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Grid Connected Hybrid Renewable Energy Power Generation by ZVS Based RSC with Single Stage Power Conversion

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Abstract:- **This paper presents power-control strategies of a grid-connected hybrid power generation system with versatile power transfer. Generally hybrid system allows maximum utilization of freely available renewable energy sources like wind, fuel and photovoltaic energies. In this ZVS based RSC was proposed to perform DC/AC ,DC/DC AND AC/DC power conversions with single stage power conversion property.**

A multi level multistring converter topology for DERs performed by RSC system.. RSC is introduced with ZVS control strategy to improve the conversion efficiency during conventional boost converter& inverter operations of RSC and to stabilize the DC output voltage of various DERs such as PV, Wind and fuel cell modules. In this proposed system simulation results are presented to illustrate the operating principle of RSE, feasibility and reliability studies.

Index Terms- RSC (Reconfigurable solar converter), energy storage, photovoltaic (PV), DER (Distributed energy resources).

I. INTRODUCTION

Now a days, photovoltaic (PV) energy appears quite attractive for electricity generation because of its noiseless, pollution-free, scale flexibility, and little maintenance. Because of the PV power generation dependence on sun irradiation level, ambient temperature, and unpredictable shadows, a PV-based power system should be supplemented by other alternative energy sources to ensure a reliable power supply. Fuel cells (FCs) are emerging as a promising supplementary power sources due to their merits of cleanness, high efficiency, and high reliability. Because of long startup period and slow dynamic response weak points of FCs [1], mismatch power between the load and the FC must be managed by an energy storage system. Batteries are usually taken as storage mechanisms for smoothing output power, improving startup transitions and dynamic characteristics, and enhancing the peak power capacity [2], [3]. Combining such energy sources introduces a PV/FC/battery hybrid power system. In comparison with single-sourced systems, the hybrid power systems have the potential to provide high quality, more reliable, and efficient power. In these systems with a storage element, the bidirectional power flow capability is a key feature at the storage port. Further input power sources should have the ability of supplying the load individually and simultaneously.

Many hybrid power systems with various power electronic converters have been proposed in the literature up to now. Traditional methods that integrate different power sources to form a hybrid power system can be classified into AC coupled systems [4], [5] and ac-coupled systems [6]–[12]. However, the main shortcomings of these traditional integrating methods are complex system topology, high count of devices, high power losses, expensive cost, and large size. In recent years, several power conversion stages used in traditional hybrid systems are replaced by multi-input converters (MICs), which combine different power sources in a single power structure. These converters have received more attention in the literature because of providing simple circuit topology, centralized control, bidirectional power flow for the storage element, high reliability, and low manufacturing cost and size. In general, the systematic approach of generating MICs is introduced in [13], in which the concept of the pulsating voltage source cells and the pulsating current source cells is proposed for deriving MICs. One of the samples of these MICs is utilized in [14] to hybridize PV and wind power sources in a unified structure. Besides, a systematic method to synthesize MICs is proposed in [15]. This paper deals with two types of MICs: in the first type, only one power source is allowed to transfer energy to the load at a time, and in the second type, all the input sources can deliver power to the load either individually or simultaneously. As another basic research in MICs, in [16] assumptions, restrictions, and conditions used in analyzing MICs are described, and then it lists some basic rules that allow determining feasible and un- feasible input cells that realize MICs from their single-input versions. Two multiple-input converters based on flux additivity in a multi winding transformer are reported in [17] and [18]. Because there was no possibility of bidirectional operating of the converter in [17], and complexity of driving circuits and output power limitation in [18], they are not suitable for hybrid systems. In [19], a three port bidirectional converter with three active full bridges, two series resonant tanks, and a three- winding high-frequency transformer are proposed. In comparison with three-port circuits with only inductors and Diode Bridge at the load side, it gives higher boost gain and reduced switching losses due to soft-switching operation.

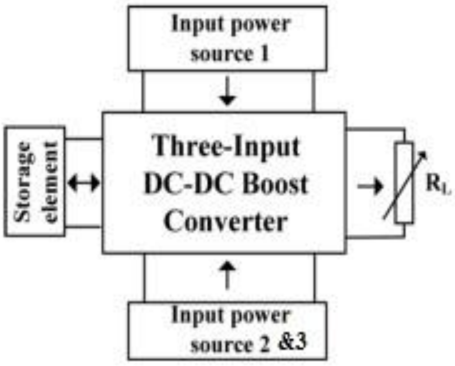


Fig.1 Proposed system overview.

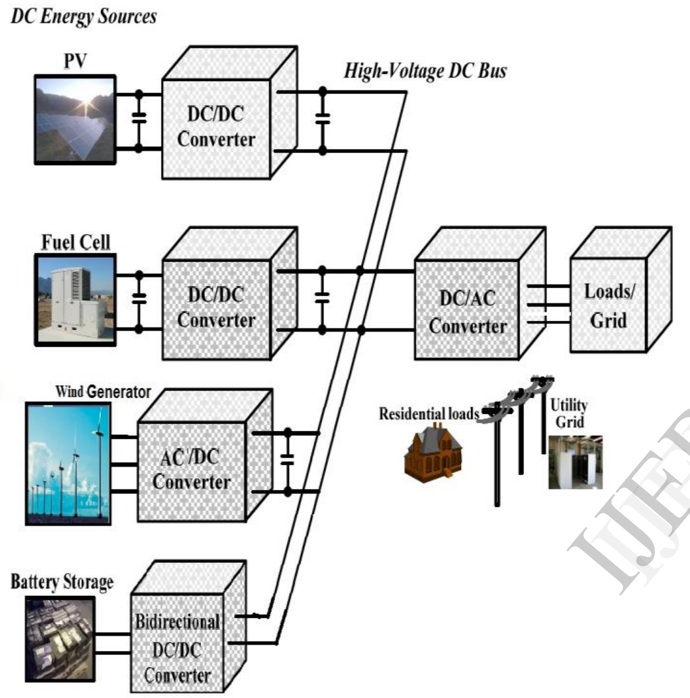


Fig.2 Configuration of multi string inverter for various DERs application.

