AN EFFICIENT POWER ELECTRONIC CONVERTER FOR THE INTEGRATION OF SOLAR POWERED ELECTRIC VEHICLE AND GRID

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ABSTRACT

Electric vehicles (EVs) are needed in densely populatedurban areas to reduce air pollution. Battery chargers are needed to supply dc voltage to charge the high-energy batteryPacks used in EVs.Battery chargers are designed to be used as offboardarrangements or on-board arrangements. With on-board battery chargersthe weight, size and cost are challenging issues otherwise we can charge the vehicle anywhere and at any time.In this paper an efficient power electronic converter that integrates the electric vehicle with ac or dc grid that minimizes the system weight, size and cost is designed. Electric vehicles that use grid power to charge their batteries, traction components are generally not involved during charging and hence the traction motor and inverter of the powertrain can be used as an integral part of the converter. The windings of the traction motor can serve as the inductors of the power converter along with power devices of the traction inverter to transfer power. The converter has bidirectional capability that allows power to flow in both directions from vehicle to grid and vice-versa. And therefore the power converter of the electric vehicle can draw power from the grid when it requires, and also can deliver power to the grid in the peak time when the grid needs power. Electric vehicles with this type of converter can also be used as intermittent energy storage devices to store energy produced by renewable energy sources like solar and wind in addition to V2G services.The converter that integrates electric vehicles with both ac and dc grid has been analyzed using mat lab/simulink software, It is also analyzed in the simulation that the electric vehicle with this type of converter can also store the energy produced by solar system and supplies the stored energy when the grid needs power.*The simulation and experimental results havedemonstrated that the proposed converter is more efficient in achieving high performance and reliability for vehicle to grid capable vehicles.*

Key Words: Electric Vehicle, Bidirectional Converter, Vehicle to Grid Technology

I. INTRODUCTİON

Electric vehicles (EVs) are expected to drive reduction of air pollution in densely populated metropolitan areas. The increasing use of EVs will inevitably prompt the use of a large number of battery chargers to supply the dc voltage required to charge battery packs. Battery chargers often are designed to be used as off-board or on-board arrangements. The use of battery chargers with an on-board arrangement would allow battery charging at any time, given the availability of the supply grid. But the on-board battery charger limits power density because of the size and weight constraints. In case of battery electric vehicles, generally traction components are not involved in charging and hence, the traction motor and inverter of the powertrain can be used as an integral part of the converter. The windings of the traction motor can serve as the inductors of the power converter along with power devices of the traction inverter to transfer power. If the power converter has bidirectional capability, it will allow the vehicle to charge from the grid whenever it requires and also can deliver power to the grid in the peak time when the grid needs power.

Several research activities for integrating the battery charging system with the traction drive have been reported in [1] and [2]. In one approach, traction motor windings used as filter components have been used for battery charging systems [3]. An on-board integrated charger has been proposed with reconfiguration of the stator windings of a special electric machine in [4]. The interleaving technique is another interesting approach used in designing dc–dc converters for reduced switching stresses and increased efficiency [5]–[7]. The approach reduces the size and power rating of the converter passive components.

In this paper an efficient integrated power electronic converter is proposed that can be used as the traction motor drive, a battery charger, and a power converter to transfer energy from vehicle-to-grid (V2G) through reconfiguration of the inverter topology using relays or contactors. The traction inverter with the proposed reconfiguration method can also transfer power from the vehicle to a dc grid and from a dc grid to the vehicle using the traction motor windings with the appropriate relay settings. The three phase machine windings and the three inverter phase legs can be utilized with an interleaved configuration to distribute the current and reduce the converter switching stresses.

EVs that are incorporated with this type of power electronic converter can also act as distributed energy storage device to store the energy produced by intermittent energy sources like solar and wind. EVs with this type of converter is acting as a distributed energy storage device to store the energy produced by solar power and fed back the stored power to the grid is discussed in this paper.

