PV Based EV Charging Using KY Converter

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Abstract—The transition toward sustainable transportation has intensified the need for efficient integration of renewable energy sources with electric vehicle (EV) infrastructure. This research presents a photovoltaic (PV)-based EV charging system utilizing an improved KY converter, offering an effective solution for managing the variability of solar energy while ensuring reliable EV charging. The KY converter's unique ability to operate in both step-up and step-down modes allows it to accommodate fluctuating PV output voltages, delivering a stable and regulated DC supply. Its features—low output voltage ripple, fast transient response, and high efficiency—position it as a superior alternative to conventional DC-DC converters in renewable energy applications. To further enhance system stability, a proportional-integral (PI) controller is integrated, enabling dynamic adjustment of the converter's duty cycle to maintain a constant DC link voltage under varying solar irradiance. This closed-loop control significantly improves the system's responsiveness and reliability, ensuring optimal performance regardless of environmental conditions. Simulation results confirm the effectiveness of the proposed system in maintaining voltage stability and efficient energy transfer, validating its potential for real-world implementation. By reducing dependence on fossil fuels and minimizing greenhouse gas emissions, the system supports broader environmental goals and advances clean energy adoption in transportation. This work demonstrates that the combination of PV technology with intelligent power electronic control through the KY converter offers a scalable and eco-friendly solution for EV charging. The findings contribute to the development of sustainable, smart transportation systems that align with global energy and climate objectives.

Index Terms—Electric Vehicle (EV) Charging, KY Converter, Photovoltaic (PV) System, Proportional-Integral (PI) Control, Renewable Energy Integration

I. INTRODUCTION

The global shift toward sustainable energy and transportation has made electric vehicles (EVs) a vital component in reducing greenhouse gas emissions and fossil fuel dependency. Unlike traditional vehicles powered by internal combustion engines, EVs rely on electric motors and rechargeable batteries, offering cleaner and more efficient transportation solutions [1], [2]. With the rapid growth of the EV market, there is an increasing need for reliable, efficient, and widely accessible charging infrastructure [3], [4].

EV battery charging typically occurs across three standardized levels: Level 1 uses standard 120V AC outlets and offers the slowest charging rate, making it suitable for overnight home charging. Level 2, operating at 240V, provides faster charging and is common in residential and commercial environments. DC Fast Charging (Level 3) uses high-power direct current to rapidly recharge vehicles, often restoring 80% of battery capacity in under an hour [5], [6]. However, as EV charging stations become more widespread, concerns about increased grid loads, peak demand, and carbon emissions have intensified.

To address these concerns, integrating renewable energy sources, particularly photovoltaic (PV) solar energy, with EV charging systems presents a promising solution. PV systems convert sunlight into electricity and can be deployed on rooftops, carports, or open land, providing decentralized, emissions-free energy for vehicle charging [7], [8]. Solar-powered EV charging not only reduces dependency on grid electricity but also enhances energy sustainability by minimizing lifecycle emissions associated with EV operation [9], [10].

However, the inherent variability of solar energy, due to fluctuating irradiance, temperature, and shading, results in inconsistent voltage and current outputs from PV panels [11]. This variability poses

challenges for directly charging EV batteries, which require stable and controlled voltage and current levels to ensure battery safety, lifespan, and efficiency. To overcome this, DC-DC converters are essential in PV charging systems to regulate and condition the output before supplying it to the battery [12].

DC-DC converters also facilitate maximum power point tracking (MPPT), a critical technique that ensures PV panels operate at their most efficient point under changing environmental conditions [13], [14]. By dynamically adjusting the operating voltage of the PV array, MPPT enables maximum energy harvest. Common converter topologies used in such applications include buck, boost, and buck-boost converters. While effective, these traditional converters often suffer from performance limitations such as pulsating input/output currents, higher voltage ripples, and reduced efficiency under varying load conditions [15].

In contrast, the KY converter, first introduced in [16], presents a more advanced topology that offers continuous input and output currents, lower voltage ripple, and better voltage gain than conventional boost converters. These characteristics make it highly suitable for applications involving renewable energy and battery storage systems. The KY converter is particularly effective in scenarios requiring a large voltage boost from low-voltage sources like PV arrays while maintaining efficiency and minimizing electrical stress [17], [18].

Further enhancement of system performance can be achieved by incorporating a proportional-integral (PI) controller into the KY converter. The PI controller monitors the DC output voltage and dynamically adjusts the duty cycle of the converter, maintaining output stability even as the solar input fluctuates throughout the day [19]. This feedback control loop improves system responsiveness and voltage regulation, which are critical for safe and efficient EV charging.

