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Techno Economic Process for the ESS by using Bidirectional Battery Converter in Locomotive Systems

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ABSTRACT

Regenerative energy from braking should be used more frequently in high-speed rail systems in order to save operating costs and improve power quality. This technology suggests an economical method for the energy storage in the train of hybrid renewable energy sources. The proposed railway station design incorporates solar, wind, and battery technology for an effective energy storage system. Through a BUCK-BOOST converter, the solar system delivers voltage to the inverter. To regulate the DC bus by voltage and the buck-boost converter by current, an energy management strategy is given. A PWM rectifier is used in WECS with DFIG to convert AC to DC, and a PI controller is used to operate the rectifier. Through a 3 VSI, which changes the DC voltage into AC voltage, the converter's power output is delivered to the grid. The LC filter is used to improve the inverter's output. The power that is produced of the PV/FC input power sources as well as the AC power fed into the power grid are the control outputs. The results show that the proposed approach performs better with increased efficiency and less harmonics.

Key Words:ESS-Energy Storage System, PWM – Pulse Width Modulation, PI – Proportional and Integral, PV-Photovoltaic, ERS-Electric Railway System.

1. INTRODUCTION:

There has been a renewed push to reduce the usage of hydrocarbons for the production of electric power as well as transportation due to environmental and geopolitical concerns. Due to these worries, grid-connected and standalone renewable energy sources, such wind turbines and solar arrays, are increasingly being used to generate electricity [1]. However, the sporadic nature of these resources raises concerns about the stability, dependability, and power quality of the system. In order to partially decouple energy generation from demand, energy storage systems (ESSs) might be introduced as a solution to the problem of intermittent availability of renewable resources [2]. Additionally, by offering ancillary services to the grid, the ESSs can be used to alleviate the problems with the power quality. To stabilize the power output, large ESSs are frequently employed in conjunction with renewable generation, such as wind [3]. The usage of hydrocarbons is thought to be significantly reduced by electrifying transportation. Plug-in electric vehicles are equipped with an energy storage component that can store power from the grid. If this power is generated through renewable energy sources, there will be a significant decrease in the overall consumption of hydrocarbon [4]. Plug-in vehicle technology not only reduces the need for fossil fuels for vehicle propulsion but also makes available a variety of tiny distributed energy storage resources that can be utilised to locally stabilize the grid [5].

The largest and most active end user is the electric railway system (ERS). Reduced railway energy usage is essential in light of an economy that cares about the environment [6]. Using renewable energy sources to build an electric railway microgrid system (ERMS) such as photovoltaic (PV) and wind energy is one way to save electricity. Renewable energy can be used to power railroads more efficiently and help prevent the depletion of nonrenewable energy sources [7]. Therefore, building a railway smart microgrid system is essential for achieving energy conservation and emission reduction, increasing the railway's eco-friendliness in the process. However, both renewable energy sources and locomotive traction loads have high stochastic volatility [8]. For instance, the traction energy of a locomotive varies over time and is easily impacted by many circumstances, while the weather has an uncontrollable impact on the production of renewable energy. The railway power supply system's stability is impacted by these energy fluctuations. An energy-storage system (ESS) is added to the ERMS as a buffer hub for each energy system to address this issue [9]. Additionally, because the ERS produces a significant quantity of regenerative braking energy (RBE), the ESS must be used to store extra energy. Therefore, installing a railway microgrid system is essential for ensuring the stability of the railway grid and achieving energy utilization [10].The contribution of the paper is implementto use hybrid renewable energy sources in the train to reduce energy consumptions through a techno-economic procedure for energy storage. To deploy a buck-boost converter-based energy management system for batteries in order to lessen switching losses and voltage stress.

2. PROPOSED SYSTEM EXPLANATION

This system's novel energy storage strategy uses ESS in the train with the aim of reducing energy consumption. The proposed railway station design incorporates solar, wind, and battery technology for an effective battery backup system. Programmes for renewable energy sources, such solar power, are synchronized with the grid. The effects of climatic fluctuations, such as irradiance and temperature, have a minimal impact on the PV voltage. The required DC supply is provided by a diesel engine and a DFIG-based wind energy conversion system using a PWM rectifier. A reliable PI Controller is used, one that doesn't ask for details about the actual model. Using a PI Controller, the best DC voltage from the PV panel is retrieved and then sent into a Buck Boost converter to help augment the DC voltage.

