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Improved strategy for solar powered e-rickshaw using hydrogen fuel cell and PMSM

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ABSTRACT:An auto rickshaw is a motorized version of the pulled rickshaw or cycle rickshaw. An American blacksmith called Albert Tolman is said to have invented the rickshaw in 1846. Rickshaws are three-wheeled small vehicles that are used extensively in many Asian countries for the transport of people and goods. In India, auto-rickshaws are commonly used as taxis. At present auto-rickshaws produce a huge pollution problem in major Indian cities. This is due to the use of an inefficient engine, typically a 2 or 4 stroke, with almost no pollution control. This will overcome by using an electric rickshaw. It is a good alternative auto-rickshaw because of its low fuel cost, and less human effort compared to pulled rickshaws. They are being widely accepted as an alternative to petrol/diesel/CNG rickshaws. This paper presents a transportation system based on auto-rickshaws that operate in an environmentally friendly way. The e-rickshaw is working based on renewable energy resources like solar, in the absence of solar light, it will work by the hydrogen fuel cell. This innovation is made to overcome the increases in petrol/diesel/CNG rate.

KEYWORDS: Solar panel, Boost converter, MPPT, PMSM

I. INTRODUCTION

In Asian countries like India, auto-rickshaw are largely used for taxi services, because of the miniature size. The auto-rickshaw arrives from pulled/cycle rickshaw then that will be modified by the use of petrol/diesel engine. It will produce high pollution and fuel cost is high. That will be reduced by using CNG/LPG machines. Pollution is reduced but the maintenance and the fuel cost higher. The auto-rickshaw is used as a taxi in many cities, the main reason is less charge for transportation. But the increased fuel charge, road tax, and maintenance will affect the auto-rickshaw drivers. These reasons will introduce electric rickshaw. By using an e-rickshaw the initial cost is high because of the solar panel fixing. And it has less maintenance, no permit, and road tax. Our thought is to modify the e-rickshaw by the use of renewable energy resources. By using this e-rickshaw will increases efficiency and less maintenance. In the absence of solar panel use hydrogen fuel cell as a source of energy, it is more efficient than the solar rickshaw. Hydrogen is taken as a future fuel.

This paper is organized as follows: Section I presents the overall structure and related work Section II discusses the design specification of the proposed system and architecture of the system. Section III implementation of the proposed system and simulation results.

A. Related Work

A.R. Chowdhury evaluates the health problems of cycle rickshaw pullers in and around of countries metros and suburbans. Author redesigns the manual pulling or pedalling rickshaws to reduce the energy consumed by the drivers who operated these vehicles either by hands for pulling or by the legs for pedalling as well. It is assessed that near 2 million cycle rickshaws employ on Indian streets, conveying around 68 billion traveller km/year. The correct number could beconsiderably more prominent, since there are no dependable records accessible

Priscilla Mulhall, Srdjan M. Lukic, Sanjana G. Wirasingha, Young-Joo Lee, and Ali Emadi a solar-assisted electric rickshaw in 2010. The analysis that the solar radiation per square meter per day received on average in most parts of India is about 4 to 7 kWh. The rickshaw has about 3.4 m 2 of space available on the roof alone to put solar panels. Considering only being able to capture about 5 to 10 percent of that energy, the actual energy recoverable per day may be less than 1 to2.5 kWh when using the entire surface. Therefore, solar

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panels covering the roof would supply more than enough to meet their experiment.

Malik Sameeullah in 2016 investigated the performance of a solar electric rickshaw and he analyzed that for the maximum utilization of the rickshaw roof for the PV panel installation 560 W PV system can be installed above the roof of the Rickshaw. Under partial shading conditions, the power extraction efficiency of the PV array is degraded and overall concepts to use the PV array as an additional source are diminished. He suggested that it can be reduced by using the Maximum Power Point Tracking algorithm, which works to reduce the effect of partial shading and also reduce the tracking time in comparison to other Global MPPT.

E. Starschich and A. Muetze compare the performance of motorized vehicles with human-powered ones and the result is useful for the design and development of solar rickshaws as the next stage. There are gauges that rickshaw pulling is significantly more unpleasant than even hard work. The rickshaw fabricating directly is a disorderly trail industry with no quality control and there is the same number of rickshaw outlines as the urban communities in which they handle. In this manner, there is a need to enhance the outline of the current rickshaw to make it easy to use and get quality control of its produce.

