Novel Hybrid Source Inverter for Electric Vehicle

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Abstract: Keeping in view the future demands, engineers worldwide are trying to develop some suitable strategy for hybrid storage system in electrical vehicles because we all know that most of the vehicles run on the fuel but the fuel cost is rapidly increasing day by day. Also the chances of the fuel prices coming down drastically fuel are very grim. So keeping in view this scenario, engineers developed HESS by using UC /battery combination to improve the battery life, but these topologies are not that effective because in these strategies, there is use of conventional hybrid power train that uses a DC/DC converter to provide adjustment of voltage level for better operation of overall system. However the use of DC/DC converter makes the entire circuitry bulky and expensive thereby increasing the installation cost and operational cost and hence this is not affordable for common people In order to overcome these problems, here we introduce a new strategy, which uses Multi-source inverter instead of DC/DC converter for effective operation and increase the driving range and make the system cost effective.

Keywords - Energy management, thermal management, battery, ultra-capacitor, reliability, efficiency, enhance the battery life, optimum sizing of ESS.

I. Introduction

The major concern of the today's scenario is pollution which is created by fuel operated vehicles. As per survey, in India near about 12,00000 people die every year due to the excessive amounts of carbon dioxide and other dangerous gases released into the environment from fuel vehicles. To add to this, fuel vehicles create noise pollution.[1]

On the other hand, the industrial zone in India is expanding day by day and for the industrial purpose, we need large quantity of fuel source. That's why the fuel stock is dwindling day by day. As well as the cost of fuel is increase high rocket sky. Therefore we need a permanent solution for above mention problems. Keeping view in these problems electrical vehicles were developed which uses battery as a energy storage device. But battery have poor power density So single battery does not fulfil the peak power demand of overall energy storage system but still it is used because higher power density batteries available in market are costly and not portable due to bulky nature thus making them inefficient and unaffordable for operation. Also other limitations are lesser life cycle of battery, frequent charging & discharging of the battery and thermal management.

After extensive research work, engineers developed HESS which uses UC along with the battery. This is so because although both the battery and UC are energy storage devices but they have different characteristics.[2] The battery has high energy density but low power density where as UC have high power density but low energy density, this combination overcomes the above mentioned problems.[3]

But unfortunately there is a major drawback with this topology as it includes DC/DC converter for regulating the voltage level and these DC/DC converters are heavy and occupy large space thereby making the overall circuitry quite bulky. Also they are expensive.

So here we introduce a new topology using Multi-source inverter for improving battery life and make the system cost effective and compact by avoiding the use of DC/DC converter. Life cycle of UC is much better than battery. Our proposed topology will make a smooth current sharing operation. We use a PI controller for control the overall system.[4]

II. RAGONE PLOT

The ragone plot always gives idea about power density and energy density of various electronics equipment. The fig.1 shows ragone plot, in that plot, we get clear idea that power density of UC is higher and energy density of UC is lower. On the other hand, energy density of battery is higher and power density of battery is lower. So here it is evident that the system will become more efficient if both the equipments work together.[5]

The battery will fulfil base power demand and UC will fulfil peak power demand during traction. The UC also controls the thermal management and utilises the overall energy efficiently.

