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A Novel Converter Topology for Hybrid Renewable Energy System for Microgrid Applications

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Abstract:

The main concept of the new converter is to use a Single - stage three phase grid ties - solar PV converter to perform dc/dc and dc/ac operations. This converter solution is appealing for PV- battery applications, because it minimizes the number of conversion stages, improving efficiency and reducing cost, weight and volume. This converter solution is appealing for PV-battery application, because it minimizes the number of conversion stages, thereby improving efficiency and reducing cost, weight, and volume. In this paper, a combination of analysis and experimental tests is used to demonstrate the attractive performance characteristics of the proposed RSC.

Keywords:

Converter, Energy Storage, Photovoltaic (PV), Solar.

I.INTRODUCTION:

SOLAR photovoltaic (PV) electricity generation is not availableand sometimes less available depending on the time ofthe day and the weather conditions. Solar PV electricity outputis also highly sensitive to shading. When even a small portionof a cell, module, or array is shaded, while the remainder is insunlight, the output falls dramatically. Therefore, solar PV electricityoutput significantly varies. From an energy source standpoint,a stable energy source and an energy source that can bedispatched at the request are desired. As a result, energy storagesuch as batteries and fuel cells for solar PV systems has drawnsignificant attention and the demand of energy storage for solarPV systems has been dramatically increased, since, with energystorage, a solar PV system becomes a stable energy source andit can be dispatched at the request, which results in improvingthe performance and the value of solar PV systems.There are different options for integrating energy storage intoa utility-scale solar PV system. Specifically, energy storage canbe integrated into the either ac or dc side of the solar PV powerconversion systems which may consist of multiple conversion stages. Every integration solution has its advantagesand disadvantages. Different integration solutions can be comparedwith regard to the number of power stages, efficiency,storage system flexibility, control complexity, etc.

This paper introduces a novel single-stage solar convertercalled reconfigurable solar converter (RSC). The basic conceptof the RSC is to use a single power conversion system to performdifferent operation modes such as PV to grid (dc to ac), PV tobattery (dc to dc), battery to grid (dc to ac), and battery/PV togrid (dc to ac) for solar PV systems with energy storage. TheRSC concept arose from the fact that energy storage integrationfor utility-scale solar PV systems makes sense if there is anenough gap or a minimal overlap between the PV energy storageand release time.

In case (a), the PV energy is alwaysdelivered to the grid and there is basically no need of energystorage. However, for cases (b) and (c), the PV energy shouldbe first stored in the battery and then the battery or both batteryand PV supply the load. In cases (b) and (c), integration of thebattery has the highest value and the RSC provides significantbenefit over other integration options when there is the time gapbetween generation and consumption of power.

Reconfigurable solar converter:

The schematic of the proposed RSC is presented in Fig. 1. The RSC has some modifications to the conventionalthree-phase PV inverter system. These modifications allow theRSC to include the charging function in the conventional threephasePV inverter system.

Assuming that the conventionalutility-scale PV inverter system consists of a three-phase voltagesource converter and its associated components, the RSCrequires additional cables and mechanical switches, as shown in Fig. 1. Optional inductors are included if the ac filter inductanceis not enough for the charging purpose.

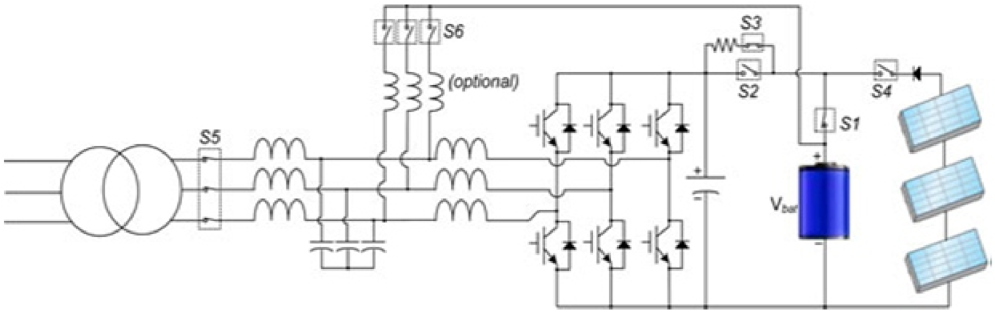

Fig. 2: Schematic of the proposed RSC circuit

Modes of operation:

In Mode 1, the PV is directly connected to the gridthrough a dc/ac operation of the converter with possibility ofmaximum power point tracking (MPPT) control and the S1 andS6 switches remain open. In Mode 2, the battery is charged withthe PV panels through the dc/dc operation of the converter byclosing the S6 switch and opening the S5 switch. In this mode,the MPPT function is performed; therefore, maximum power isgenerated from PV. There is another mode that both the PV andbattery provide the power to the grid by closing the S1 switch.This operation is shown as Mode 3. In this mode, the dc-linkvoltage that is the same as the PV voltage is enforced by thebattery voltage; therefore, MPPT control is not possible. Mode4 represents an operation mode that the energy stored in thebattery is delivered to the grid. There is another mode, Mode 5that the battery is charged from the grid.

The technical and financial benefits that the RSC solutionis able to provide are more apparent in larger solar PV powerplants. Specifically, a large solar PV power plant using the RSCscan be controlled more effectively and its power can be dispatchedmore economically because of the flexibility of operation.Developing a detailed operation characteristic of a solarPV power plant with the RSC is beyond the scope of this paper.However, different system controls as shown in Fig. 5 can beproposed based on the requested power from the grid operatorPreq and available generated power form the plant Pgen. Thesetwo values being results of an optimization problem (such asunit commitment methods) serve as variables to control the solarPV power plant accordingly.

II.CONTROL STRATEGY:

DC/AC Operation:

The dc/ac operation of the RSC is utilized for deliveringpower from PV to grid, battery to grid, PV and battery to grid,and grid to battery. The RSC performs the MPPT algorithm todeliver maximum power from the PV to the grid. Like the conventionalPV inverter control, the RSC control is implementedin the synchronous reference frame. The synchronous referenceframe proportional-integral current control is employed. In areference frame rotating synchronously with the fundamentalexcitation, the fundamental excitation signals are transformedinto dc signals.

As a result, the current regulator forming theinnermost loop of the control system is able to regulate ac currentsover a wide frequency range with high bandwidth andzero steady-state error. For the pulsewidth modulation (PWM) scheme, the conventional space vector PWM scheme is utilized. Fig. 2 presents the overall control block diagram of the RSCin the dc/ac operation. For the dc/ac operation with the battery,the RSC control should be coordinated with the batterymanagement system (BMS), which is not shown in Fig. 2.

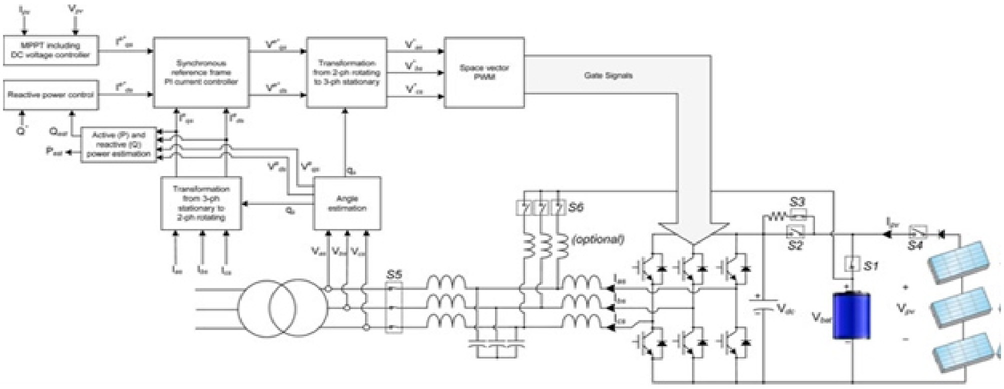

Fig. 2: Overall control block diagram of the RSC in the dc/ac operation

DC/DC Operation:

The dc/dc operation of the RSC is also utilized for delivering the maximum power from the PV to the battery. The RSC inthe dc/dc operation is a boost converter that controls the currentflowing into the battery. In this research, Li-ion batteryhas been selected for the PV-battery systems. Li-ion batteriesrequire a constant current, constant voltage type of charging algorithm.In other words, a Li-ion battery should be charged ata set current level until it reaches its final voltage. At the finalvoltage, the charging process should switch over to the constantvoltage mode, and provide the current necessary to holdthe battery at this final voltage. Thus, the dc/dc converter performingcharging process must be capable of providing stablecontrol for maintaining either current or voltage at a constantvalue, depending on the state of the battery. Typically, a fewpercent capacity losses happen by not performing constant voltagecharging. However, it is not uncommon only to use constantcurrent charging to simplify the charging control and process.The latter has been used to charge the battery. Therefore, fromthe control point of view, it is just sufficient to control only theinductor current. Like the dc/ac operation, the RSC performsthe MPPT algorithm to deliver maximum power from the PVto the battery in the dc/dc operation. Fig. 3 shows the overallcontrol block diagram of the RSC in the dc/dc operation. In thismode, the RSC control should be coordinated with the BMS, which is not shown in Fig. 3.

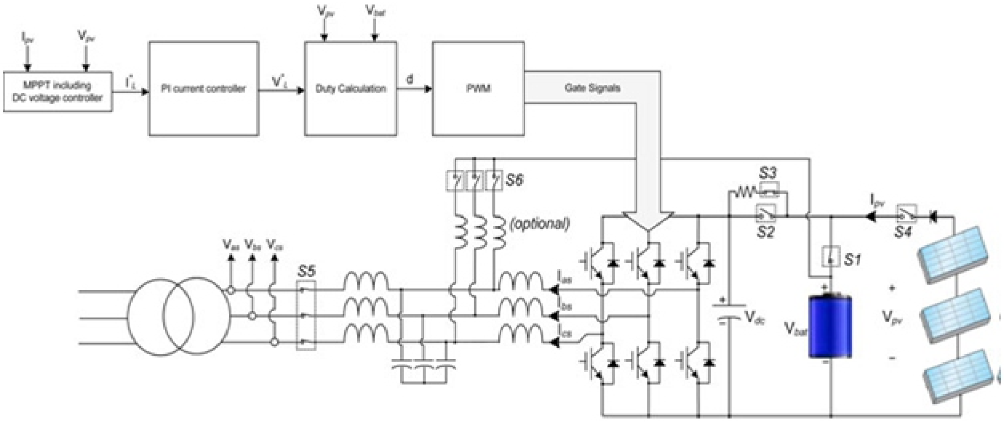

Fig. 3: Overall control block diagram of the RSC in the dc/dc operation.

III.PROPOSED CONVERTER:

One of the most important requirements of the project is thata new power conversion solution for PV-battery systems musthave minimal complexity and modifications to the conventionalthree-phase solar PV converter system. Therefore, it is necessaryto investigate how a three-phase dc/ac converter operates as adc/dc converter and what modifications should be made.It is common to use a LCL filter for a high-power three-phasePV converter and the RSC in the dc/dc operation is expected touse the inductors already available in the LCL filter.

There arebasically two types of inductors, coupled three-phase inductorand three single-phase inductors that can be utilized in the RSCcircuit.Using all three phases of the coupled three-phase inductorin the dc/dc operation causes a significant drop in the inductancevalue due to inductor core saturation. Table I presents anexample of inductance value of a coupled three-phase inductorfor the dc/dc operation, which shows significant drop in theinductance value. The reduction in inductance value requiresinserting additional inductors for the dc/dc operation which hasbeen marked as “optional” in Fig. 1.

To avoid extra inductors,only one phase can perform the–dc/dc operation.However, whenonly one phase, for instance phase B, is utilized for the dc/dcoperation with only either upper or lower three insulated-gatebipolar transistors (IGBTs) are turned OFF as complementaryswitching, the circulating current occurs in phases A and Cthrough filter capacitors, the coupled inductor, and switches, resultingin significantly high current ripple in phase B current, asshown in Fig. 4.

To prevent the circulating current in the dc/dc operation, thefollowing two solutions are proposed;1) all unused upper and lower IGBTs must be turned OFF;2) the coupled inductor is replaced by three single-phaseinductors.While the first solution with a coupled inductor is straightforward,using three single-phase inductors makes it possible touse all three phase legs for the dc/dc operation. There are twomethods to utilize all three phase legs for the dc/dc operation:

1)Synchronous operation;2) interleaving operation.