This research proposes a PV-based EV charging system utilizing a KY converter integrated with a PI controller, aiming to improve the energy conversion efficiency, voltage stability, and overall system reliability. The system is modeled and simulated in MATLAB/Simulink to evaluate its performance under varying irradiance levels and loading conditions. Emphasis is placed on analyzing voltage ripple, tracking response, output regulation, and converter efficiency. Simulation results demonstrate the proposed converter's ability to provide a clean, regulated DC output suitable for EV charging.

In summary, this study presents an efficient and reliable solution for solar-powered EV charging using a KY converter, showcasing its potential to enhance the practicality and sustainability of electric mobility.

II. THEORETICAL BACKGROUND

A KY converter is a type of DC-to-DC converter that can boost the input voltage to a higher output voltage. It is a relatively new type of converter, having been first proposed in 2005, but it has quickly gained popularity due to its number of advantages over more traditional boost converters. One of the key advantages of the KY converter is its fast transient response. This means that it can quickly respond to changes in load current, making it ideal for applications where load fluctuations are common. Another advantage is its low output voltage ripple. This is because the output current of the KY converter is non-pulsating, which reduces the stress on the output capacitor and results in a smoother output voltage. The KY converter is also more efficient than traditional boost converters, and it can operate over a wider range of input and output voltages. This makes it suitable for a wide range of applications like renewable energy systems, such as solar and wind power, electric vehicles and hybrid electric vehicles, battery-powered devices, industrial automation systems and power supplies for electronic devices.
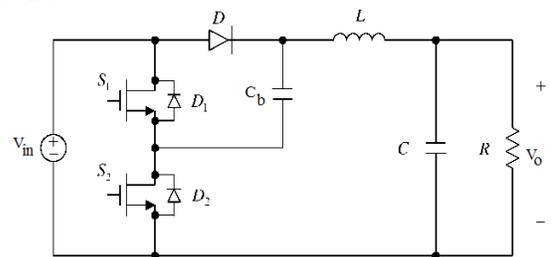

Fig.1. Basic KY converter

Fig.1 shows the KY boost converter. It is constructed with two semiconductors switching devices S_1 and S_2, a diode D, energy transferring capacitor C_b, output

inductor L, and the output capacitor C. The working of KY converter can be explained in two modes as follows:

Mode-1: $S_1 = ON, S_2 = OFF$
In this mode, the inductor L is magnetized as the voltage across inductor L is,
$$V_L = V_{in} + V_c - V_O$$
Neglecting voltage drop across diode D,
$$V_C = V_{in}$$
$$\therefore V_L = 2V_{in} - V_O$$
Here the capacitor Cb is discharged

Mode-2: $S_1 = OFF, S_2 = ON$
In this mode, the inductor L is demagnetized as the voltage across inductor is,
$$\therefore V_L = V_{in} - V_O$$
Here the capacitor Cb is quickly charged to the input voltage level in very short interval.
The voltage gain is thus given as
$$A = \frac{V_O}{V_{in}} = 1 + D$$

III. PROPOSED SYSTEM

The block diagram of proposed KY converter-based PV system is shown in Fig.2. The output voltage of PV panel and the load voltage is taken as feedback for the controller. The controller generates PWM pulses to compensate for error between desired voltage and actual voltage. A driver circuit is required to provide the necessary isolation between low power controller circuit and the high-power circuit of the converter.
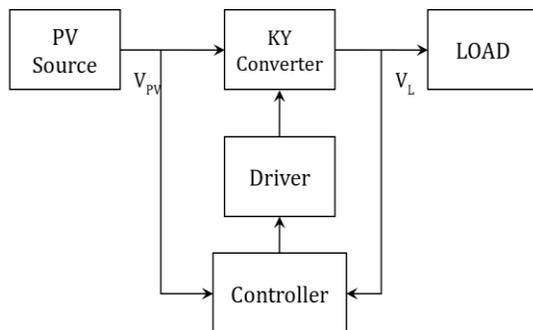

Fig.2. Block diagram of proposed system

The KY converter will be designed by considering the rating of PV panel and the load. It is proposed to regulate the output voltage of KY converter by PI control. This controller will regulate the output voltage by controlling the duty cycle of PWM pulses.

IV. DESIGN OF KY CONVERTER FOR EV CHARGING APPLICATION

For case study, a KY converter is designed for the specifications as mentioned in table I.