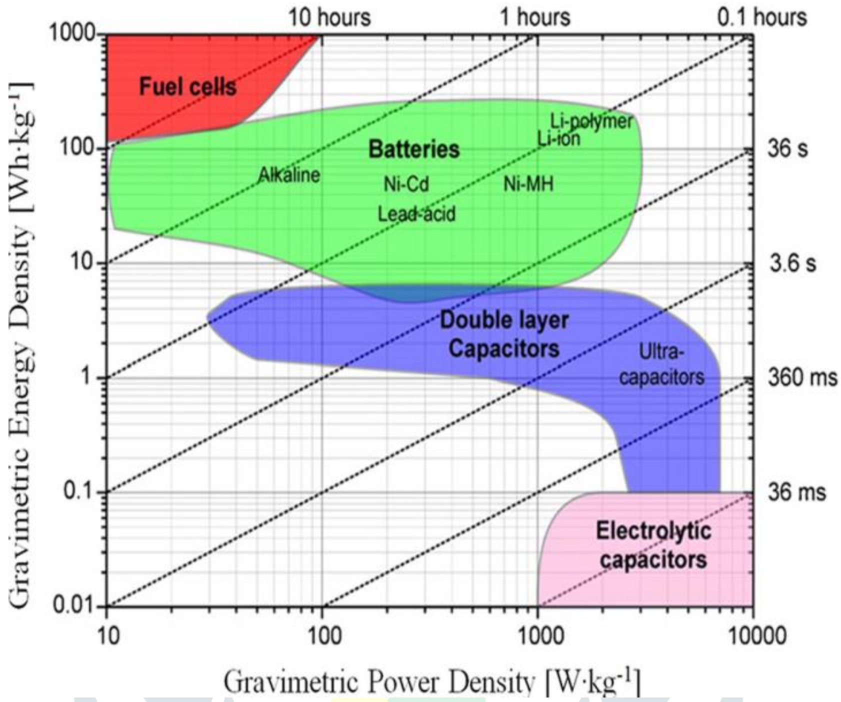

Fig.1. Ragone curve

TABLE 1
TYPICAL CHARACTERSTICS OF BATTERY CELLS AND UC

Chemistry	Nominal cell voltage(volt)	Energy density (Wh/kg)	Power density (kW/kg)	Cycle life (times)
Li-ion	3.6	80-170	0.8-2	Up to 1200
UC	2.5/2.7	2-30	4-10	Over 1,000,000

The batteries and ultracapacitor both are the category of chemical devices but their chemical properties are totally different and theses properties help for achieving optimal performance.

III. COVENTIONAL TOPOLOGY

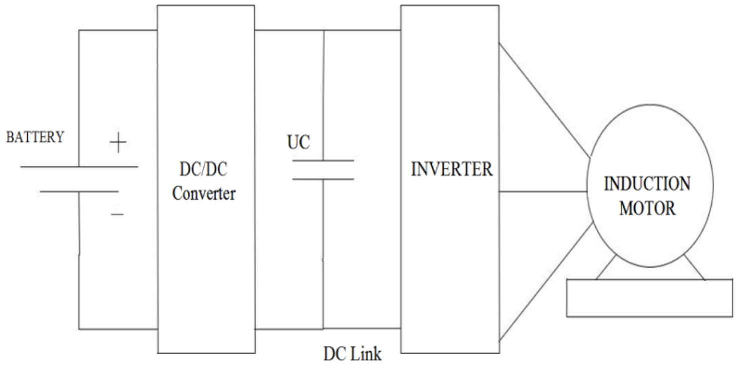

Fig.2 Battery/UC configuration

The fig.2 shows the overall circuit of battery/UC configuration. There is a simple battery and UC connected with each other in parallel and the DC/DC converter is connected between battery and UC and after that this voltage is given to the Induction motor by using inverter. But the major concern about this topology is additional DC/DC converter used is heavy thereby making the overall system non portable. Also the installation cost and the operation cost is not affordable and therefore the efficiency of the system as a whole does not meet the expectations.[2]