II. CONCEPT OF INTEGRATION OF EV WITH GRID

BEVs incorporated with this type of bidirectional power flow capable converter when plugged in, the power can flowboth ways:when electric power stored in electric vehicles flows to power grid, it is called vehicle-to-grid (V2G); the opposite flow of electric power, which means charging batteries in EVs, is referred to as grid-to-vehicle (G2V). The figure below shows the two operation modes.

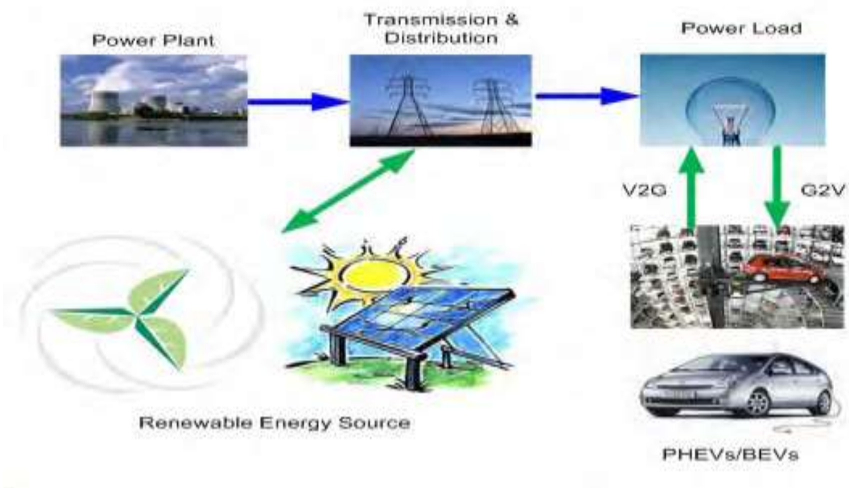


Fig.1.1 Block Diagram of V2G and G2V Connections

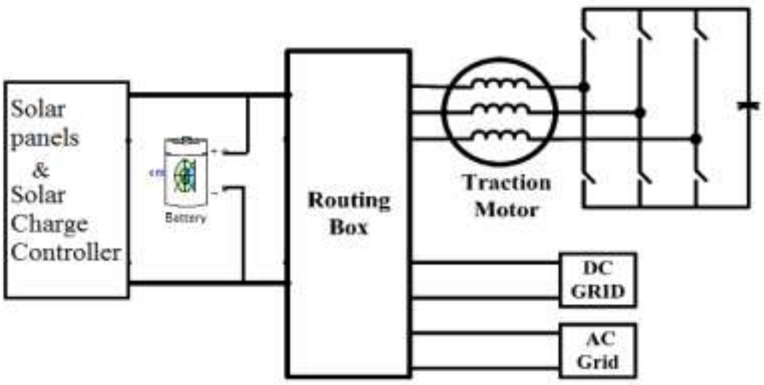
In general, by serving in two modes: G2V and V2G, BEVs can provide benefits to the power system operation. The G2V mode can be used to charge BEVs atreduced cost when the power system load is reduced and generation capacity is abundant,such as during night time. The V2G mode may be used whendemand is high or supply isaccidentally lost since the stored electric energy can be released from BEVs in anaggregated way, which will offer major contributions to regulation service and spinningreserves, as well as load-shedding prevention.

Most of the time vehicles sit idle parked at homes, streets, parking lots, or garages; henceBEVs battery capacity can be fully utilized during such times. BEVscould serve as decentralized energy storage in a smart grid and can act as either a load or a generator as needed. PEVs/BEVs may be an attractive integral part of a smart grid,when aggregated in sizeable numbers and capable to operate in the V2G mode.The V2G approach considers batteries in PEVs/BEVs as a generation resource for thebuildings via bidirectional power transfer through energy exchange stations(chargers/dischargers) at certain periods of time, which could increase the flexibility ofthe electrical distribution system operation.

With the help of advanced control and communication methods, BEVs can work as a generation resource connected to the power grid via bidirectional power transfer through energy exchange stations. This could increase the flexibility of the electrical distribution system operation since the additional storage will allow for more widespread use of solar and wind generation, which are currently underutilized due to lack of storage. By participating in the ancillary services market, BEVs based V2G will improve the grid's stability and reliability.