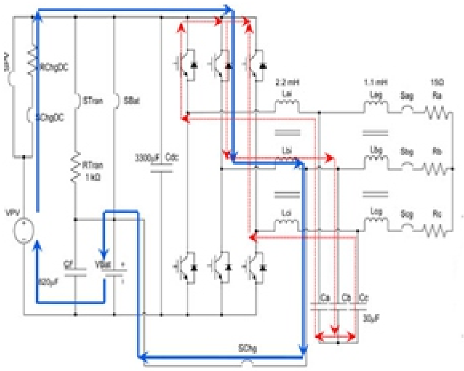

Fig. 4: Circulating current path if one phase is used for the dc/dc operation of the RSC with a coupled three-phase inductor

In the first solution, all three phase legs can operate synchronouslywith their own current control. In this case, the batterycan be charged with a higher current compared to the casewith one-phase dc/dc operation.

This leads to a faster chargingtime due to higher charging current capability. However, eachphase operates with higher current ripples. Higher ripple currentflowing into the battery and capacitor can have negative effectson the lifetime of the battery and capacitors.

IV.SIMULATION RESULTS:

The simulation circuit diagram of the RSC shown in Fig. 5 is used toverify the RSC concept experimentally. Fig. 5 shows the componentsused in the RSC circuit. The conventional grid-tie PVinverter is connected to the grid and delivers the power fromthe PV to the grid. Therefore, the conventional grid-tie PV inverterrequires grid synchronization and power factor controlfunctions.

For RSC verification, the aforementioned functionsare not implemented and tested. Since the RSC uses the same algorithms for those functions as the conventional grid-tie PV inverter, it is not necessary to verify them. Therefore, the RSC circuit is connected to a passive load.

The conventional PV inverter also performs the MPPT to extract the available maximum power from the PV. For RSC verification, the MPPT is also not implemented and tested, since the RSC employs the same MPPT algorithms as the conventional PV inverter. Thus, verification of the RSC circuit is done with a controllable dc power supply, as shown in Fig. 5.

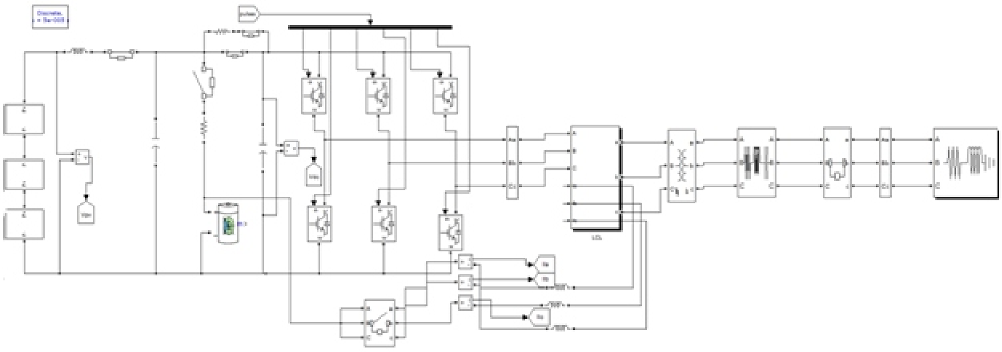

Fig 5: Simulation circuit of the proposed Converter

As shown in Fig. 14, theRSC consists of six IGBTs and diodes that have the rating of1.2 kV and 100 Apeak• There is a pre-charging circuit that limitsan inrush current flowing into the capacitors of the three-phaseinverter, when the dc power supply is initially connected to thethree-phase inverter. The filter capacitors are used to reducevoltage and current ripples for the batteries.

There is the voltagebalancing circuit that limits an inrush current flowing into thefilter capacitors of the batteries, when the battery system includingthe battery filter capacitors is initially connected to theinverter. There are three relays used for battery charging in thedc/dc operation. The relay rating is determined by the batterycharging current requirement. As mentioned earlier, a passiveload is used in RSC verification. A passive load has a maximumpower of 3 kW under the air-cooled condition.

At the top of the circuit is the RSC consisting of six IGBTs,six diodes, filter inductors, capacitors, relays, and wires. Atthe bottom of the picture is the energy storage device, the K2Li-ion battery. The K2 battery has its own BMS. The master controlsfour slaves who have nine battery cells assigned. The BMSmeasures the state of the battery cell voltages, temperatures, andthe current flowing into or out of the battery.

