International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 9, Issue 7, July 2022

Interval Type 2 Fuzzy Logic Control for Energy Management of Hybrid Electric Autonomous Vehicles

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Abstract: Autonomous vehicles are aimed to reduce accidents and traffic congestion. Since hybrid electric vehicles offer feasiblesolutions to reduce energy consumption and emission to the environment, it is expected that autonomous vehicles will be powered through a hybrid electric system compared to otheralternatives. In this paper, a hybrid electric autonomous vehicle is studied under significant amount of uncertainty and ambiguity in the road environment and driver behavior. A Type 1 fuzzy logic controller is constructed here to address the uncertainties of driving conditions. The design involves building an intelligent energy management system for the hybrid electric autonomous vehicle. We have also examined the potentials of the Interval Type 2 fuzzy logic control, especially for energy consumption management. Two simulations are implemented, to demonstrate that the intelligent system, proposed trough Type 1 and Interval Type 2 fuzzy logic control, decreases the fuel usage of the vehicle from 6.74 to 6.58 L/100km, respectively. It is also demonstrated that the Interval.

Keywords: Autonomous vehicle, Intelligent energy management, Interval type 2 fuzzy logic controller, Hybrid electric autonomous vehicle, Intelligent control.

I. INTRODUCTION

AN Autonomous Vehicle (AV) is a vehicle that is capable of travelling safely without driver's input. The AVs are classified as those employing the art of driving using acomputer and are increasingly becoming realistic [1], [2]. Theycan significantly impact our life as they have potentials to dramatically reduce crashes, traffic-induced costs, energy consumption and greenhouse emissions. Ten million AVs will be expected to be in use by the end of this year and companies are envisaged to generate around $7 trillion annual revenue stream from AV's market in 2050 [3]. The hybrid electric AVs are speculated to be more popular in the near future than the conventional AVs [4] as they offer the benefits of a conventional and electric vehicle at the same time [5].

II. PROPOSED FUZZY LOGIC CONTROL HYBRID ELECTRIC AUTONOMUS VEHICLES

The sun is an eco-friendly and everlasting reliable energy source. The energy radiated from sun is received directly for power generation by way of photovoltaic. One of the significant methodologies utilized from solar power is photovoltaic (PV) which is capable of converting sunlight into electricity using photovoltaic effect. The basic building block of photovoltaic modules which produces electricity from the light energy by photovoltaic effect is a Solar cell.

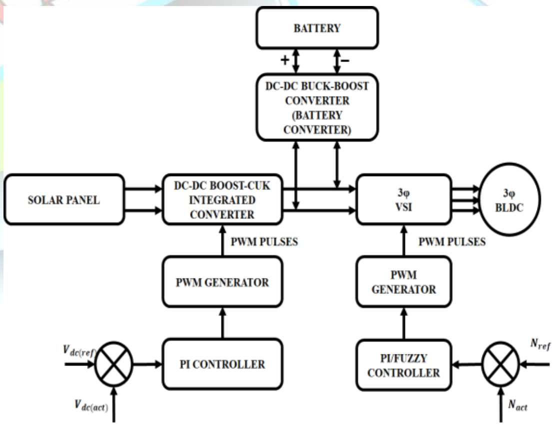

Figure:1 Proposed Block Diagram

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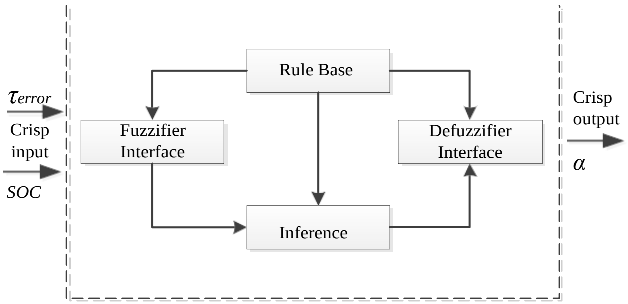

Figure 2. A type-1 fuzzy controller.

Fuzzy rules are determined so that the appropriate electric throttle signal is produced to provide an auxiliary torque as needed. Thus, the engine can be operated inan optimal area without negatively affecting battery performance. The output (electric throttle signal) falls into six.