Simulation & results of existing strategy

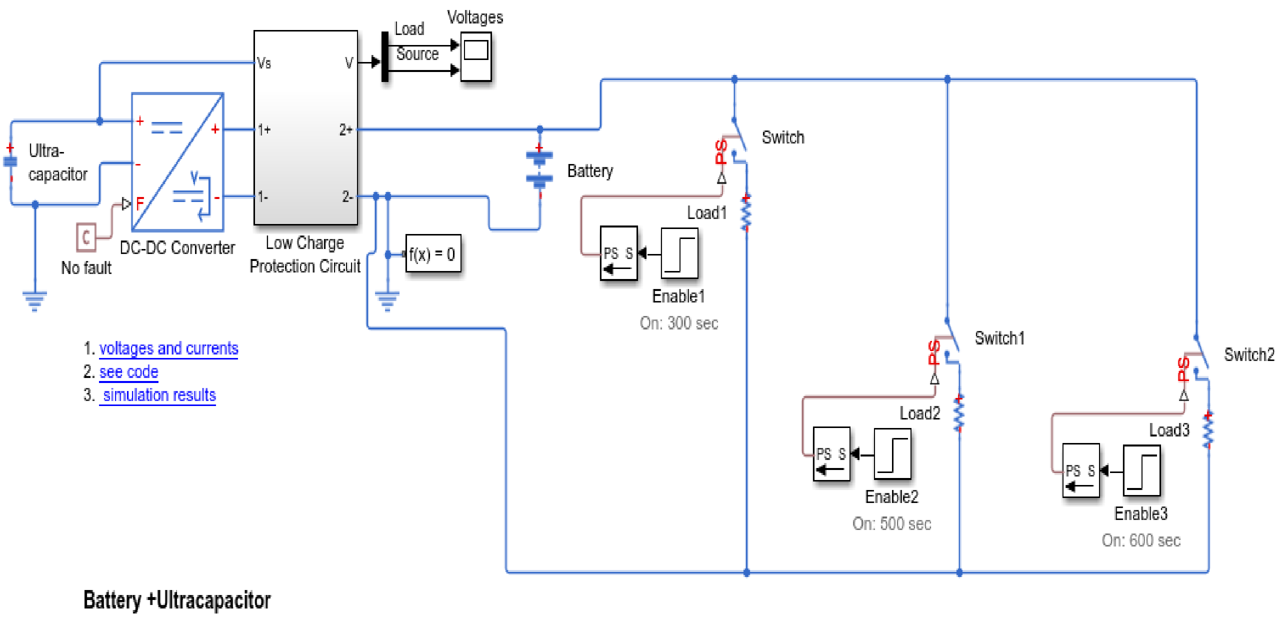

Fig.3 Simulation of UC/Battery Configuration

Battery of 12V with A/h capacity of 50 is selected with 20 Farad ultracapacitor. Three loads with time delays connected for loading purpose. Low charge protection provided with control switches. Simulation using DC/DC converter is developed using MATLAB environment.