III. SYSTEM CONFIGURATIONS

Different types of topologies have been developed for electric vehicles for battery charging and bidirectional power flow between the battery and the power supply. However, the traction inverter uses the standard six-switch configuration that has elements of the various power converter topologies. The converter topology utilizing the traction inverter along with the switches used for reconfiguration is shown in Fig.1.2 (a) and (b) shows the detailed switch or relay arrangements required for different modes of operations.



(a)

Most of the time vehicles sit idle parked at homes, streets, parking lots, or garages; henceBEVs battery capacity can be fully utilized during such times. During these times, the battery of electric vehicle can be charged through the solar power and can supply the stored power to the grid through the converter when the grid needs power. The power electronic converter can operate in different modes: it acts as a battery charger, it can integrate solar powered electric vehicle with either dc or ac grid, it can operate in traction mode also.

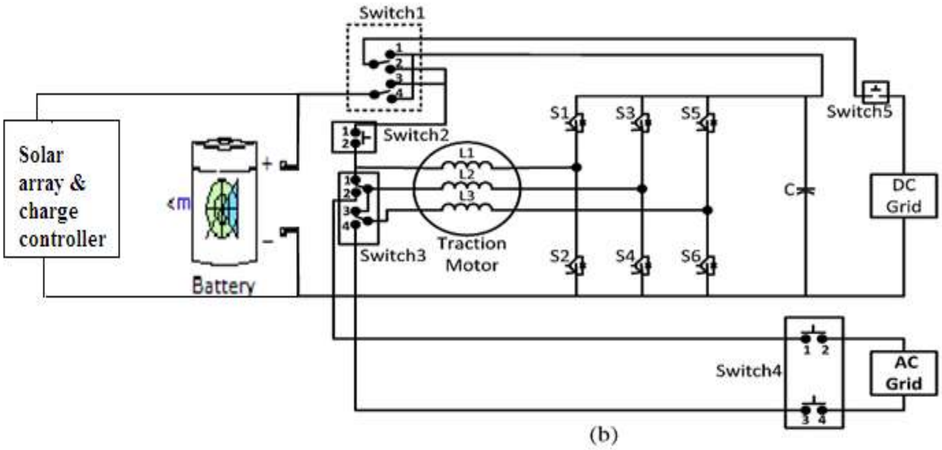


Fig 1.2: An Efficient Power Electronic Converter With Switches Capable of İnterfacing Solar Based Ev With Both Ac and Dc Grid

(a). Combined(b). Details.

IV. IMPLEMENTATION OF EFFİCİENT POWER ELECTRONİC CONVERTER FOR THE INTEGRATION OF SOLAR POWERED EV AND GRID

Here the integration of electric vehicle with the dc grid for boost mode(with solar panel and with battery alone) and traction mode of operation has been discussed.

Mode 1: Vehicle to Dc Grid Boost Mode with Battery Alone

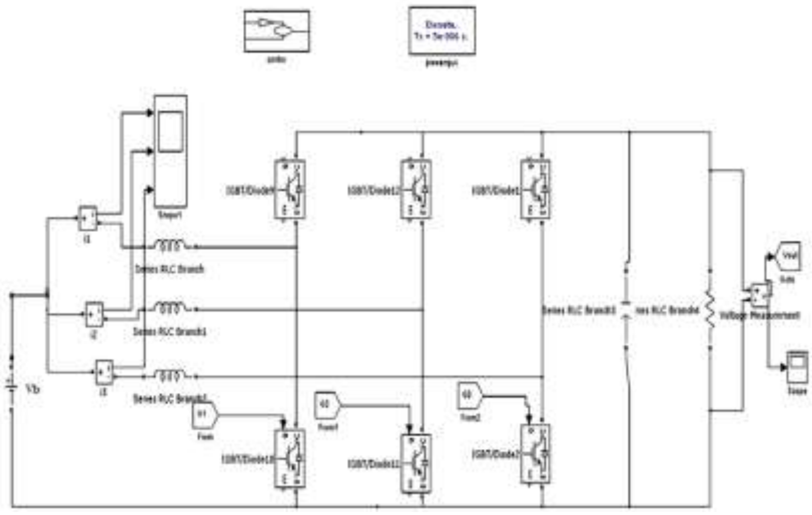


Fig1.3.1: Simulink Model of The İntegrated Converters And İnduction Machine With Dc Grid V2G Boost Mode of Operation.