A.R.M. Siddique, A.A. Khondokar, M.N.H. Patoary, andM.S. Kaiser analyze these types of rickshaws and incorporates small motor through microcontroller-based which reduces the human energy for these rickshaw pullers. It is, be that as it may, shocking that ponder strategies in the greater part of the urban towns of creating nations have been made by the concerned experts to eliminate these rickshaws. These non-contaminating vehicles are being supplanted by polluting (both air-and commotion-savvy) oil and diesel-controlled three-wheelers.

Murari Lal Azad, Soumya Das, Pradip Kumar Sadhu, Biplab Satpati, Anagh Gupta, P. Arvind have proposed a paper on the P and O algorithm-based MPPT technique for solar PV System under different weather conditions. They said that This method structures a simple regulation in a closed-loop incorporating only a few controlled parameters. The P and O algorithm compares the previously delivered power with the one after disturbance by periodically varying the voltage of the panel with a minuscule incremental step to reduce the oscillation around the MPP or the desired step. This algorithm has a wide application in commercial systems due to its simplicity and involvement of few measured parameters.

B. Case study

Rickshaws are three-wheeled small vehicles that are used extensively in many Asian countries for the transport of people and goods. In the beginning pulled rickshaws are used one of the people will pull the rickshaw manually, to reduce the human effort many companies introduce petrol/diesel/CNG engine- based auto rickshaws. That will make the rickshaw efficient and take less time for transportation. But this will cause pollution, more maintenance cost and increased fuel cost is not afforded by the taxi drivers.

In India, e-rickshaws are widely spread all over the country, starting to gain popularity around 2011. Now so many developments are arising in electric auto. Compared to a pulled rickshaw, an auto- rickshaw will pay road tax and take a permit for transportation. The cost of the auto-rickshaw on-road amount is 1.85 lakh and the extra fittings, insurance, Maintenance are around 48800. Per day fuel cost is 200 and per year is 73000. In an auto-rickshaw one litre of fuel will cover 30 Km.

Based on these reasons the Electric rickshaw is made for a taxi. It is efficient compared to auto-rickshaw, with less cost for electricity and maintenance or nil. Because the e-rickshaw has high space and no noise. No need for a permit and road tax. But the initial cost is high 2.5 lakh. A fully charged e-rickshaw can cover 120 Km, 2.5 to 3.5 hours take for full charging. Approximately 50 paisa/Km.

E-rickshaw using the solar system are highly efficient with no fuel cost. But the initial cost is high for the solar panel. And these rickshaws are working in solar light on the day time 9 am to 3 pm. Other times the rickshaw is run with a hydrogen fuel cell. Only 5 minutes is required to fully charge the battery and can cover above 400 miles.

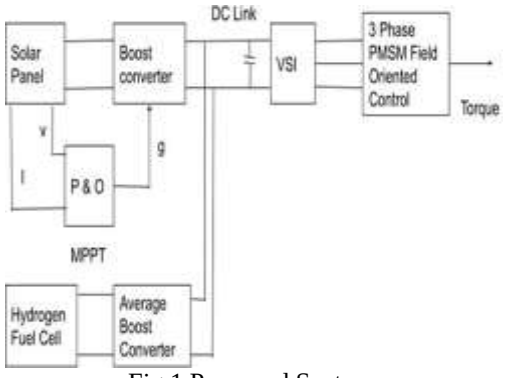

Fig.1.Proposed System

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II. DESIGN SPECIFICATION OF THE PROPOSED CONVERTER

Our proposed system is an E-rickshaw run with solar energy and hydrogen fuel cell. It will contain a solar panel and hydrogen fuel cell. The power from the panelnot stable so the MPPT technique is used. The boost controller is used to boost up the power and also VSI controller is for proper charging. To run the e-rickshaw PMSM drive is used. The proposed system is shown in figure 1.

When the solar energy will available the solar panel will produces electrical energy by MPPT. This energy will boost up by a boost converter and available as DC link voltage this DC voltage is converted into 3 phase AC and the PMSM will run using this energy.

In the absence of solar light, the rickshaw is run based on the hydrogen fuel cell. In the hydrogen fuel cell input the hydrogen and the compressed air to develop the energy. Boost converter will boost up this developed energy to run the PMSM. Finally, PMSM will develop the required torque to run the rickshaw. PMSM torque production can be controlled by field oriented control.