It also determinesthe battery operating status such as normal, warning, and errorin which status BMS uses the relays to protect the batterysystem and prevent any damage. The battery system includes apre-charging circuit to limit an inrush current flowing from thebatteries into the capacitors that can be connected to the batteryin parallel for a filtering purpose.

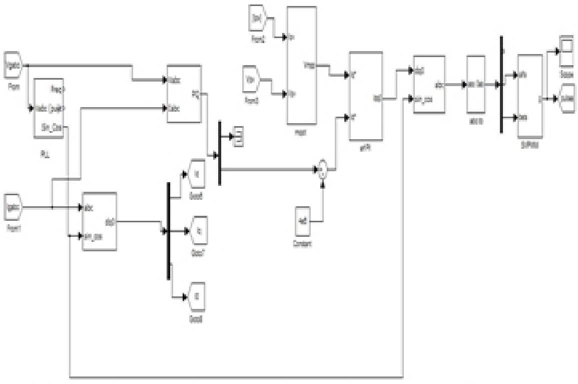

Fig 6: control circuit for dc/ac operation

Mode1:

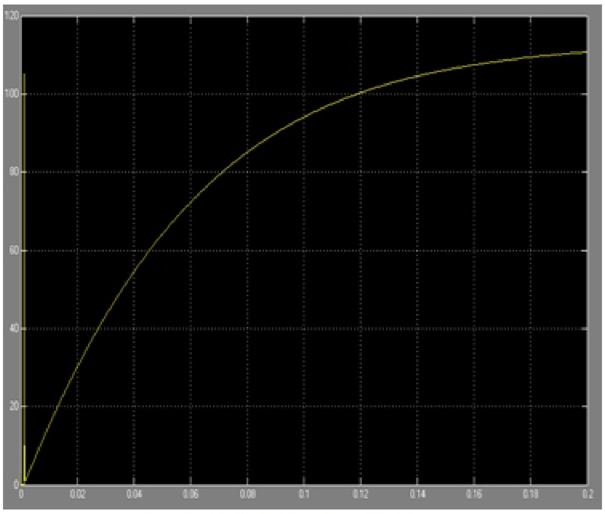

Fig 7: PV array voltage

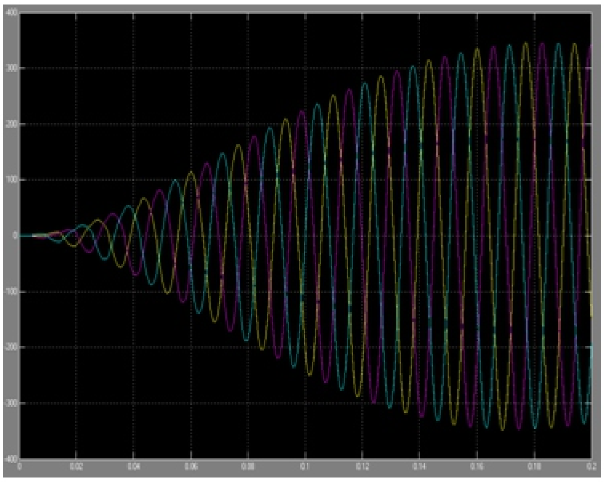

Fig 8: Grid voltage

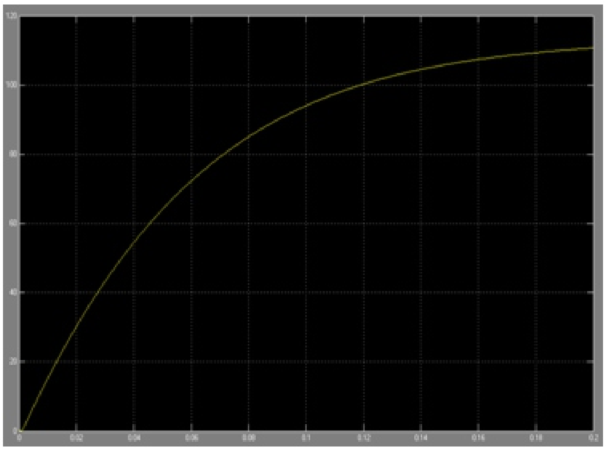

Fig9: dc voltage

Mode 2:

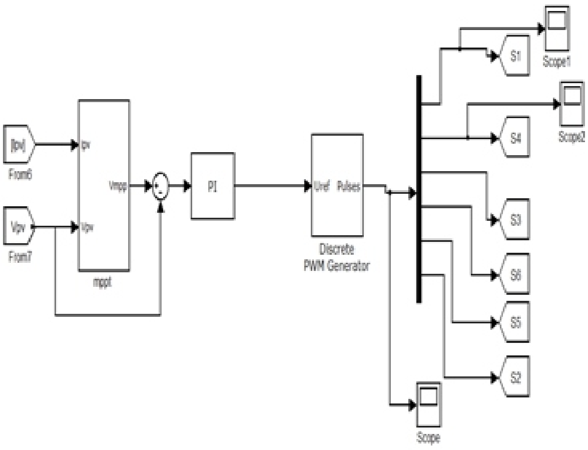

Fig 10: control circuit of dc/dc operation

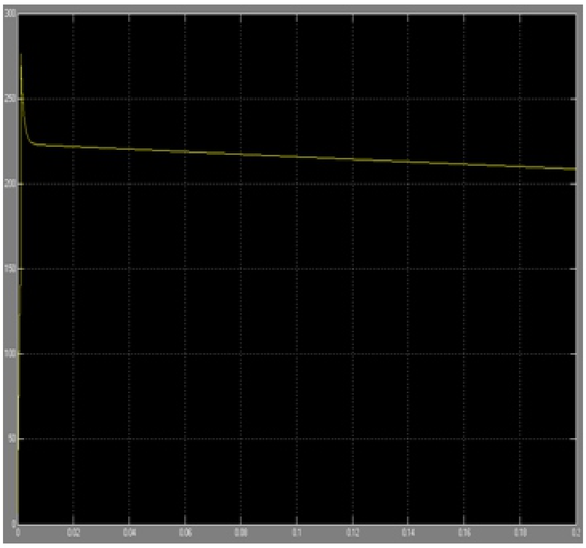

Fig 11: PV voltage

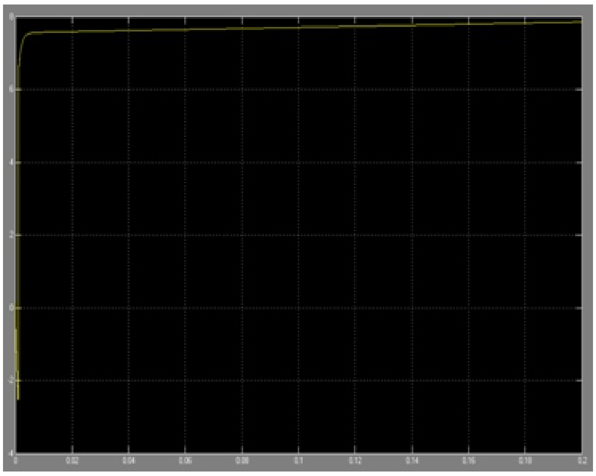

Fig 12: PV current

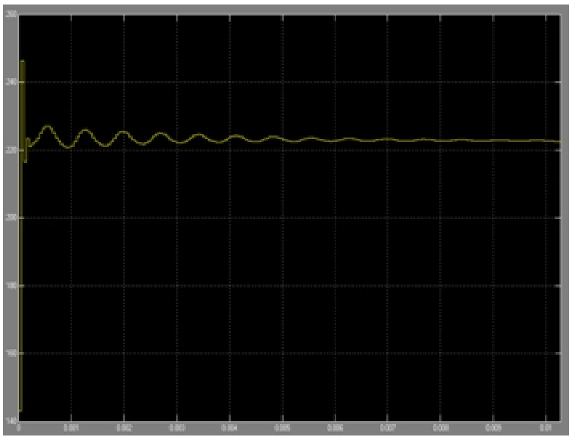

Fig 13: DC voltage

Mode 3:

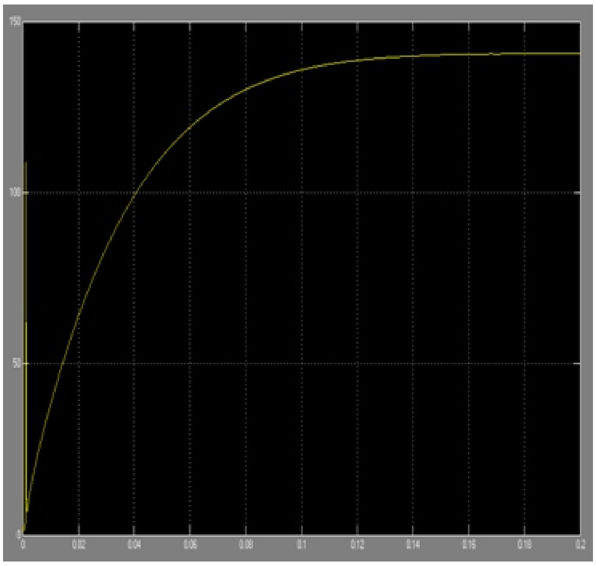

Fig 14: PV voltage

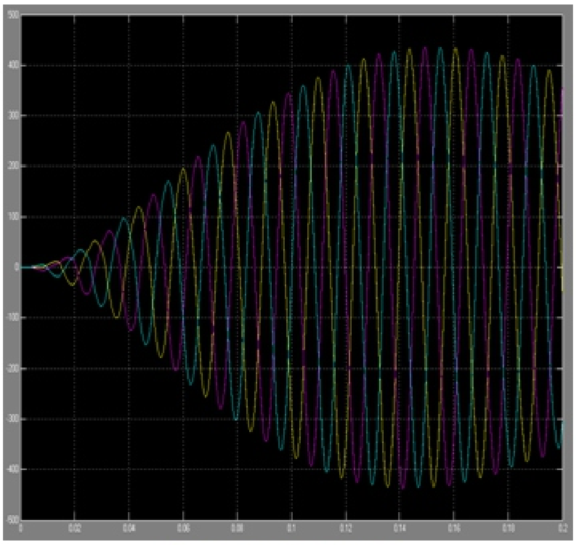

Fig 15: grid voltage

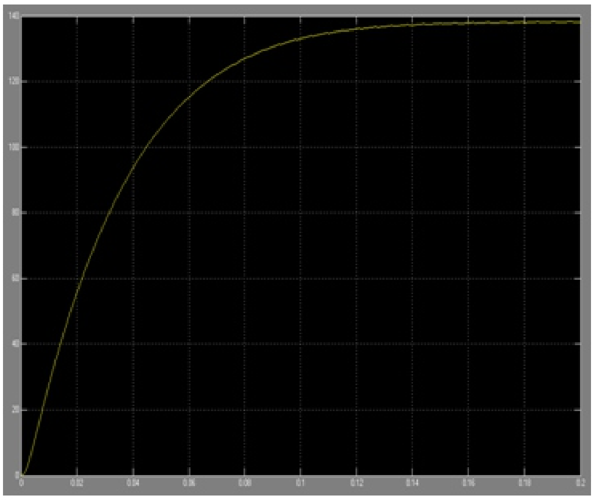

Fig16: dc voltage

Mode 4:

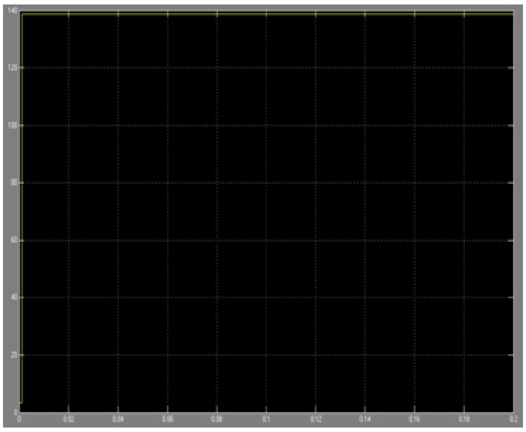

Fig 17: PV voltage

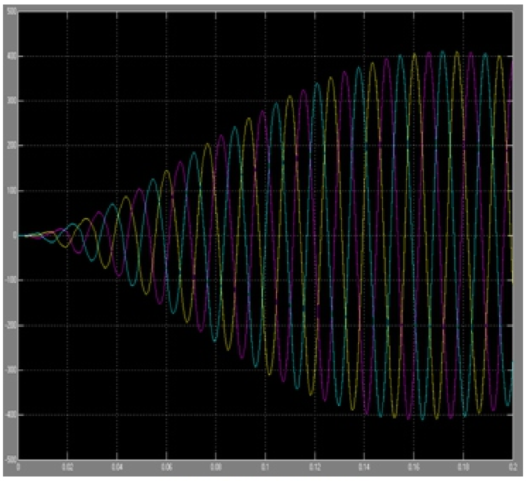

Fig 18: grid voltage

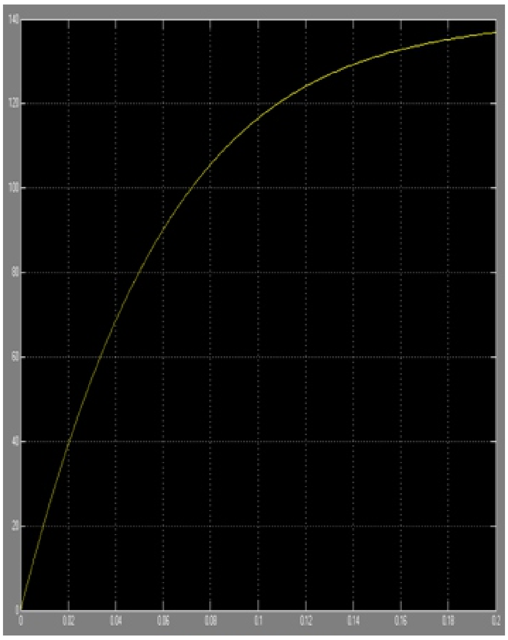

Fig 19: DC voltage

V.CONCLUSION:

This paper introduced a new converter called RSC forPV-battery application, particularly utility-scale PV-batteryapplication. The basic concept of the RSC is to use a singlepower conversion system to perform different operation modessuch as PV to grid (dc to ac), PV to battery (dc to dc), batteryto grid (dc to ac), and battery/PV to grid (dc to ac) forsolar PV systems with energy storage. The proposed solutionrequires minimal complexity and modifications to the conventionalthree-phase solar PV converters for PV-battery systems.Therefore, the solution is very attractive for PV-battery application,because it minimizes the number of conversion stages,thereby improving efficiency and reducing cost, weight, and volume.

REFERENCES:

[1] U.S. Department of Energy, "Solar energy grid integration systems-energystorage (SEGIS-ES)," May 2008.

[2] D. Bundestag, "GesetzzurNeuregelung des Rechts der erneuerbarenEnergienimStrombereich und zur A¨ nderungdamitzusammenha¨ngenderVorschriften," Bundesgesetzblatt, 2008.

[3] H. Konishi, T. Iwato, and M. Kudou, "Development of large-scale powerconditioning system in Hokuto mega-solar project," in Proc. Int. PowerElectron. Conf., 2010, pp. 1975–1979.

[4] J. H. Enslin and D. B. Snyman, "Combined low-cost, high efficient inverter,peak power tracker and regulator for PV applications," IEEE Trans.Power Electron., vol. 6, no. 1, pp. 73–82, Jan. 1991.

[5] H. Ertl, J. W. Kolar, and F. Zach, "A novel multi-cell dc-ac converter forapplications in renewable energy systems," IEEE Trans. Ind. Electron.,vol. 49, no. 5, pp. 1048–1057, Oct. 2002.

[6] C. Zhao, S. D. Round, and J. W. Kolar, "An isolated three-port bidirectionaldc/dc converter with decoupled power flow management," IEEETrans. Power Electron., vol. 23, no. 5, pp. 2443–2453, Sep. 2008.

[7] M. Bragard, N. Soltau, R. W. De Doncker, and A. Schiemgel, "Designand implementation of a 5 kW photovoltaic system with Li-ion batteryand additional dc/dc converter," in Proc. IEEE Energy Convers.Congr.Expo., 2010, pp. 2944–2949.

[8] W. Li, J. Xiao, Y. Zhao, and X. He, "PWM plus phase angle shift controlscheme for combined multiport dc/dc converters," IEEE Trans. PowerElectron., vol. 27, no. 3, pp. 1479–1489, Mar. 2012.

[9] N.Benavidas and P.Chapman, "Power budgeting of a multiple-input buckboostconverter," IEEE Trans. Power Electron., vol. 20, no. 6, pp. 1303–1309, Nov. 2005.