Battery is connected to the converter through the interleaved windings of the induction machine. The machine windings acts as inductances that helps in the transfer of power between battery and dc grid. Here the load resistance is assumed as DC grid.The interleaved machine windings reduce the voltage stresses of the switches unlike the conventional boost converter, thus improves the converter efficiency. Capacitor is used to remove the ripples in the converter output voltage.In this mode the power electronic converter acts like an interleaved boost converter. Each phase of the machine acts like a single coupled-inductor boost converter cell; the three phases are connected in parallel and operated at the same switching frequency but at a phase shift of 120 degrees.

The control circuit to drive the switches of converter is shown in fig.1.3.1. Here the upper IGBTS are always turned off, lower IGBTs turned on/off. The pulses for lower IGBTs are generated by using this control circuit, here actual voltage is compared with the reference value, and the error is processed by a PI controller, the output of PI controller is used as one signal and which is then compared with the saw tooth repeating sequence to generate the pulses.

Simulation parameters for vehicle to dc grid boost mode are:Battery voltage is taken as 200V, output reference voltage is assumed as 280V, machine phase inductance is 5mH, capacitance of capacitor is 3300µF, load resistance of 20Ω is assumed as dc grid. The switching frequency of converter is 10 KHz.

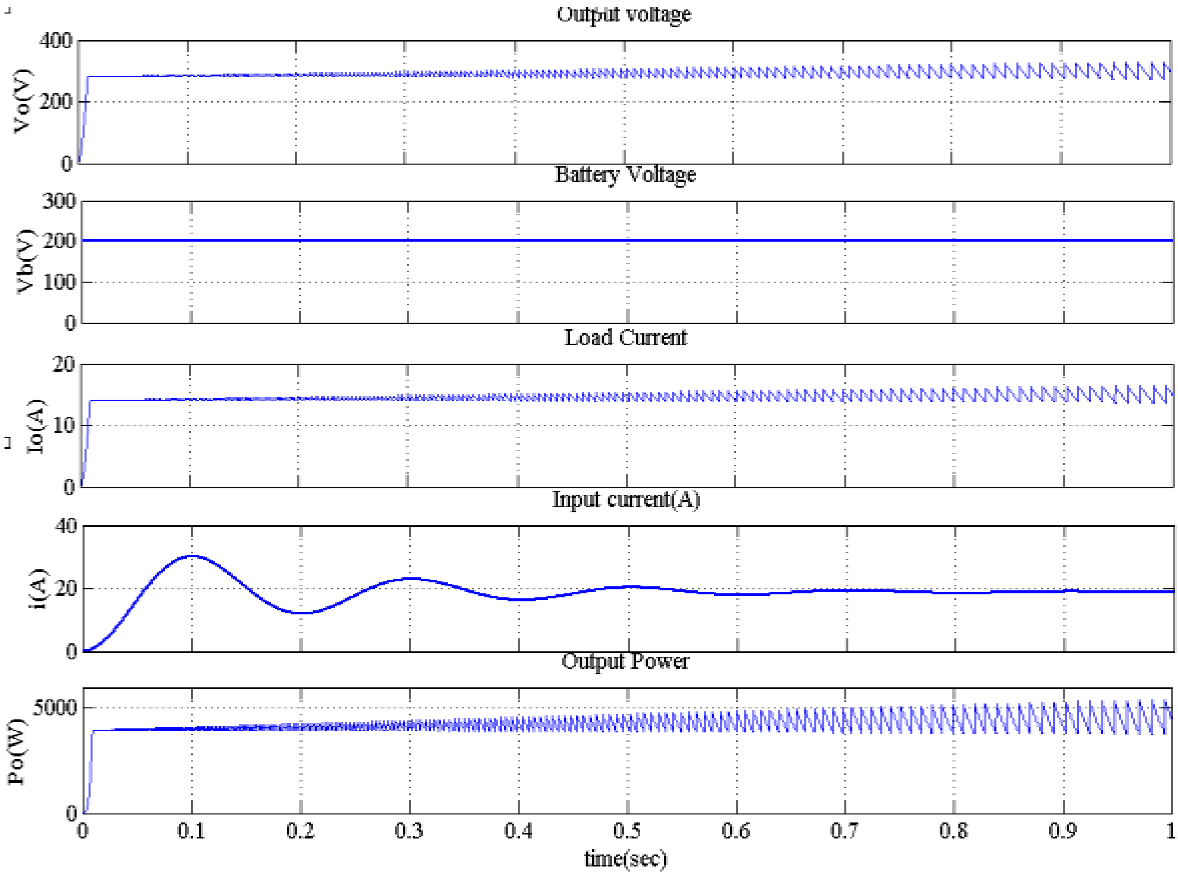


Fig 1.3.2: Output voltage, battery voltage, load current, and input current, output power of integrated motor/converter for V2G boost mode of Operation with dc grid.

The output voltage, battery voltage, load current, input current, output power is shown in fig.1.3.2. From the simulation results it is observed that the output voltage is following the reference voltage of 280V in the boost mode of operation. Battery voltage is taken as 200V. Load current is about 15A, input current drawn from the battery is pulsating and settles down to 20A at t=0.6sec.

Shared input currents in the three phase windings on the machine and Input current in boost mode of operation are shown in fig. 1.3.3.

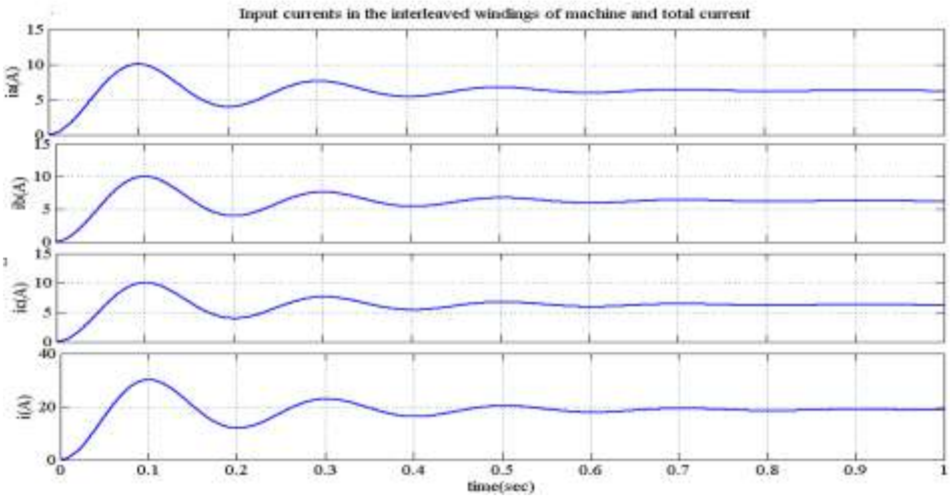


Fig 1.3.3: Shared İnput Currents in The Three Phase Windings on The Machine and Input Current in Boost Mode of Operation.

The Input current is equally shared through the interleaved windings of the three phase induction machine. During t=0s to t=0.1s inductors store energy and from t=0.1s to t=0.2s the stored energy in inductor is discharging during this period.

Mode 2: Integration of solar powered Electric vehicle with dc grid for boost mode

The simulation model of the efficient power electronic converter for the integration of solar powered EV and DC grid for V2G boost mode of operation is shown in, fig.1.4.1.

