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Renewable Energy based Grid Interactive Charging Station with DC-DC Converter for EV with Power Quality Improvement

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Abstract: The rapid growth of the electric vehicle (EV) market has led to an increased demand for efficient and sustainable charging infrastructure. This paper presents a novel approach to addressing this demand by introducing a renewable energy-based grid-interactive charging station equipped with a DC-DC converter for EVs, focusing on power quality enhancement. The proposed system integrates renewable energy sources, such as solar panels and wind turbines, to contribute to the charging station's power supply. The DC-DC converter plays a pivotal role in managing power flow between the renewable energy sources, the grid, and the EVs. The key objective of this research is to not only facilitate the charging process for EVs but also to ensure the overall power quality of the grid. Power quality improvement is achieved through advanced control strategies that enable bidirectional power flow and voltage regulation. The DC-DC converter functions as an intermediary device, enabling efficient power transfer between various sources and loads while maintaining stable voltage levels. This contributes to a reduced impact on the grid, mitigating issues such as voltage fluctuations and harmonic distortions. Moreover, a unified controller is designed to achieve four-quadrant operation (V2G/G2V), vehicle to home power transfer, reactive power compensation and active filtering etc.
Keywords: *EV (Electric Vehicle), Renewable energy, DC-DC Converter, Power Quality, Bidirectional Converter.*

I. Introduction

The increasing adoption of electric vehicles (EVs) as a sustainable transportation solution has led to the growth of charging infrastructure. However, the integration of EV charging stations into the existing power grid presents several challenges, including power quality issues and the need for renewable energy integration. To address these challenges, the concept of a Renewable Energy-Based Grid-Interactive Charging Station with DC-DC Converter for EVs with Power Quality Improvement has emerged as a promising solution. The global shift towards sustainable transportation has accelerated the demand for electric vehicles. EVs offer lower emissions, reduced dependency on fossil fuels, and overall environmental benefits. As the EV market expands, the need for efficient and reliable charging infrastructure becomes paramount.

This study aims to contribute to the field of sustainable transportation and energy by proposing an integrated solution that benefits both the EV users and the power grid. The implementation of renewable energy sources and advanced control strategies can lead to reduced carbon emissions, increased grid stability, and enhanced overall power quality. The integration of renewable energy sources, DC-DC converters, and intelligent control strategies in grid-interactive charging stations holds immense potential for advancing the EV charging infrastructure while improving power quality and contributing to a more sustainable energy ecosystem.

II. Power Quality

For the purpose of this article, we shall define power quality problems as:
“Any power problem that results in failure or mis operation of customer equipment, Manifests itself as an economic burden to the user, or produces negative impacts on the environment.”
When applied to the container crane industry, the power issues which degrade power quality include:

- Power factor
- Harmonic Distortion
- Voltage Transients
- Voltage Sags or Dips

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- Voltage Swells

The AC and DC variable speed drives utilized on board container cranes are significant contributors to total harmonic current and voltage distortion. Whereas SCR phase control creates the desirable average power factor, DC SCR drives operate at less than this. In addition, line notching occurs when SCR's commutate, creating transient peak recovery voltages that can be 3to 4 times the nominal line voltage depending upon the system impedance and the size of the drives. The frequency and severity of these power system disturbances varies with the speed of the drive. Harmonic current injection by AC and DC drives will be highest when the drives are operating at slow speeds. Power factor will be lowest when DC drives are operating at slow speeds or during initial acceleration and deceleration periods, increasing to its maximum value when the SCR's are phased on to produce rated or base speed. Above base speed, the power factor essentially remains constant. Unfortunately, container cranes can spend considerable time at low speeds as the operator attempts to spot and land containers.

Poor power factor places a greater kVA demand burden on the utility or engine-alternator power source. Low power factor loads can also affect the voltage stability which can ultimately result in detrimental effects on the Life of sensitive electronic equipment or even inter mittent malfunction. It has been our experience that end users often do not associate power quality problems with Container cranes, either because they are totally unaware of such issues or there was no economic Consequence if power quality was not addressed. Before the advent of solid-state power supplies, Power factor was reasonable, and harmonic current injection was minimal. Not until the crane Population multiplied, power demands per crane increased, and static power conversion became the way of life, did power quality issues begin to emerge.

III. Existing System

The most common way to integrate the PV array with the charging station is through a DC-DC boost converter, which is used for maximum power point tracking of PV array. Instead of using a VSC for the integration of a permanent magnet brushless DC generator (PMBLDCG), a simple topology consisting only of a diode bridge rectifier followed by a boost converter is used for the conversion of power from WECS based on PMBLDCG.