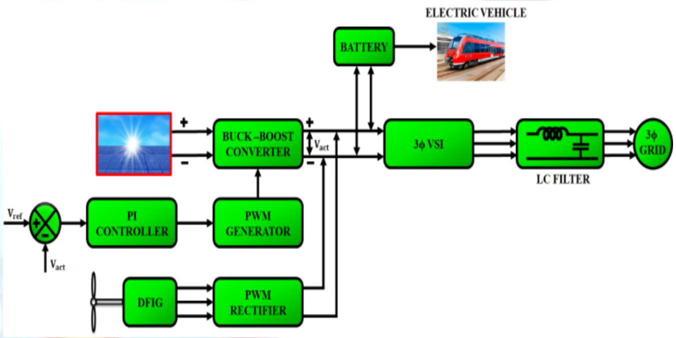


Fig.1. Proposed Diagram

The battery functions as a bi-directional system, ensuring that the DC power it stores is sent into the train to power both the system's operation and the grid. PV panel power is delivered into the Buck Boost converter, which boosts its output and converts it to AC through a 3phase VSI, which is then pumped into the grid after correct synchronization. To keep the DC link's voltage constant and improve grid performance, a PI controller is used. In this study, the PWM generator is used to produce the right pulses. The electricity has been safely fed into the grid by rectifying the harmonic present in the VSI using an LC filter.

3. PROPOSED SYSTEM MODELLING

3.1 PV panel

A semiconductor transistor that has been exposed to light is a solar cell. Few of the variously energetic particles in this solar output are caught at the p-n contact. In contrast to band gap, this sector employs the greatest energy rays. A single diode is utilized to construct comparable devices that are frequently used to represent PV cells, which offers a better balance between accuracy and usability. In Fig.2, the equivalent schematic is shown.

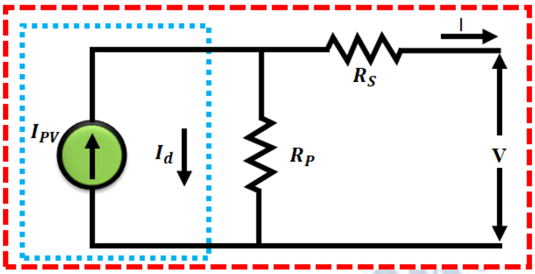


Fig.2. Corresponding circuit of PV cell

The V-I characteristic equation is given by,

$$I_{out} = I_{Sh} - I_{sat}\left[exp\left(\frac{V_{out}+I_{out}.R_s}{V_{th}}\right)-1\right]-\left(\frac{V_{out}+I_{out}.R_s}{R_{sh}}\right) \quad (1)$$

Thus the showing of PV classification is achieved and from (1), the yield voltage and the input voltage are assessed.

3.2 Buck-Boost Converter

The family of DC-DC converters also includes the important buck-boost converter. Fig.3. (a) shows the ideal equivalent circuit for the basic buck-boost converter design. The buck-boost converter operates in CCM and DCM similarly to the boost converter. The following are the two stages that operates in CCM:

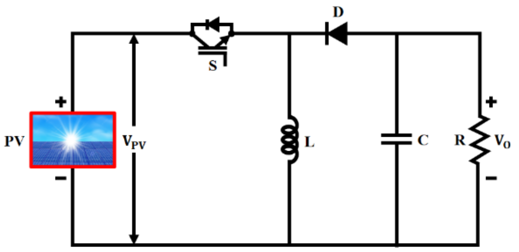
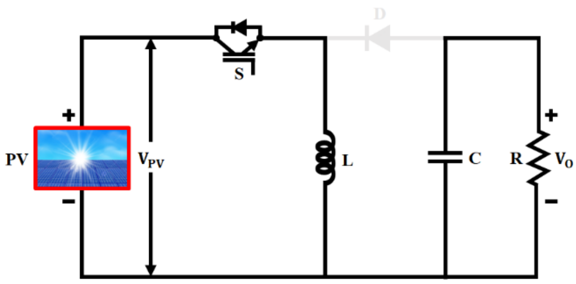
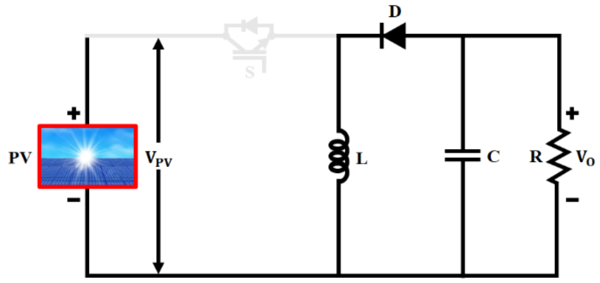


Fig.3. Buck-Boost converter (a) Circuit Topology



(b) Stage 1 Operation



(c) Stage 2 Operation

Stage 1: Time Interval $(0 < t \leq DT)$: Since the input is positioned across the inductive element and the diode is reverse biased, the power switch is in the ON position during this sub-interval, increasing the value of the inductor current. The analogous circuit for this sub-interval is shown in Fig.3. (b). in this phase, the output capacitor discharges and sends power to the load. The input voltage, which is determined by, equals the voltage across the inductor.

$$V_L = V_{PV} = L\frac{di_L}{dt} \quad (2)$$

Stage 2: Time Interval $(DT < t \leq T)$: The power switch is off and the diode is in the ON state during this sub-interval. Along with the inductor being discharged, the capacitor is also charged. Across the diode, the inductor current linearly drops. Fig.3. (c) shows the buck-boost converter power stage for stage 2. Equation for voltage gain is,

$$\frac{V_O}{V_{PV}} = \frac{D}{1-D} \quad (3)$$

Where D is the duty cycle, which is given as,

$$D = \frac{V_O}{V_O - V_{PV}} \quad (4)$$

The value of inductance and capacitance is given as,

$$L = \frac{R(1-D)^2}{2f} \quad (5)$$

$$C = \frac{D}{Rf\Delta V_O/V_O} \quad (6)$$

3.3 Three Phase Voltage Source Inverter

Two stage converters are used in a rectifier fed inverter system. This study describes inverter side control. To determine duty cycle, one uses the rectifier side control. Voltage control is necessary for the majority of inverter applications. Due to changes in the inverter source voltage and internal regulation, this control may be necessary. Three groups can be made out of it:

- Regulation of the voltage delivered to the inverter.
- Voltage regulation inside the inverter
- Regulation of the inverter's voltage output

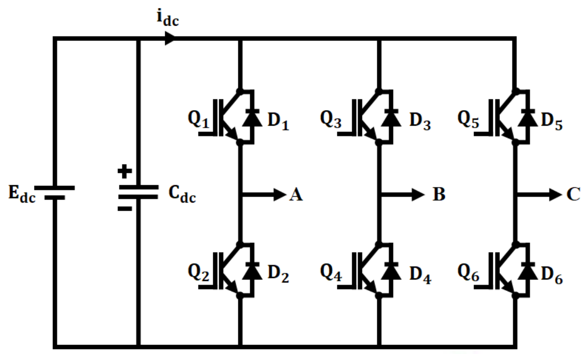


Fig.4. Topology of a 3-phase VSI

Fig.4. depicts the usual power-circuit topologies of a three-phase voltage source inverter. For purposes requiring medium output power, n-channel IGBTs are the preferable devices in these topologies, which only require a single dc source. The input DC supply is designated as "Edc," and the supply terminals are connected by a sizable DC link capacitor (Cdc). In order to reduce stray resonance between the capacitance and the inverter switches, capacitors and switches are connected to the dc bus using short leads.It goes without saying that the physical arrangement of the positive and negative bus lines is crucial for preventing accidental inductances. Switches Q1, Q2, Q3, and so on are quick and controlled. Fast recovery diodes D1, D2, D3, and so on are linked in anti-parallel with the switches. The terminals on the output end of the inverter that are connected to the ac load are "A," "B," and "C." A single-phase inverter only has one pair of load terminals, whereas a three-phase inverter has three load-phase terminals.

