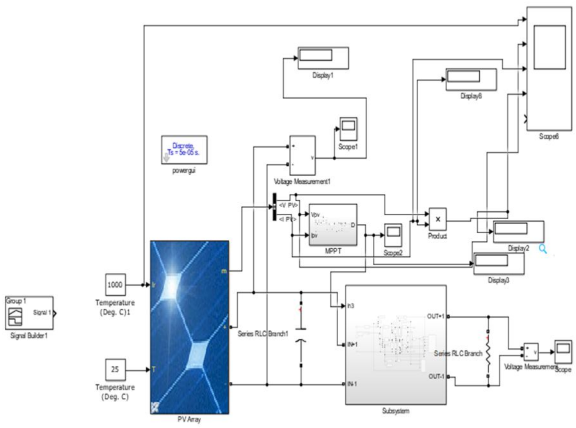

Fig.12.simulation diagram of proposed system

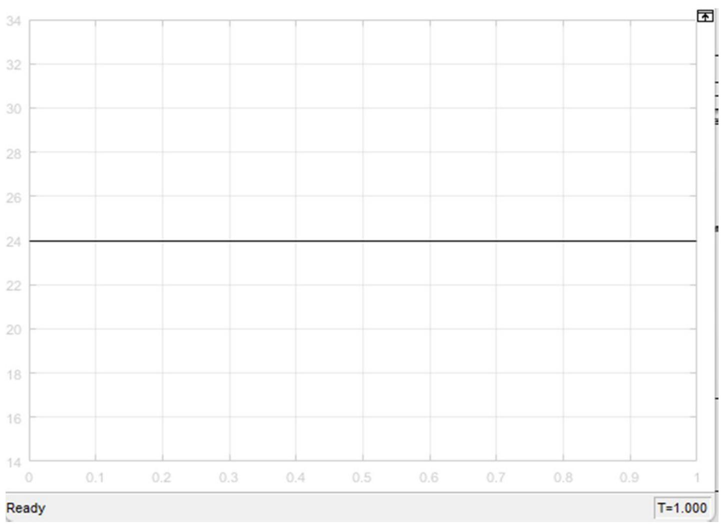

Fig.13. input waveform of converter

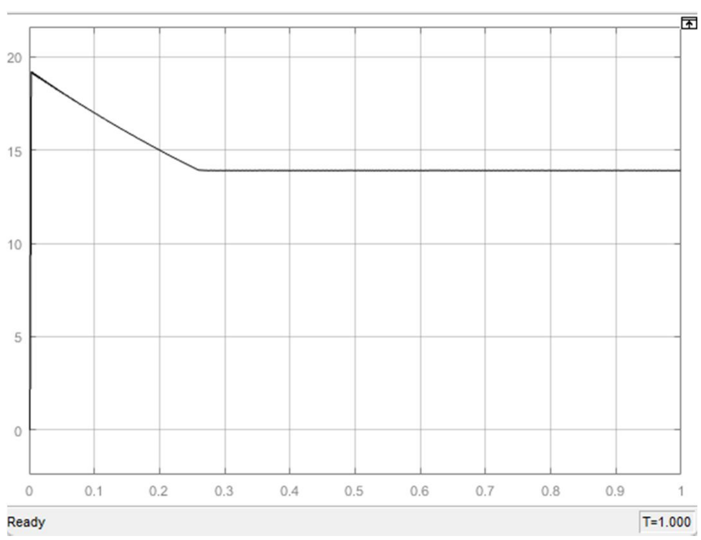

Fig.14. waveform of charging mode

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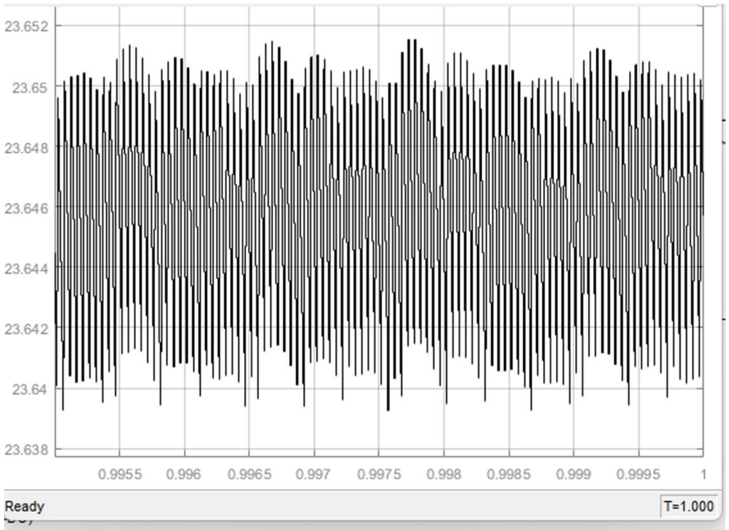

Fig.15 waveform of discharging mode

VIII. HARDWARE IMPLIMENTATION

The hardware of the proposed system was setup at the laboratory. The figure 16 shows the prototype of the proposed system. The main components in the hardware section are explained. The switching pulse is given to the modified converter by a PIC microcontroller and are amplified with the help of a TLP250H driver circuit. The metal-oxide semiconductor field-effect transistor is a type of field-effect transistor that is most typically made by oxidizing silicon under regulated conditions. Electronic signals can be amplified using the capacity to vary conductivity with the amount of applied voltage. In this circuit, the MOSFET is an IRF460. It has the benefits of repetitive avalanche ratings, extremely low losses and easy to use/drive

Here we use a dc source instead of pv panel. A battery of 12 v is used for charging purpose. LED light of 24 V is given as load .

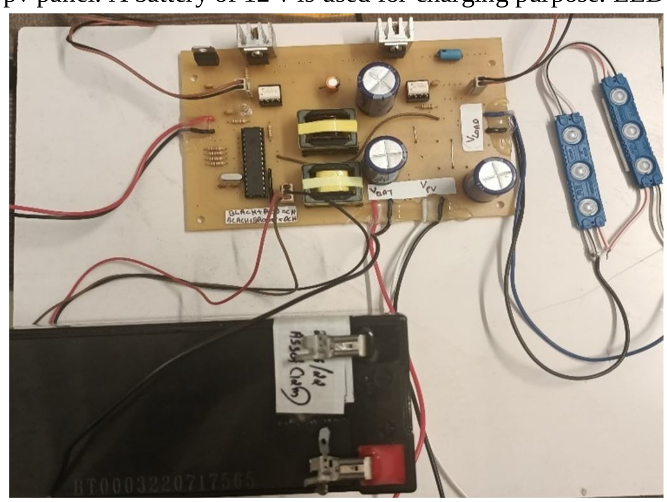

Fig.16.1Hardware diagram

IX. CONCLUSION

Implemented a zeta-sepic based multifunctional integrated converter for pv fed street light system. The maximum power is tracked by fractional order incremental conductance (FO-INC).The MPPT technology is analyzed using MATLAB simulation and is satisfactory for the integrated converter. The proposed converter act as a single power electronics interface for complete action. Here charging and discharging is take place through the single integrated converter unlike the existed one hence it contributes to the low cost and 91% efficiency over performance. The operation of the proposed integrated converter is analyzed through MATLAB simulation and verified the theoretical concept and derived the equation and waveforms. Developed an efficient integrated converter for pv fed street light system

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