Table I. System Specifications

Particulars	Specification
Input Voltage (Vin)	12V
Output Voltage (Vo)	20V
Frequency	10Khz
PV Panel	12V, 50 W

The output current of KY converter is,
$$I_o = \frac{P_O}{V_O} = \frac{50}{20} = 2.5A$$
The input current of KY converter is,
$$I_{in} = \frac{P_{in}}{V_{in}} = \frac{50}{12} = 4.16A$$
The voltage gain is
$$A = \frac{V_O}{V_{in}} = \frac{20}{12} = 1.66$$
Therefore, the duty cycle of converter is calculated as,
$$A = 1 + D$$
$$\therefore D = 0.66$$
For calculating inductor value, the voltage across inductor is considered.
By KVL, the voltage across inductor is,
$$V_L = 2\,V_{in} - V_o = 4V$$
The basic equation of inductor is,
$$V_L = L\frac{di}{dt}$$
$$\therefore L = V_L\frac{dt}{di}$$
Here, the interval dt is,
$$dt = \frac{D}{f}$$
The current di is ripple current of the inductor. It is assumed that the inductor ripple current is 30%
The inductor current is,
$$I_L = 2\,I_{in} = 2 * 4.16 = 8.32\ A$$
$$\therefore di = 0.40 * 8.32 = 3.33\ A$$
Substituting these values in the equation of inductance,

$$L = V_L \frac{dt}{di} = V_L \frac{D}{f.di} = 4 \frac{0.66}{10000 \times 3.33} = 79 \mu H$$

The current through capacitor C_b is,

$$I = C_b \frac{dV}{dt}$$

$$C_b = I \frac{dt}{dV} = I_{in} \frac{D}{f \, dV}$$

Assuming dV, the ripple voltage across capacitor to be 2% of the source voltage,

$$dV = 0.01 \times 12 = 0.24$$

$$C_b = I_{in} \frac{D}{f \, dV} = 4.16 \frac{0.66}{10000 \times 0.24} = 1100 \, \mu F$$

For output capacitor,

$$I = C_o \frac{dV}{dt}$$

Assuming dV, the ripple voltage across capacitor to be 1% of the output voltage,

$$dV = 0.01 \times 20 = 0.2$$

$$C_o = I_{out} \frac{D}{f \, dV} = 2.5 \frac{0.66}{10000 \times 0.2} = 825 \, \mu F$$

Table II summarizes the component specifications of the KY converter

Table II. KY Converter Components Specifications

Particulars	Specification
Input Voltage (Vin)	12V
Output Voltage (Vo)	20V
Frequency	10Khz
PV Panel	12V, 50 W

V. MATLAB SIMULATION AND RESULTS

The MATLAB Simulink Model of PV based EV charger with KY converter is shown in Fig.3. The system consists of a PV array as a source of energy. The KY converter is deployed as a boost converter to increase the voltage. The EV battery of 18V is to be charged with this converter. Hence the KY converter is tuned to deliver 10% higher voltage than that of the battery voltage. The reference voltage for KY converter is set to 20V. The difference between the reference voltage and actual voltage i.e. error signal is fed to a PI controller which gives the duty cycle as output signal. This duty cycle is further given as input to the PWM generator. The PWM generator provides the gate pulses for the operation of the KY converter. The converter delivers 20V output voltage for charging of the EV battery.
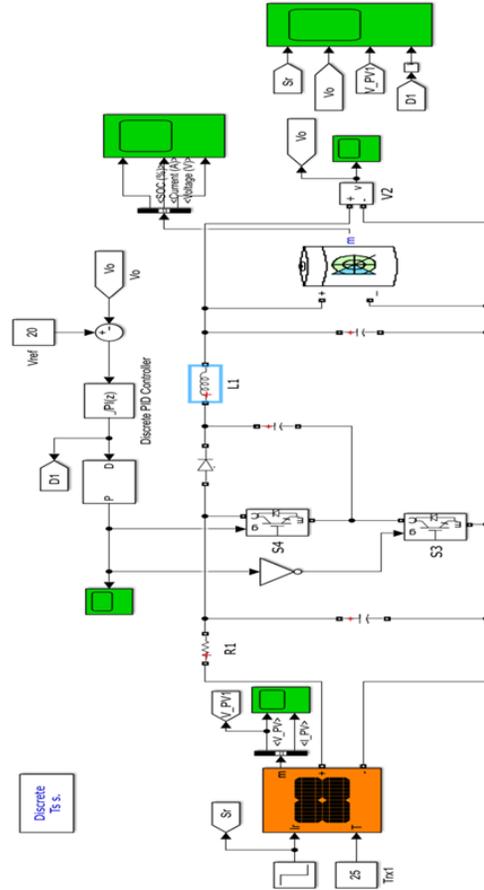