3.1Disadvantages

- SOGI-FLL (Second order generalized integrator) makes it difficult to implement at variable voltage condition.
- Poor Power Quality.
- High Harmonics distortions

IV. Proposed System

- Design of a PV array and WECS based integrated system for EV charging and household supply.
- An Bidirectional based current control is used to control the charging station and to enhance the grid's power quality at distorted and unbalance voltages with the presence of DC offset in load currents.
- A PV array with boost converter and WECS with DC-DC converter are connected to the charging station.
- A unified controller is designed to achieve four-quadrant operation (V2G/G2V), vehicle to home power transfer, reactive power compensation and active filtering.

BLOCK DIAGRAM

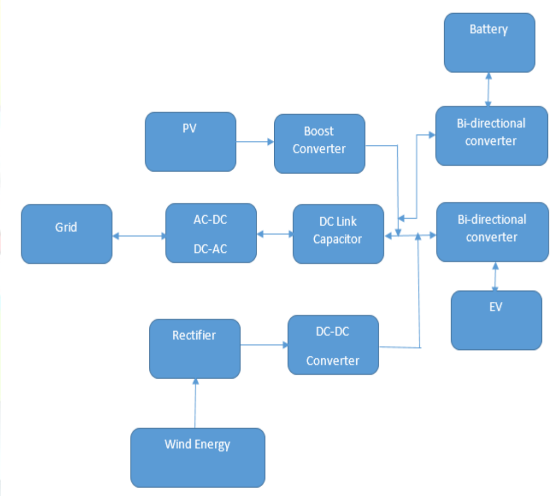


Fig 1: Proposed Block Diagram

APPLICATIONS

- EV battery charging
- Electronics device charging
- Small scale Industrial application
- Grid power transfer applications

V. DC-DC Boost Converter

Power for the boost converter can come from any suitable DC sources, such as battery, PV, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC converter.

A boost converter is a DC to DC converter with an output voltage greater than the input voltage. A boost converter called a step-up converter and its "steps up" the source voltage. Since power ( ) must be conserved, the output current is lower than the input current. Examples of DC to DC converter are:

- **Boost converter** is power converter which input voltage is less than DC output voltage. That means solar input voltage is less than the battery voltage in system.

PV CELL MODELING

A p-n junction fabricated in a layer of a semiconductor forms a photovoltaic cell structure. The ideal solar cell is a semiconductor diode connected in parallel to a current source with series resistance, and parallel resistance as shown in Fig. 3 [13].

Fig. 2. Photovoltaic unit

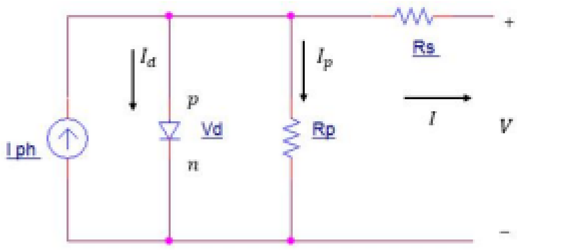


Fig. 3. Equivalent circuit of a PV cell with single-diode model

$$I = I_{ph} - I_0[e^{\frac{q(V+R_S I)}{nkT}} - 1] - \frac{V + R_S I}{R_{ph}} \quad (1)$$

$$V_d = V + IR_s \quad (2)$$

A simple equivalent photovoltaic cell circuit model includes a diode in parallel with a current source and a resistor as shown in Fig. 3.

VI. SIMULATION RESULTS

Simulation circuit diagram:

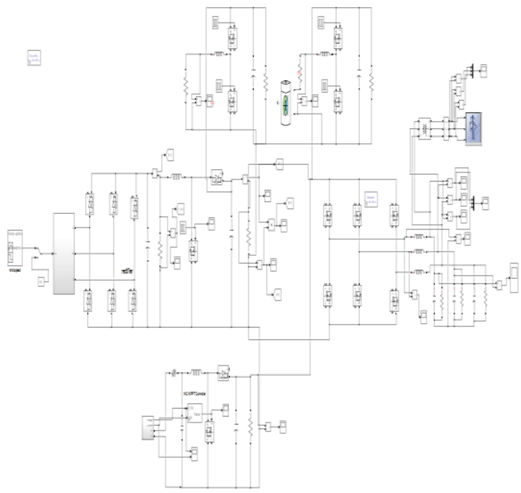
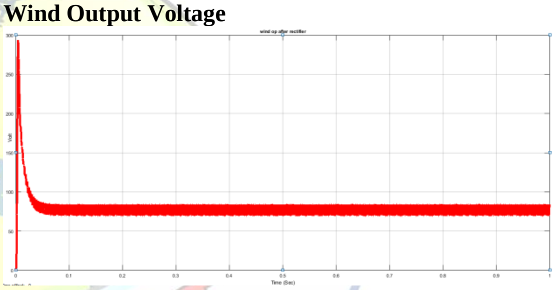
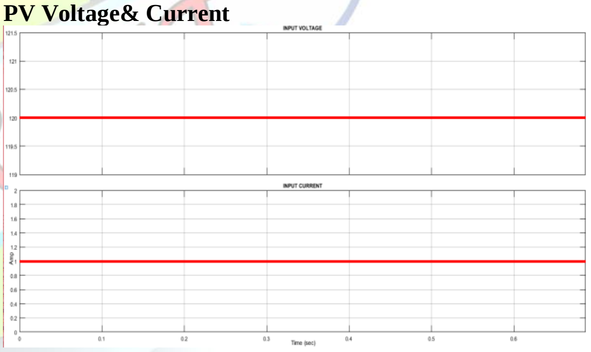