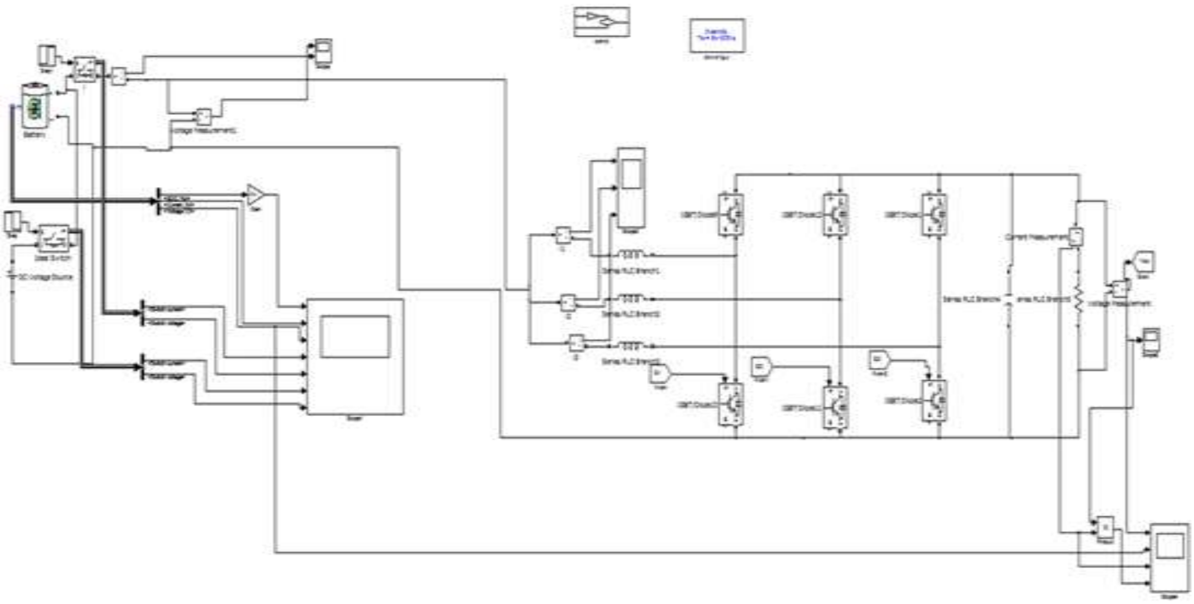


Fig.1.4.1: Simulink model of the efficient power electronic converter for the integration of solar based EV and DC grid for V2G boost mode of operation.

In this mode battery is connected to the solar system through the switches which are controlled by using step signal and it is also connected to the dc grid through the converter. Here the converter acts like an interleaved boost converter which uses inductors on battery side. DC voltage source which is controlled through the ideal switch is treated as solar system and the resistance is taken as dc grid.

When V2G capable solar vehicles are parked, they can use the solar power to charge their batteries, or else they can act as micro grid when aggregated in large number and supplies the nearby dc grid or ac grid when the grid needs power. Here the circuit is implemented to supply the dc grid when the grid needs power or else it can charge the batteries during off-peak loading through solar power. Capacitor is used to remove voltage ripples in the converter output, and converter acts like an interleaved boost converter which boosts the battery voltage to a level that suits the grid voltage**.**

Simulation parameters during this mode are: Battery is taken as 12V, 100Ah lead acid battery, dc voltage source which is controlled through ideal switches is taken as solar power source .DC voltage is taken as 15V and it is controlled to supply 6A to the battery, machine phase inductance is 5mH, capacitance of capacitor 3300μF, load resistance of 3 Ω is assumed as dc grid.