A. Solar Panel

Solar energy is the most abundant energy. we have come a long way in developing solar cells which are the devices powering our future, converting the sun as energy into electricity. Solar panel working is shown in figure 2. Solar panels are really useful in broad daylight but we need energy when the sun is not shining above our rooftops. In an E- rickshaw, the solar panel is placed on the roof of it. After the sunlight is incident on the panel it emits photons and which creates a flow of current. Now as this current is dependent on the photon emission, which is in turn dependent on the sunlight, thus it is unregulated. The current-voltage characteristics of the PV module shown in Figure 5. By using the MPPT technique and VSI controller, we can drive this vehicle in sunlight.

An MPPT controller is an electronic DC-DC converter that optimizes the match between the solar array (PV panel) and battery bank. These are sometimes called power point trackers. A suitable MPPT algorithm along with a DC/DC converter is to be connected between PV panel and load to operate PV system at MPP (Maximum Power Point) at all operating conditions as shown in Figure 3.

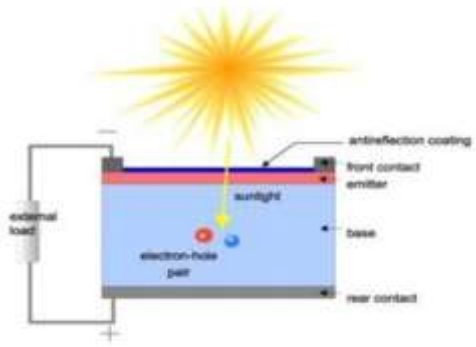

Fig. 2. Solar Panel

MPPT means to operatethe PV system at maximum power point with the help of an algorithm and a converter. MPPT algorithm estimates the MPP and force the PV system to operate at that estimated MPP by the helpof a converter by providing an appropriate duty signal to it.

The novel adaptive P and O is adaptive. In particular, when the operating point is far from the MPP, large perturbation amplitudes are chosen, whereas near to the MPP point small perturbation amplitudes are chosen. Here current perturbation is chosen instead of voltage perturbation as in conventionalPO method to speed up the tracking performance as shown in Figure 4.

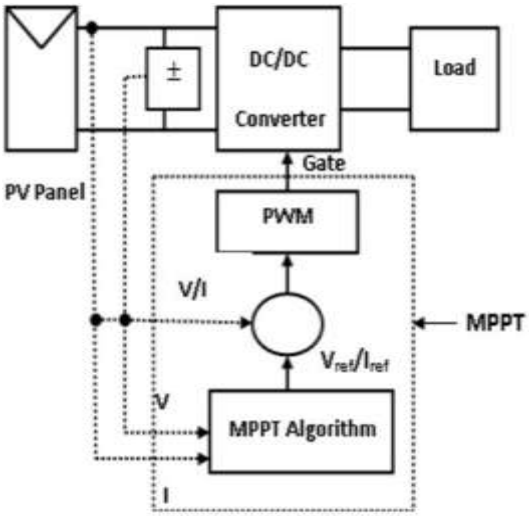

Fig. 3. Stand alonePV system with MPPT

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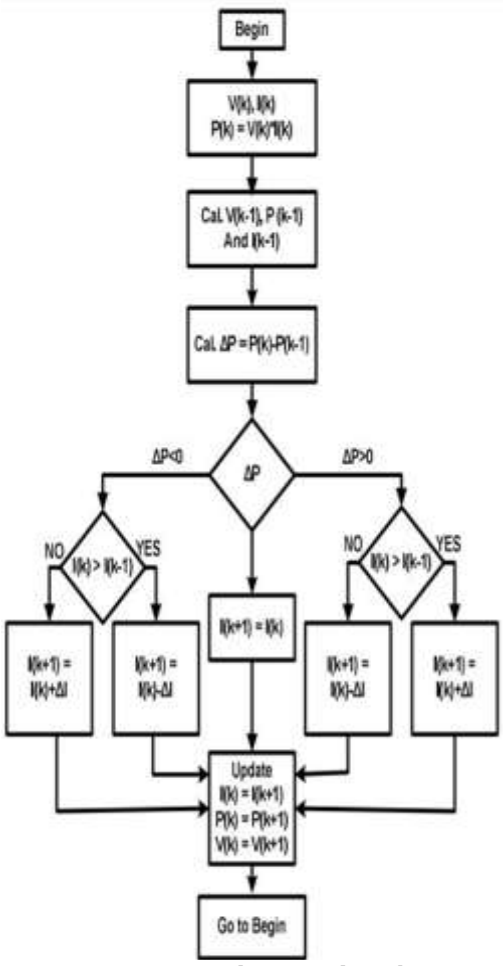