III. PROPOSED INVERTER TOPOLOGY

The typical power-circuit topologies of a single-phase and a three-phase voltage source inverter respectively. These topologies require only a single dc source and for medium output power applications the preferred devices are n-channel IGBTs. 'Edc' is the input dc supply and a large dc link capacitor (Cdc) is put across the supply terminals

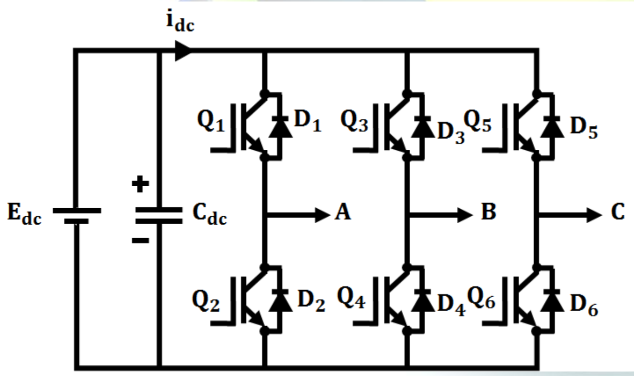

Figure 3 Topology of a 3-phase VSI

It is a nonlinear control approach applied for tracking the maximal power point of the nonlinear characteristics of the PV system. It has the ability to operate in conditions of uncertainty and does not rely on the actual system model. It also offers improved tracking as well as high robustness compared to other approaches. The basic fuzzy logic structure is shown in figure 4.

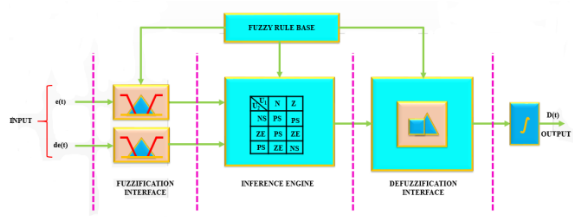

Figure 4. Basic fuzzy logic controller

$$e(t) = \frac{P(t) - P(t-1)}{I(t) - I(t-1)}$$

Where, $P = V \times I$ *and the change in error is* $de(t) = e(t) - e(t-1)$

IV. ELECTRONIC COMMUTATION OF ELECTRIC MOTOR

The P-HEV, showed in Figure 3.1, utilizes an electric motor to create, or increase torques with the crankshaft to drive a vehicle. This motor can also serve as a generator to convert the torque into electricity when needed. The reverse and forward functions (store or consume energy) depends on the demand of the HEV system. The final motor torque can be calculated as follows.

$$\tau_m = \alpha \tau_{e-max}$$

Where α and τ_{e-max} are electronic throttle and max torque of the motor, respectively.

The battery power is adopted as follows.

$$P_b = \frac{\tau_m \cdot \omega_m}{9550\, \eta_m}$$

V. SIMULATION RESULTS

Now that our model has been constructed, we are ready to simulate the system. To do this, go to the simulation menu and click on start, or just click on the "Start/pause simulation" button in the model window toolbar (looks like the "play" button. Because our example is a relatively simple model, its simulation runs almost instantaneously.

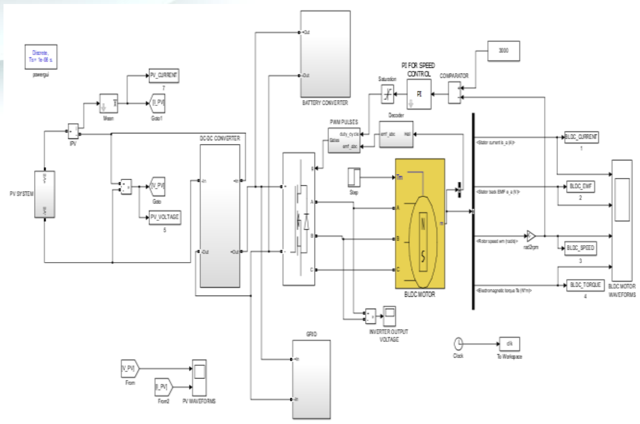

Figure 5 Proposed System Simulink result.