Fig.3. MATLAB Model of PV based EV Charger with KY Converter

The Fig.4 shows waveforms for PV system. The effect of varying irradiance on PV voltage and current is seen. The top graph demonstrates a step change in irradiance (measured in lux), where the value drops from approximately 1000 lux to about 500 lux at the 0.06-time mark. This simulates what happens when a cloud passes over a solar panel or when partial shading occurs in real-world conditions. The abrupt nature of this change allows us to observe how quickly the PV system responds to variations in solar intensity. The middle graph tracks the PV voltage (V_PV) over the same time period. Before the irradiance change, the voltage stabilizes at approximately 15V. When the irradiance drops at t=0.06, there is a slight decrease in voltage to about 13-14V, but the change is relatively minor compared to the 50% reduction in irradiance. The bottom graph shows the PV current (I_PV) response. The current experiences initial transients at system startup but stabilizes at around 8A before the irradiance change.
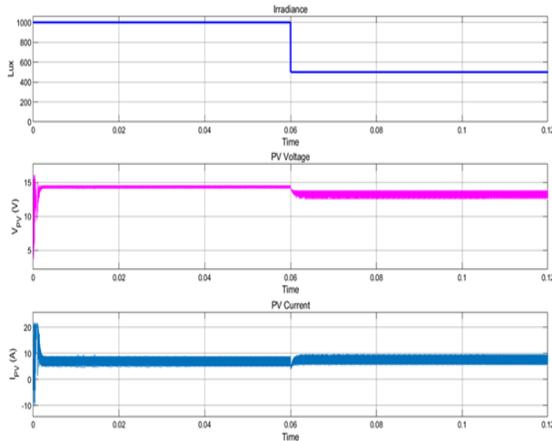
Fig.4. Irradiance, PV Voltage and PV Current

The Fig.5 show the graph of the output voltage of KY converter, irradiance, and duty cycle. The change in PV radiations causes the PV voltage to drop a bit. The closed loop controller increases the duty cycle in proportion and hence the output voltage of the KY converter is regulated to a constant value despite the changes in input source. Hence the closed loop system of KY converter is capable of delivering a constant voltage for charging of the battery.
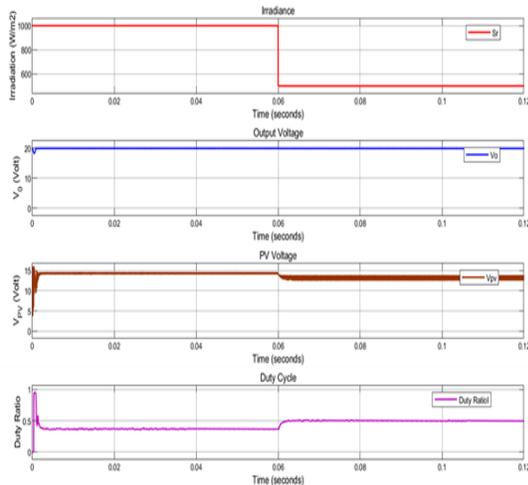

Fig.5. Irradiance, KY Converter Output Voltage, PV Voltage and duty cycle

The Fig.6 shows graph of state of the charge, current and voltage of the battery system. The increasing value of the state of charge throughout the simulation interval indicates that the battery is getting charged. At the time instance, 0.06S, a small drop in the current is seen on account of decreased PV radiation.
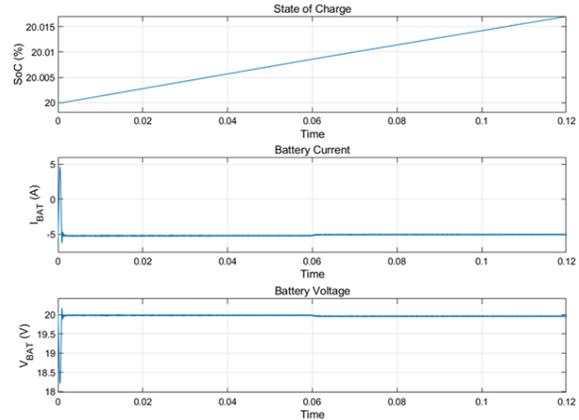

Fig.6. Battery SoC, Current and Voltage

VI. CONCLUSION

The implementation of a photovoltaic (PV)-based electric vehicle (EV) charging system using an improved KY converter demonstrates significant advancements in renewable energy utilization for sustainable transportation. The KY converter efficiently steps up or down the fluctuating PV output voltage, ensuring a stable and optimized power supply for EV charging. Its low voltage ripple, rapid transient response, and high efficiency make it superior to conventional converters. The integration of a proportional-integral (PI) controller further enhances system stability by dynamically adjusting the converter's operation to maintain a steady DC link voltage despite variations in solar irradiance. This system not only supports clean energy generation but also reduces reliance on fossil fuels, contributing to lower greenhouse gas emissions. By combining PV energy with advanced power electronics like the KY converter, the solution ensures reliable, efficient, and environmentally friendly EV charging. Such innovations pave the way for scalable renewable energy applications in modern transportation systems while addressing global energy and environmental challenges.

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