Fig: 6.1 Proposed simulation Circuit

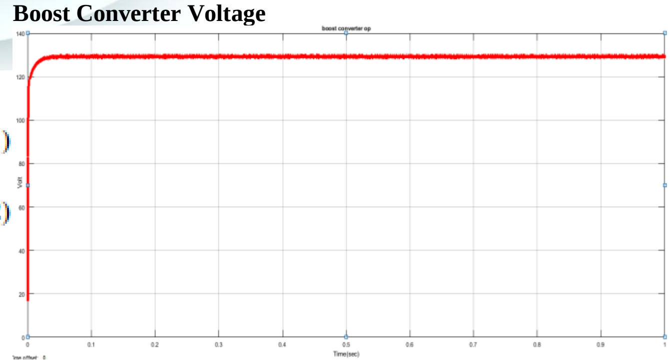
Wind Output Voltage



PV Voltage& Current



Boost Converter Voltage



Battery Charging Voltage

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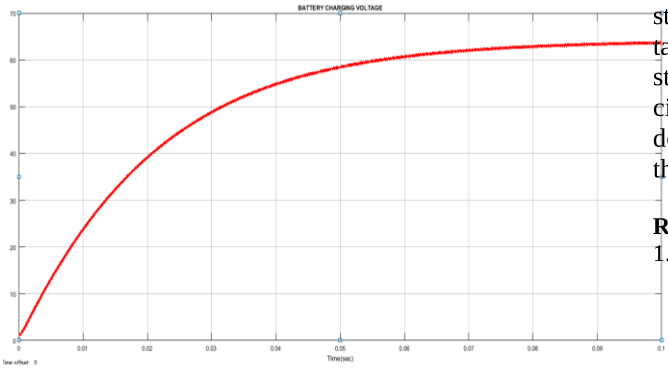
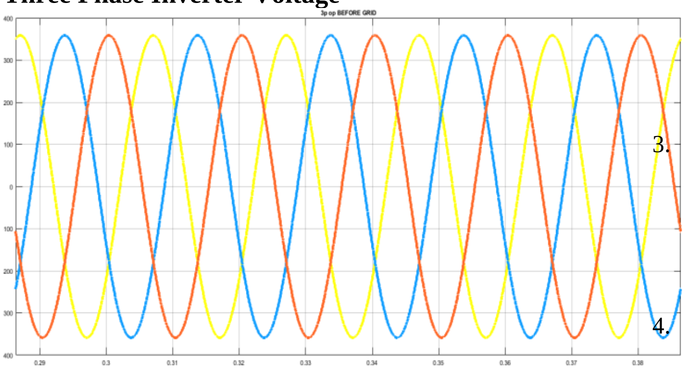
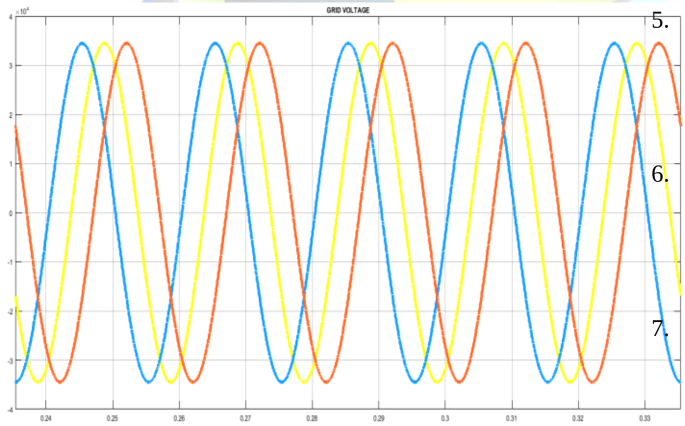


Three Phase Inverter Voltage



Grid Voltage



VII. CONCLUSION

In this study, a hybrid renewable energy system with EV charging system is comprised of the energy obtained from wind including accumulator energy storage unit is designed and tested. It is concluded that the power quality problems caused by the variable factors in the wind turbine are reduced with the proposed system. The proposed system has reduced the fluctuations in power a better quality in power. At the same time, modeling has been found to improve system stability and reliability, and the proffered system takes a rapid transient response, providing a stability in the operation even under the unexpected circumstance. In this system, the energy supply and demand balance was realized and it was concluded that the efficiency of the system increased.

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