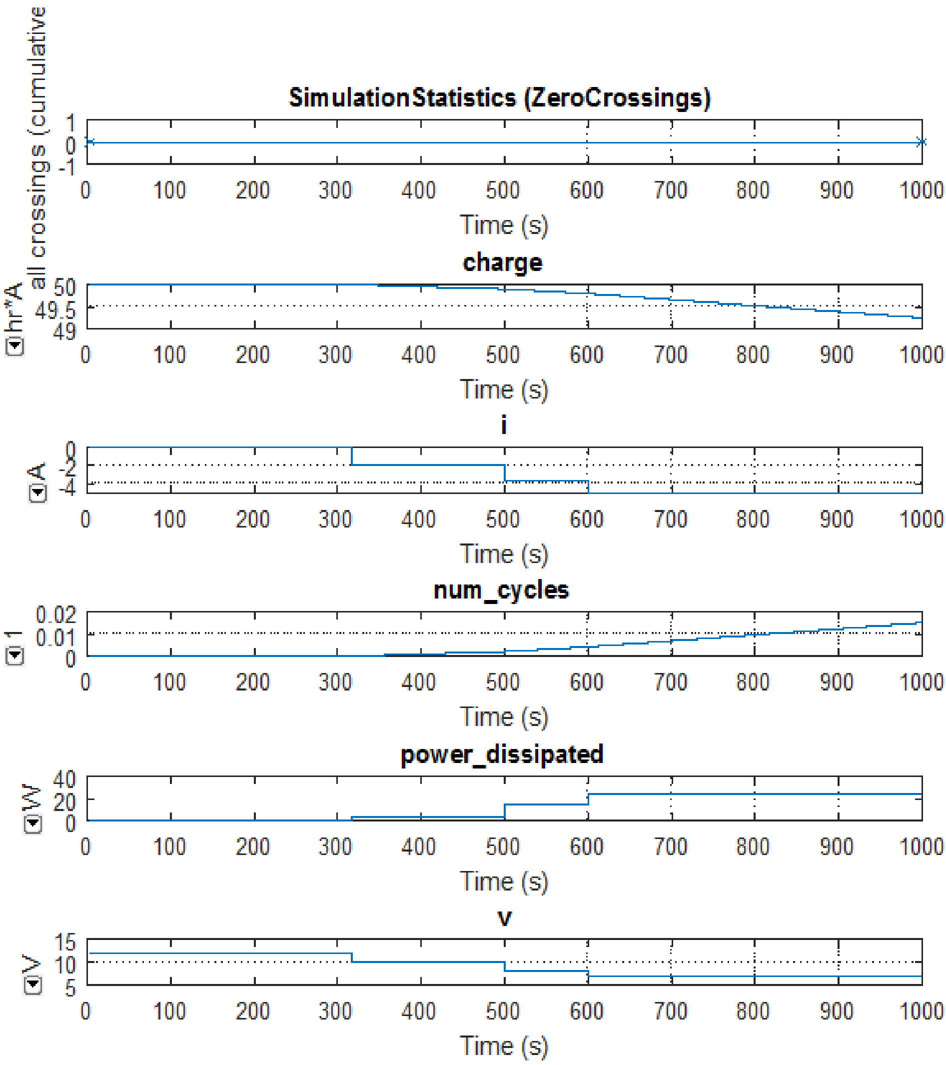

Fig.4 Battery characteristics

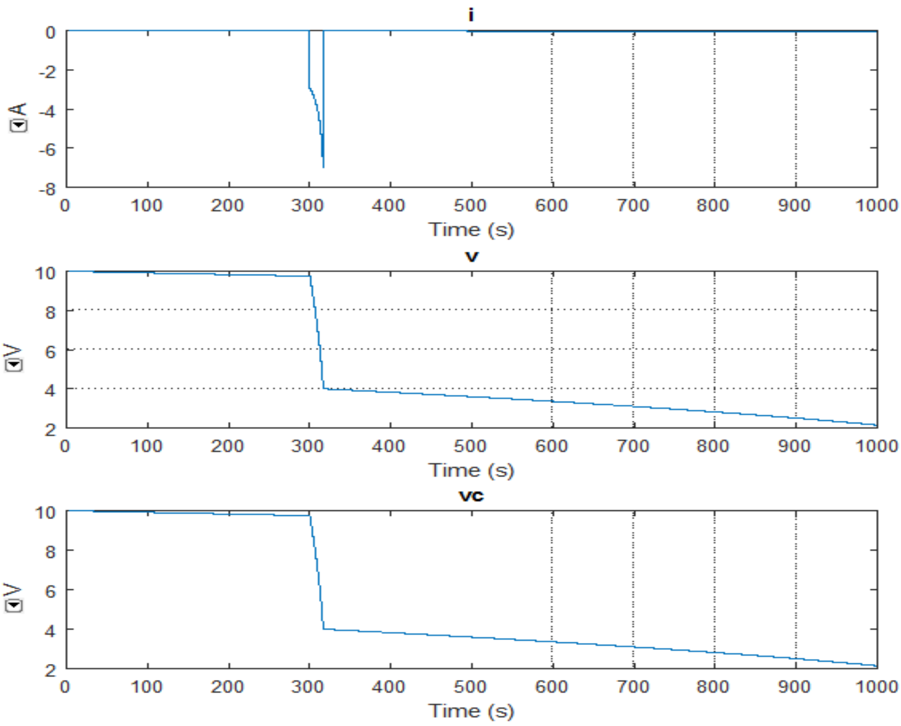

Fig.5 UC current, voltage & Battery voltage characteristics

IV. PROPSED MULTI-SOURCE INVERTER

The intrinsic feature of Multi-source inverter is to agglutinate several DC sources to 3 phase AC load. Multi-source inverter avoids the use of bulk size DC/DC converter because it does not add any additional stage between motor and DC source. This will make the overall system economical and also increase response of electric vehicle. Here two DC sources namely battery and ultra capacitor are cascaded and 3 phase induction motor is used as a load.