Fig. 4. Proposed MPPT algorithm

B. Boost Converter

The boost DC-DC converter is a power converter that steps up the input voltage while stepping down the input current. The boost converter is a category of power converters and it is an electric circuit that converts a source of direct current (DC) from one voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). It is a class of switched-mode powersupply (SMPS) having at least one energy storage element (a capacitor, an inductor, or the two in combination) and at leasttwo semiconductors (a diode and a switch).

Boost converters can be designed to transfer power in onlyone direction, from the input to the output. However, almost all boost converter typologies can be made bi-directional. A bi-directional converter can move power in either direction, whichis useful in applications requiring regenerative braking. The amount of power flow between the input and the output can be controlled by adjusting the duty cycle (ratio of on/off time of the switch). Usually, this is done to control the output voltage,the input current, the output current, or to maintain constant power.

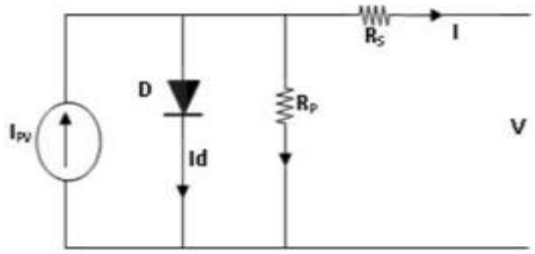

Fig. 5. Equivalent circuit of a PV module

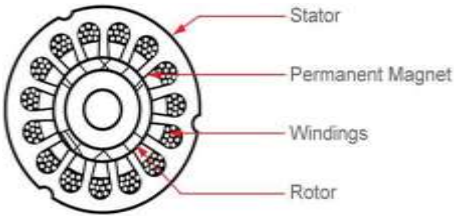

Fig. 6. PMSM cross section

C. PMSM Drive

The permanent-magnet synchronous machine (PMSM) drive is one of the best choices for a full range of motion control applications. The PMSM is known for having low torque ripple, superior dynamic performance, high efficiency, and high power density. The PMSM consists of conventional three-phase winding in the stator and permanent magnets in the rotor. The purpose of the field winding in the conventional synchronous machine is done by permanent magnets in PMSM shown in figure 6.

For the control of PM motors, FOC (Field oriented control) technique is used for the synchronous motor to evaluate as a DC motor. The stator windings of the motor are fed by an inverter that generates a variable frequency variable voltage scheme. Instead of controlling the inverter frequency independently, the frequency and phase of the output wave are controlled using a position sensor.

FOC was invented at the beginning of the 1970s and it demonstrates that an induction motor or synchronous motor could be controlled like a separately excited DC motor by the orientation of the stator MMF or current vector about the rotor flux to achieve the desired objective. For the motor to behave like a DC motor, the control needs knowledge of the position of the instantaneous rotor flux or rotor position of the permanent magnet

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motor. This needs a resolver or an absolute optical encoder. Knowing the position, the three-phase currents can be calculated. Its calculation using the current matrix depends on the control desired. Some control options are constant torque and flux weakening. These options are based on the physical limitation of the motor and the inverter. The torque components of flux and currents in the motor are separated by the vector control through its stator excitation.

D. **Voltage Source Inverter**

VSI is mainly used to convert a constant DC voltage into an AC voltage with variable magnitude and frequency. if the input DC is a voltage source, then it is called voltage source inverter. Various implementations of the VSI are also known as six-step, twelve-step, or even eighteen- step inverters.

The inverter is composed of six switches Sinv,1 through Sinv,6 with each phase output connected to the middle of each inverter leg. In the simplest form, three reference signals are compared to a high- frequency carrier waveform to control the output AC voltage of the inverter. The result of that comparison in each leg is used to turn the switches ON or OFF. It should be noted that the switches in each leg should be operated interchangeably, to avoid a dead short circuit of the DC supply shown in figure 7.