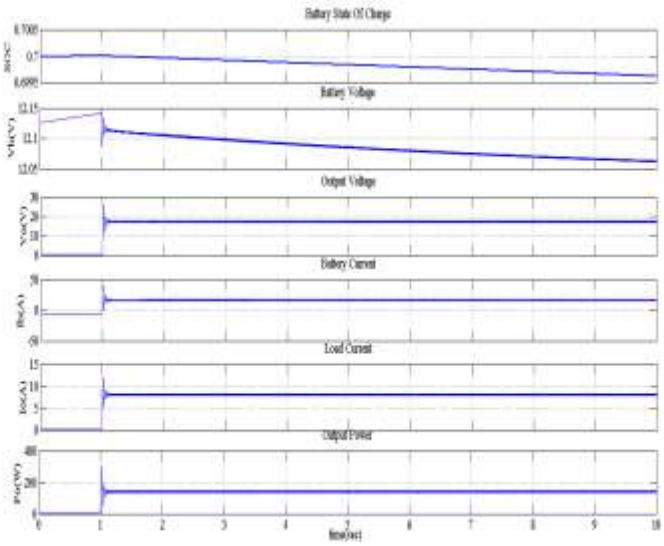


Fig.1.4.2: Simulation Results of Battery SOC, Battery Voltage, Output Voltage, Battery Current, Load Current, Output Power Versus Time.

Simulation results of battery state of charge, battery voltage, output voltage, battery current, load current, output power for the integration of solar based EV and DC grid for V2G boost mode of operation are shown in fig.1.4.2.

The circuit is designed in such a way that the battery charges from the solar system from t=0s to t=1s and at t=1s the grid (load resistance) needs power and then battery starts supplying to the dc grid.

Initially battery state of charge is assumed to be at 70%.Initially battery charges through the solar power, Battey voltage is initially 12.125V and starts increasing upto t=1s. From t=0s to t=1s,battery current is negative as it is charging,Load current and output voltage are zero.

From t=1s,battery starts discharging through the load and therefore battery State of charge and battery voltage starts decreasing. The output reference voltage is taken as 18V, from the output voltage it is seen that the output voltage is following reference voltage.Battery current is 6A, load current is about 12A.Power absorbed by the load resistance is about 150W.

Mode 3: Traction mode

Simulink model of the solar based electric vehicle with induction motor as load in traction mode is shown in fig.1.5.1.

Electric vehicle is fed by solar power. Solar array connected to the converter through solar charge controller and battery. In this mode six switch converter functions as an inverter which is driven by sinusoidal PWM control. Converter converts the battery voltage into ac voltage and its output is given to induction motor. The performance of the converter in traction mode is evaluated in traction mode and the stator currents, rotor speed & electromagnetic torque has been observed. Capacitor is used to remove voltage ripples in inverter output.

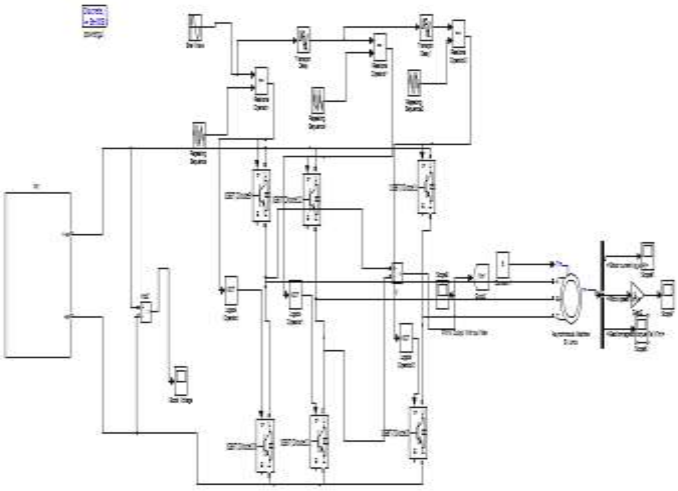


Fig. 1.5.1: Simulink Model of Converter for Solar Based Electric Vehicle with İnduction Motor as Load

Simulation parameters used in traction mode are: Battery voltage is taken a 200V, Capacitance of capacitor is 3300µF, induction motor ratings 5.4HP, 400V, 1430rpm, the switching frequency of inverter is 1.05 KHz, 1200V, and 100A inverter is used.

Three phase stator currents, rotor speed and electromagnetic torque of induction motor in traction mode are shown in fig.6.5.1.