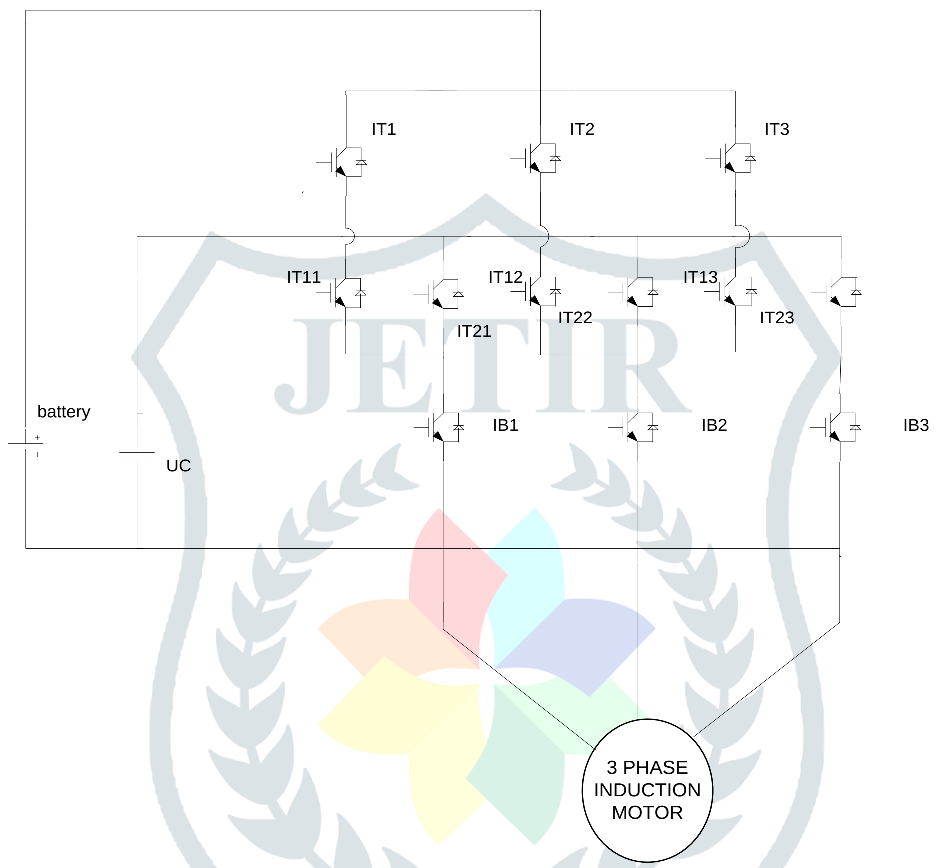

Fig.6 Proposed Multi source inverter

The model of Multi-source inverter is very much similar to three level inverter like Neutral Point Damped (NPC) and T-NPC methodology, but the main difference is the Multi-source inverter does not have neutral point for connecting upper and lower switches of each leg and the input sources of MSI are totally independent. Multi-source inverter is composed of three two level inverters so that it is possible to use three different input voltages from different sources.

According to power requirement, three switching modes are selected which are acceleration, cruising and braking of electric vehicles. In our proposed topology, the system operates in three modes. Single battery provides voltage to the three phase induction motor in first mode. In second mode, the single UC fulfils the voltage requirement for three phase induction motor and in last; there is mix mode which is a combination of battery and UC which provides the voltage for three phase induction motor.

There are three modes of operation:

1. Battery mode: The switches I_{T1}, IT_2, IT_3 and I_{B1}, I_{B2}, I_{B3} enable V_B to supply the motor and V_U is not used.

2. UC mode: V_B is not used and switches IB_1, I_{B2}, I_{B3} and I_{T11}, I_{T12}, I_{T13} enable V_U to supply the motor

3. Mix mode: The switches I_{T1}, I_{T2}, I_{T3} and I_{T11}, I_{T12}, I_{T13} enable V_B to supply the motor with charging V_U the output voltage is equal to V_B-V_U.

TABLE.2
LATCH ENABLE STATES FOR MODE-1,2 & 3

Mode	EN1	EN2	EN1*	EN2*
UC	ON (I_{B1},I_{B2},I_{B3})	OFF	OFF	ON (I_{T21},I_{T22},I_{T23})
BATTERY	ON (I_{B1},I_{B2},I_{B3})	ON (I_{T1},I_{T2},I_{T3})	OFF	OFF
MIX MODE	ON (I_{B1},I_{B2},I_{B3})	ON (I_{T1},I_{T2},I_{T3})	ON (I_{T11},I_{T12},I_{T13})	OFF