E. **Hydrogen Fuel Cell**

The hydrogen is a clean and future energy. The hydrogen fuel itself can be produced with ever-increasing cost-effectiveness through electrolysis, by splitting water into its constituent hydrogen and oxygen atoms. This generates two useful gases and, when powered by green energy, makes hydrogen production a carbon-neutral act.

At present, however, just 2 percent of the 600 billion cubic meters of hydrogen manufactured each year around the world is produced by water electrolysis, while 98 percent is produced from natural gas, with carbon dioxide as a by-product.

Depending on the charging station and battery capacity, fully electric vehicles currently require between 30 minutes and several hours for a full charge. The hydrogen tanks of fuel cell cars, on the other hand, are full and ready to go again in less than five minutes. A full hydrogen tank will last around 300 miles (approximately 480 kilometres).

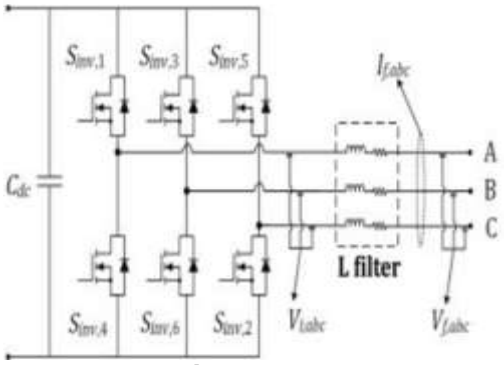

Fig. 7. Voltage Source Inverter

III. RESULTS AND DISCUSSION

In our e-rickshaw the main power source is Solar energy. The connection of the panel is three series-connected five parallel string connected topology to get maximum power from solar. The output of the solar panel is shown in figure 8. The Output from the solar panel is sometimes weak so it is given to a boost converter, the boosted solar panel output is shown in figure 9.

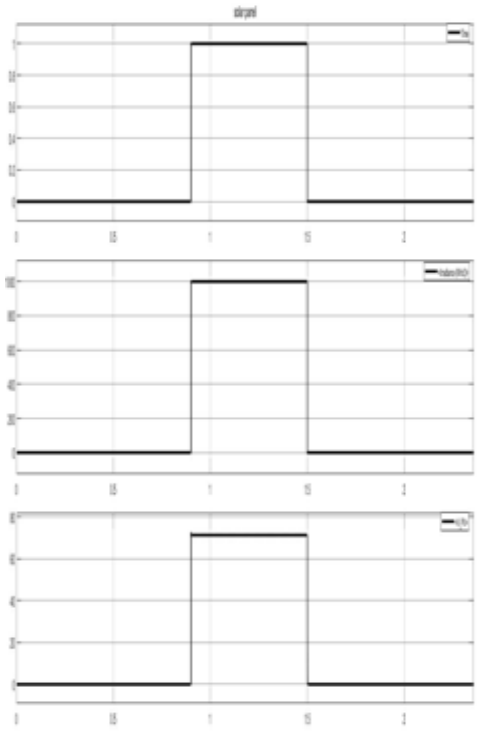

Fig. 8. Solar Panel Output with solar irradiation

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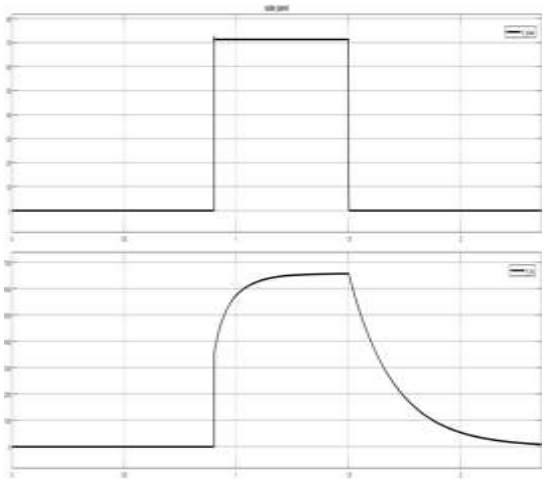