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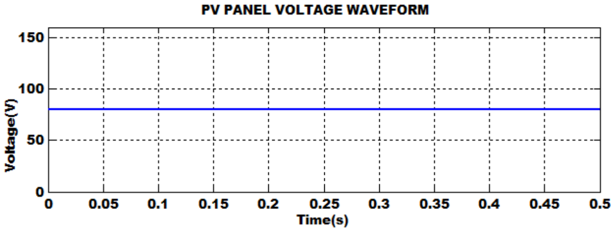


Figure 6 PV panel voltage waveform

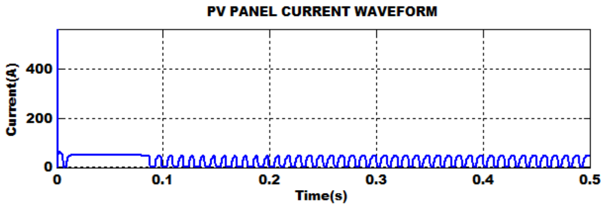


Figure 7 PV panel current wave form

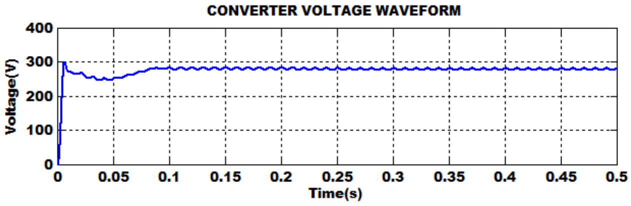
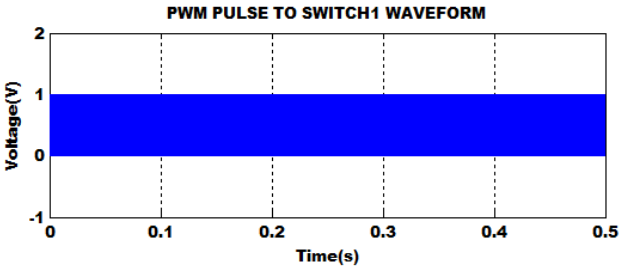
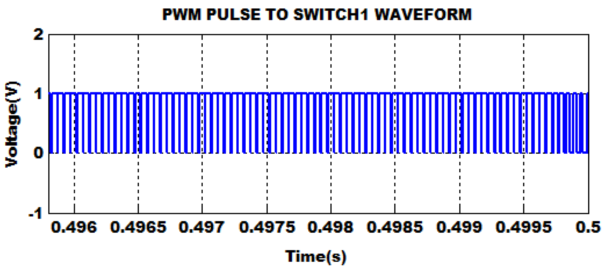


Figure 8 Converter Voltage wave form

The output of Landsman converter voltage and current waveform are shown in Figure 8 respectively



(a)



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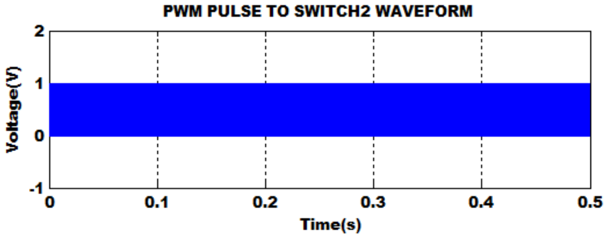

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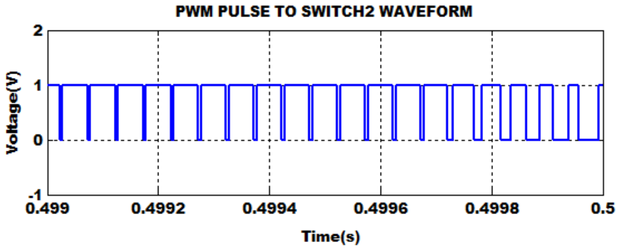

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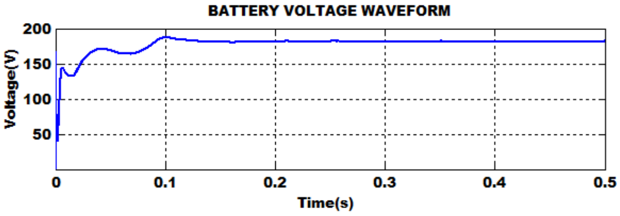

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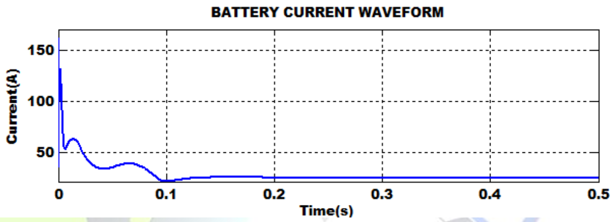