V. FLOW CHART

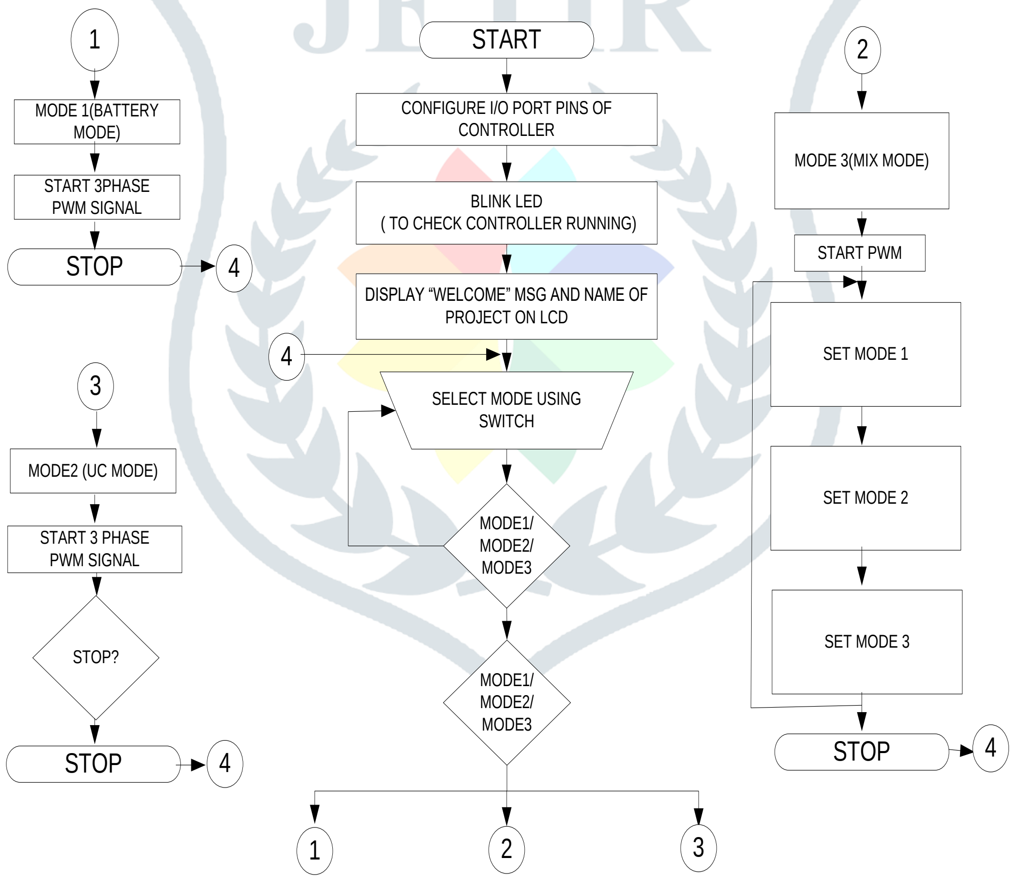

Fig.7 Flow chart of different operation modes

Simulation & results of proposed multi source inverter:

Mode 1: In this mode, only battery will provide the supply to three phase Induction motor via multi source inverter. The battery gives 24 volt output for three phase induction motor. The simulation result in fig.7 shows inverter output voltage and output current respectively, which is supplied by the single battery.

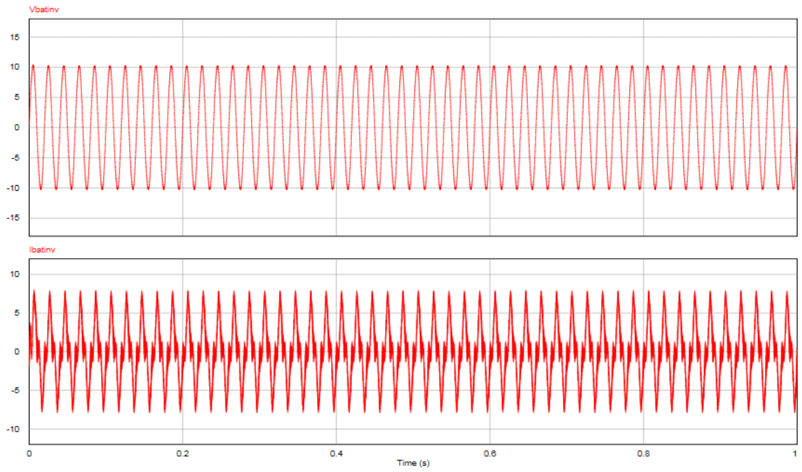

Fig.8 Voltage and current output faded by battery via inverter

Mode 2: In this mode only UC provides supply to the three phase induction motor via multi source inverter. Fig.9 shows the inverter output current and voltage.