4. RESULT AND DISCUSSIONS

The following outcomes are attained as a result of implementing the planned work in MATLAB simulation.

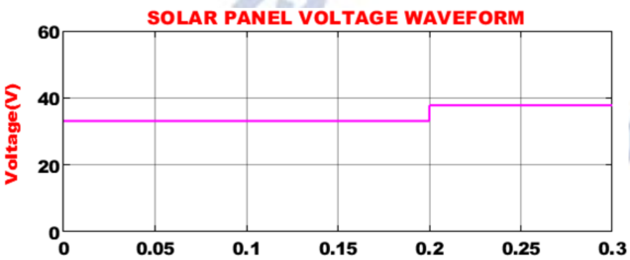


Fig.5. Converter Input voltage waveform

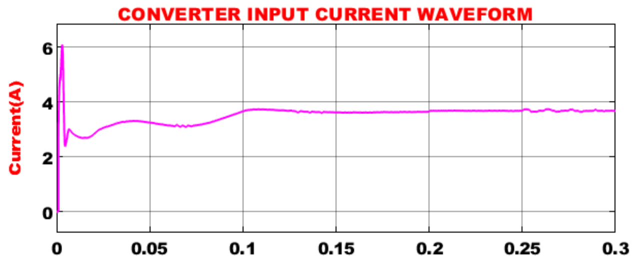


Fig.6. Converter Input Current waveform

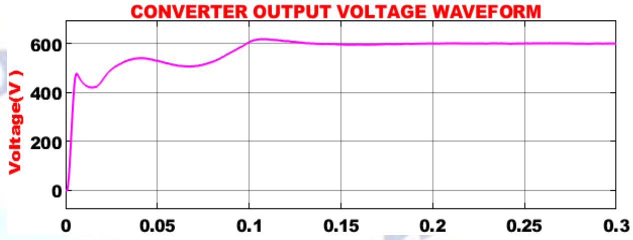


Fig.7. Converter Output voltage waveform

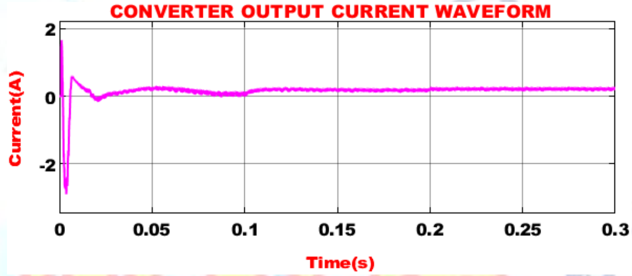


Fig.8. Converter Output current waveform

The Fig.5, 6, 7 and 8 shows the input voltage, current of solar panel and output voltage current of buck boost converter waveform, finally the Converter Output voltage value is obtain by 600V.

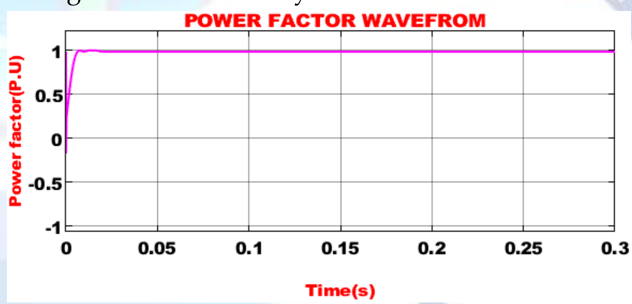


Fig.9. Power factor Waveform

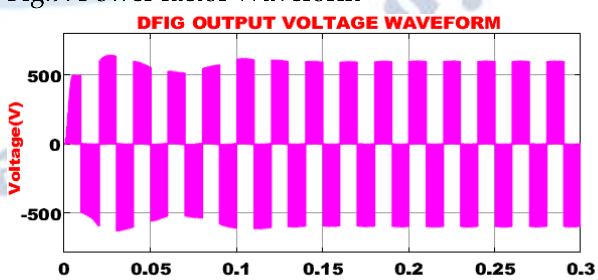


Fig.10. DFIG output voltage waveform

Fig.9. shows the power factor waveform is maintains at 0.5P.U up to the time period of 0.01s. After

0.01s the power factor waveform increasing to 1P.U and further it is maintains constant.