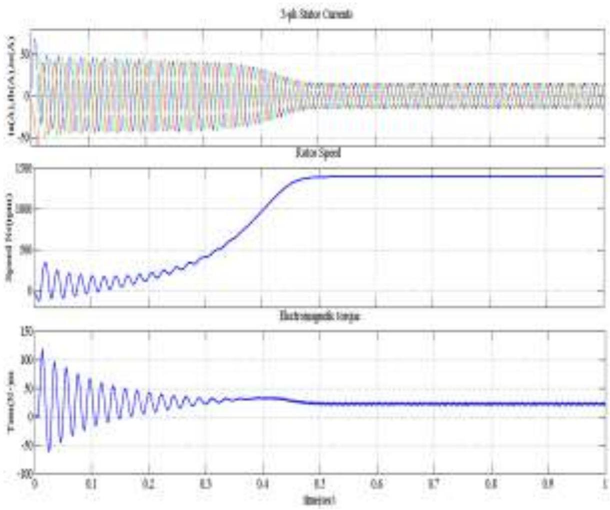


Fig.1.5.2: Three Phase Stator Currents, Rotor Speed and Electromagnetic Torque of İnduction Motor in Traction Mode.

Initially the stator current is very high and the current reaches to its nominal value of 25A at t=0.5sec.the rotor speed settle downs to rated speed of 1430rpm and starting torque is very high and it reaches its nominal value of 22.5N-m at t=0.5 sec as shown in fig.1.5.2.From the results it is observed that the stator currents and hence torque contain ripples as the induction motor is fed by a PWM inverter, but the noise is not observed in speed because it is filtered by machine inertia.

V. CONCLUSİON

An integrated machine-converter topology and reconfiguration method in which traction machine windings can be used as the inductors of the converter to transfer power between solar based electric vehicle and either a DC or an AC grid with high efficiency. The converter reconfiguration concept is useful in minimizing the size and parts in the power train of an electric vehicle. It is also analyzed in the simulation that the electric vehicle with this type of converter can also store the energy produced by solar system and supplies the stored energy when the grid needs power**.** The simulation and experimental results have demonstrated that the proposed converter is more efficient in achieving high performance and reliability for vehicle to grid capable vehicles. The machine-converter coupled simulation results showed that the integrated converter can be used for the power transfer with versatility without significantly extra power elements.

REFERENCES

[1]. Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles; IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 28,NO. 5, MAY 2013 2151;Murat Yilmaz, Member, IEEE, and Philip T. Krein, Fellow, IEEE.

[2]. Grid-Connected Integrated Battery Chargers in Vehicle Applications: Review and New Solution; IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 60, NO. 2, FEBRUARY 2013 459SaeidHaghbin, Sonja Lundmark, Mats Alaküla, and Ola Carlson

[3]. L. Solero, “Nonconventional on-board charger for electric vehicle propulsion batteries,” IEEE Trans. Veh. Technol., vol. 50, no. 1, pp. 144–149, Jan. 2001.

[4]. S. Haghbin, S. Lundmark, M. Alak¨ula, and O. Carlson, “An isolated high power integrated charger in electrified vehicle applications,” IEEE Trans.Veh. Technol., vol. 60, no. 9, pp. 4115–4126, Nov. 2011.

[5]. S. Dwari and L. Parsa, “An efficient high-step-up interleaved DC–DC converter with a common active clamp,” IEEE Trans. Power Electron., vol. 26, no. 1, pp. 66–78, Jan. 2011.

[6]. O. Hegazy, J. Van Mierlo, and P. Lataire, “Analysis, modeling, and implementation of a multidevice interleaved DC/DC converter for fuel cell hybrid electric vehicles,” J. Power Electron., vol. 27, pp. 4445–4458, Jul. 2011.

[7]. O. Hegazy, J. Van Mierlo, and P. Lataire, “Control and analysis of an integrated bidirectional DC/AC and DC/DC converters for plug-in hybrid electric vehicle applications,” J. Power Electron., vol. 11, no. 4, pp. 408–417, Jul. 2011.