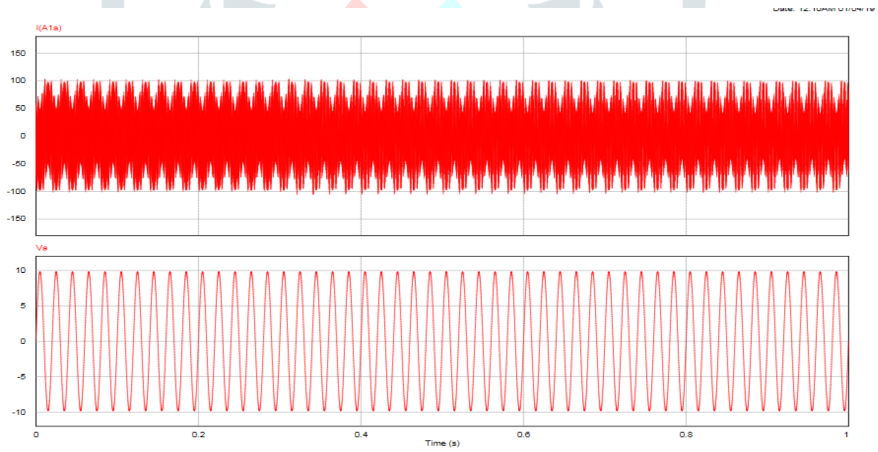

Fig.9 UC mode output voltage and current

Mode 3: In this mode, battery and UC operates simultaneously. The UC shares voltage to the motor via inverter when there is a requirement of peak power demand. Fig.10 shows inverter voltage and current output respectively.

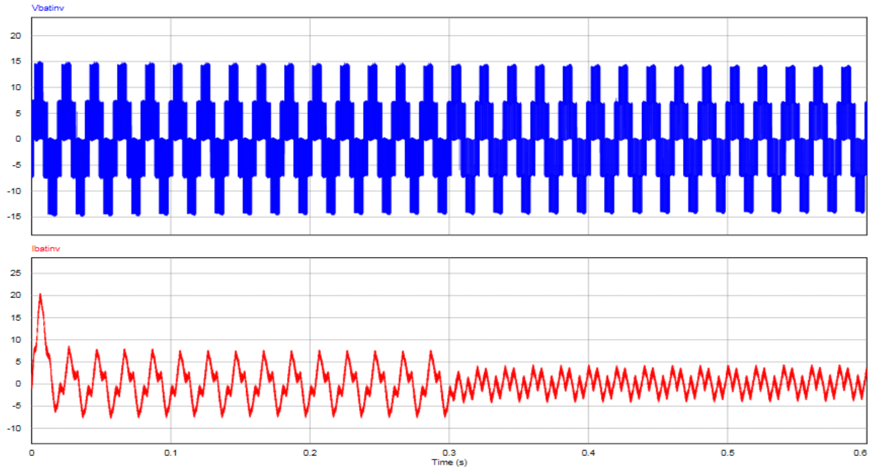

Fig.10 Mix mode operation of voltage and current

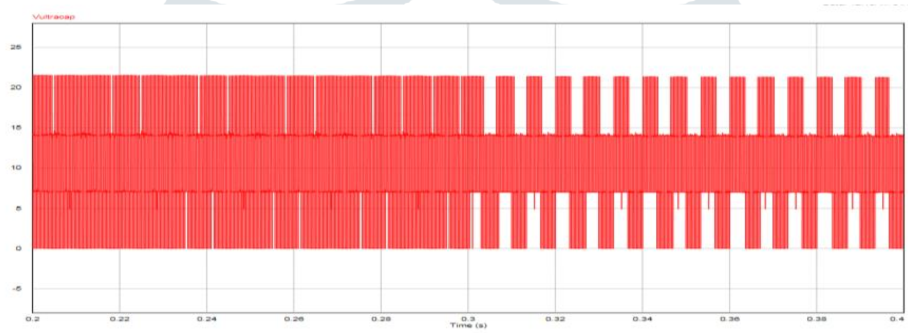

Fig.11 UC terminal voltage

VI. CONCLUSION

In this paper, a multi-source inverter topology suitable for hybrid electric vehicle is proposed which aims to connect several DC sources to get three phase AC output using single stage conversion. By using this topology, it is possible to get smooth current sharing. Also the main advantage of this topology is that it prevents the battery from frequent charging and discharging which results in enhancement of its life. Based on simulation results, it is evident that the battery supplies the constant load current and UC fulfils the peak current profile which results in enhancing the driving range.

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