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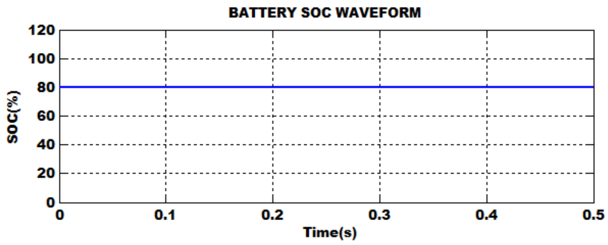

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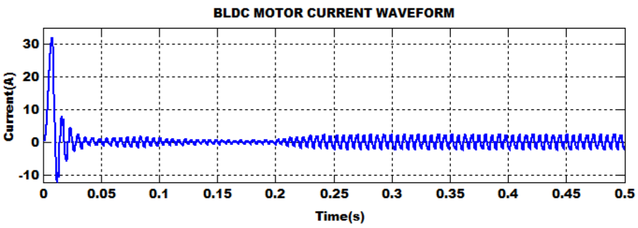


Figure 9 BLDC Motor Current wave form

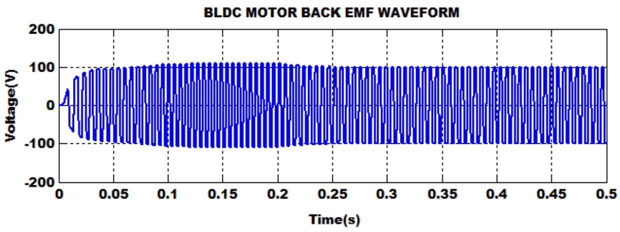


Figure 10BLDC Motor Back EMF waveform

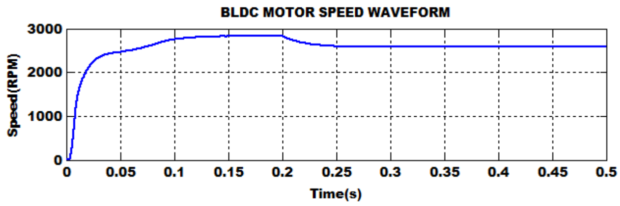


Figure 11 BLDC Motor speed waveform

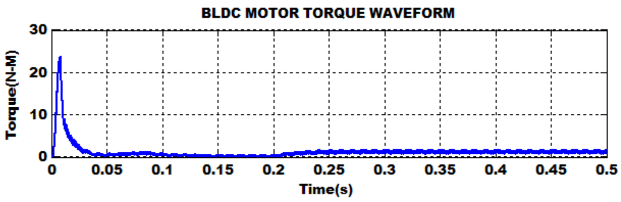
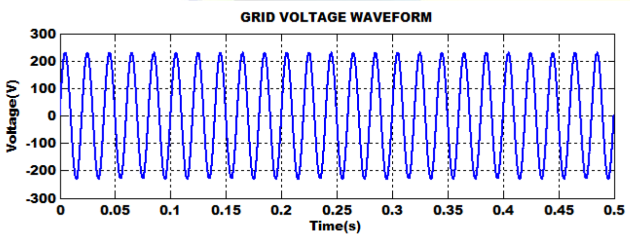
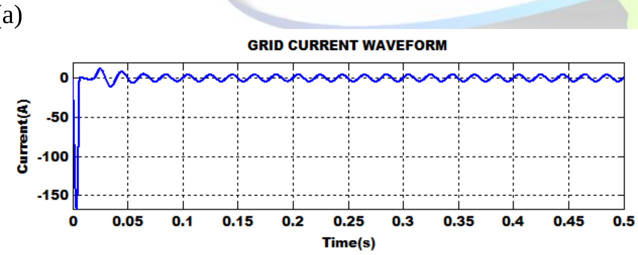


Figure 12 BLDC Motor Torque wave form



(a)



(b)

The Grid voltage and current waveform, the voltage value ranges from 220V to-220V for varying period of time in seconds. The PI controller based grid synchronization achieves reactive power compensation.

VI. CONCLUSION

In this project, a solar fed DC-DC Boost-CUK Integrated converter with PI controller, is utilized in EV applications. The output voltage generated by the PV system is not efficient, hence it is fed to a DC-DC Boost-CUK Integrated Converter which delivers a boosted output of similar polarity of the input voltage. The converter neglects the variation of irradiance level and offers improved voltage gain with minimized switching losses. A 3ϕ VSI is exploited for converting fixed DC voltage to variable frequency AC voltage. Further, the output of VSI is fed to the EV and the defined work is implemented in MATLAB/Simulink.

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