Fig.10. shows the DFIG based output voltage of the proposed wecs system, the voltage value is attained

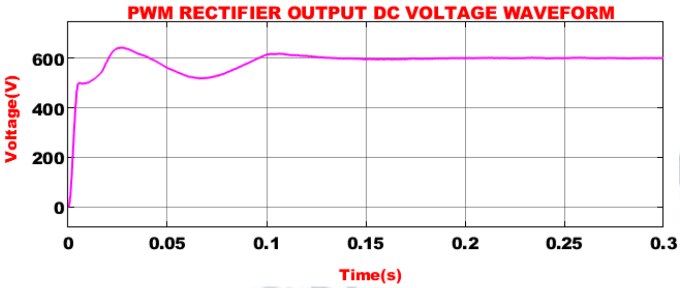


Fig.11. PWM rectifier voltage waveform

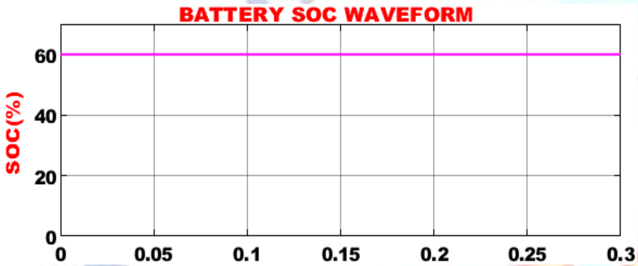


Fig.12. Battery SOC waveform

Fig.11. shows that the output voltage of the PWM rectifier, the voltage maintained around 600V. Fig.12. represent battery state of charge which attained a value around 60%.