Fig. 9. Boost Converter Output

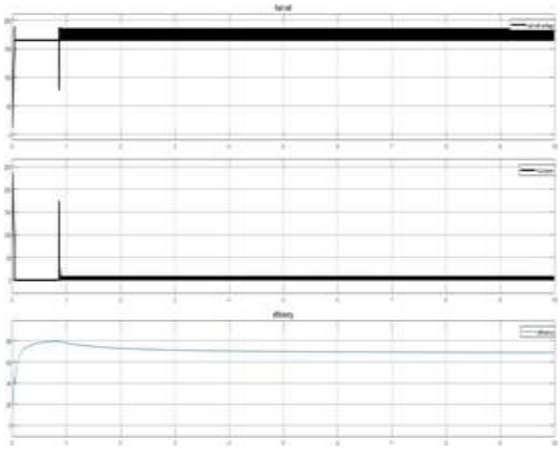

Fig. 10. Fuel Cell parameters

Figure 10 shows the fuel cell parameters such asefficiency, voltage, and current. Figure 11 will shows the Fuel cell output. The boost converter is run based on gate pulses.

The designed e-rickshaw is run with the help of a PMSM motor. Figure 12 will show the parameters of the PMSM motor and also the figure will contain electromagnetic torque produced by the PMSM motor to run the rickshaw. The speed of the PMSM motor is controlled by field-oriented control.

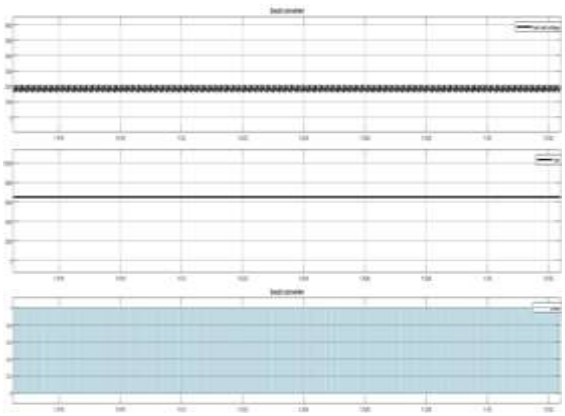

Fig. 11. Fuel Cell Output

Field oriented control is done by adjusting the stator speed and rotor current of the motor. The final result is shown in figure 13. It shows, with the change in torque, field current and speed of PMSM changes and there by field oriented control is obtained.

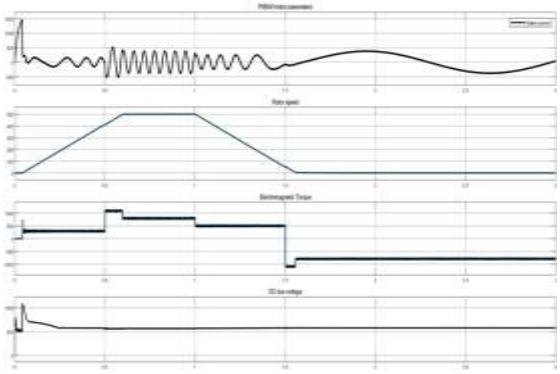

Fig. 12. PMSM Parameters

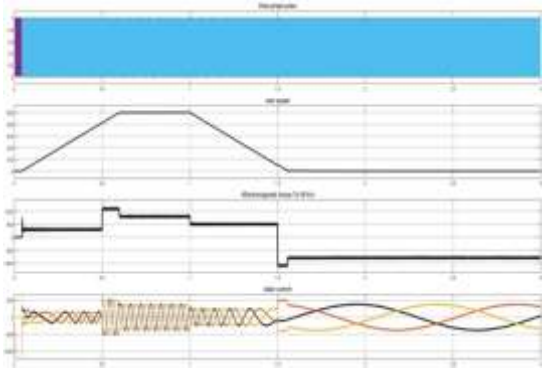

Fig. 13. Final Output

III. CONCLUSION

After the study, it can be said that being a potential bearing mode of transport of present and future e-rickshaw is the best contender and it has started making its mark in the Indian transport system. Proper implementation of the e-rickshaws

has the potential to address the issues of environmental pollution due to transportation as the specific CO2 emission for the e- rickshaws was found to be 19.129 gm/passenger-km. So, with the analysis of e-rickshaws past present and future with benefits, some issues like its slow speed and disposal of lead-acid battery. Thus, considering the drawbacks some improvements that can be done are like the use of solar panels and hydrogen fuel cell adding to increase in driving range. Using these things to reduce the weight running cost and achieve maximum speed. And also, the main thing using solar-powered rickshaws is pollution- free and environmentally friendly. Hydrogen is considered as a future fuel. More developments are arising day by day. So, the designed concept is implemented in the future with developed techniques of hydrogen fuel cell vehicles.

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