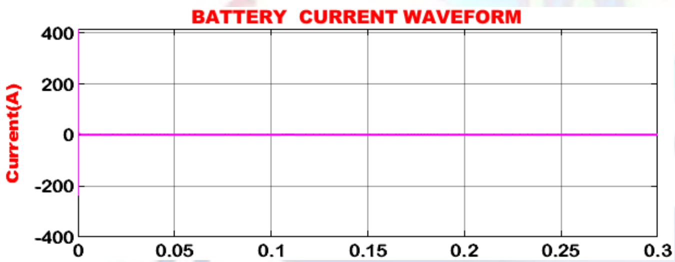


Fig.13. battery current waveform

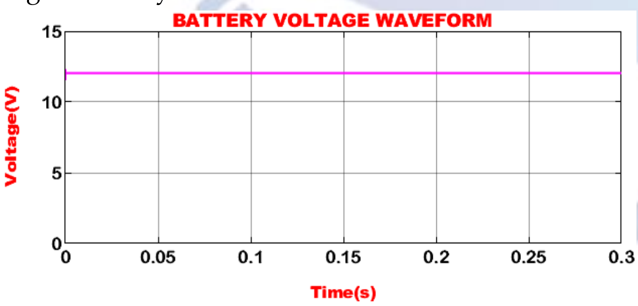


Fig.14 battery voltage waveform

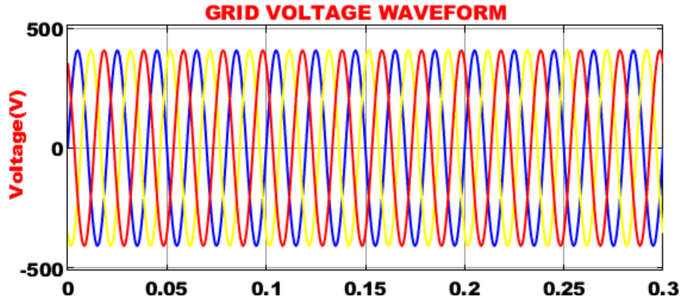


Fig.15 Grid voltage waveform

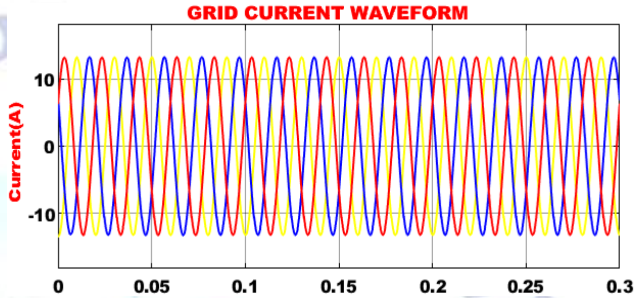


Fig.16. Grid current waveform

Fig.15 and 16 indicates the output voltage and current waveform for grid which is sinusoidal in nature with constant voltage and frequency.

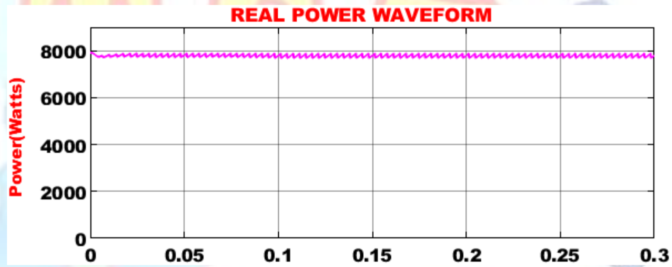


Fig.17. Real Power waveform

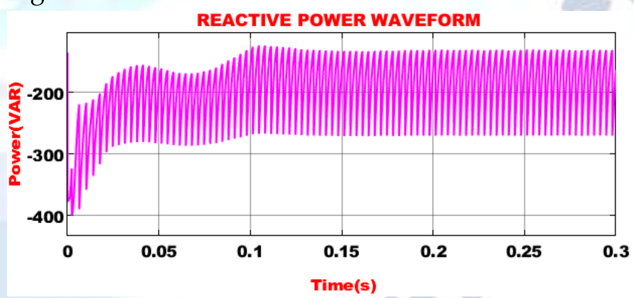


Fig.18. Reactive Power Waveform

Fig.17 and 18 shows the real and reactive power waveform of this work, the real power attained 7950(W). The assessment of the THD Value Comparison of the converters are listed in Fig.19, in which they are listed as 0.93% and 1.23% as Buck-Boost and Boost Converters respectively.

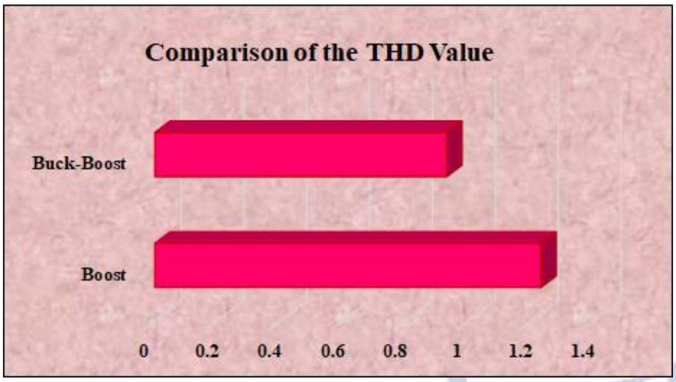


Fig.19. THD Value comparison Between the Converters.

5. CONCLUSION

In order to overcome the energy-saving restrictions of rail transportation systems, this proposed system deals with the efficient and controlled administration of railway stations with BMS based on microgrid stations. The proposed railway station design incorporates solar, wind, and battery technology for an effective energy storage system. The PV system's inefficient output voltage is sent to a buck boost converter, which produces a boosted output with the same polarity as the input voltage. The converter runs without taking into account changes in irradiance level and provides better voltage gain with lower switching losses. The battery converter serves as a bidirectional converter and supplies electricity to the three phase grid. For converting fixed DC voltage to variable frequency AC voltage, a 3 VSI is used. For an attenuation of the switching frequency's harmonics, an LC filter is used. As a result, the proposed system offers reduced distortion and increased power quality with grid synchronization. A hybrid module was simulated in MATLAB/Simulink, and the results are displayed.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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