In this paper, a new three input dc–dc boost converter is proposed for hybrid power system applications. As shown in Fig. 1, the proposed converter interfaces two unidirectional ports for input power sources, a bidirectional port for a storage element, and a port for output load in a unified structure. The converter is current source type at the both input power ports and is able to step up the input voltages. The proposed structure utilizes only four power switches that are independently controlled with four different duty ratios. Utilizing these duty ratios facilitates controlling the power flow among the input sources and the load. Powers from the input power sources can be delivered to the load individually or simultaneously.

2. OPERATION MODES OF THE RSC:

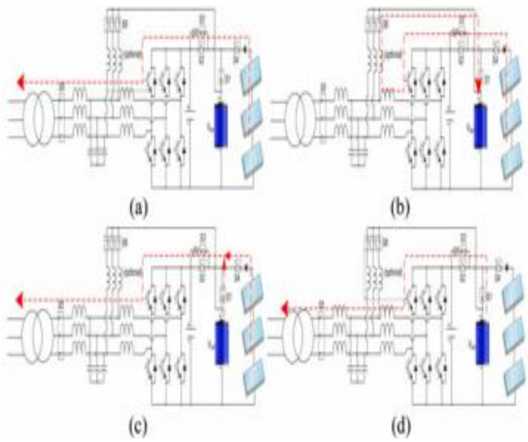


Fig. 3. All operation modes of the RSC. (a) Mode 1—PV to grid. (b) Mode 2—PV to battery. (c) Mode 3—PV/battery to grid. (d) Mode 4—battery to grid.

All possible operation modes for the RSC are presented in Fig. 3. In Mode 1, the PV is directly connected to the grid through a dc/ac operation of the converter with possibility of maximum power point tracking (MPPT) control and the S1and S6switches remain open. In Mode 2, the battery is charged with the PV panels through the dc/dc operation of the converter by closing the S6switch and opening the S5switch. In this mode, the MPPT function is performed; therefore, maximum power is generated from PV. There is another mode that both the PV and battery provide the power to the grid by closing the S1switch. This operation is shown as Mode 3. In this mode, the dc-link voltage that is the same as the PV voltage is enforced by the battery voltage; therefore, MPPT control is not possible. Mode 4 represents an operation mode that the energy stored in the battery is delivered to the grid. There is another mode, Mode 5 that the battery is charged from the grid. This mode is not shown in Fig. 3.

grid operator, different system control schemes can be realized with the RSC-based solar PV power plant as follows:

1) System control 1 for $P_{gen} > P_{req}$;
2) System control 2 for $P_{gen} < P_{req}$;
3) System control 3 for $P_{gen} = P_{req}$;

3.RSC CONTROL

A. Control of the RSC in the DC/AC Operation Modes (Modes 1, 3, 4, and 5)

The dc/ac operation of the RSC is utilized for delivering power from PV to grid, battery to grid, PV and battery to grid, and grid to battery. The RSC performs the MPPT algorithm to deliver maximum power from the PV to the grid. Like the conventional PV inverter control, the RSC control is implemented in the synchronous reference frame [1]. The synchronous reference frame proportional-integral current control is employed. In a reference frame rotating synchronously with the fundamental excitation, the fundamental excitation signals are transformed into dc signals. As a result, the current regulator forming the innermost loop of the control system is able to regulate ac currents over a wide frequency range with high bandwidth and zero steady-state error. For the pulsewidth modulation (PWM) scheme, the conventional space vector PWM scheme is utilized. Fig. 5 presents the overall control block diagram of the RSC in the dc/ac operation. For the dc/ac operation with the battery, the RSC control should be coordinated with the battery management system (BMS)[1].

B. Control of the RSC in the DC/DC Operation Mode (Mode 2)

The dc/dc operation of the RSC is also utilized for delivering the maximum power from the PV to the battery. The RSC in the dc/dc operation is a boost converter that controls the current flowing into the battery. In this research, Li-ion battery has been selected for the PV-battery systems. Li-ion batteries require a constant current, constant voltage type of charging algorithm. In other words, a Li-ion battery should be charged at a set current level until it reaches its final voltage. At the final voltage, the charging process should switch over to the constant voltage mode, and provide the current necessary to hold the battery at this final voltage. Thus, the dc/dc converter performing charging process must be capable of providing stable control for maintaining either current or voltage at a constant value, depending on the state of the battery. Typically, a few percent capacity losses happen by not performing constant voltage charging. However, it is not uncommon only to use constant current charging to simplify the charging control and process. The latter has been used to charge the battery. Therefore, from the control point of view, it is just sufficient to control only the inductor current. Like the dc/ac operation, the RSC performs the MPPT algorithm to deliver maximum power from the PV to the battery in the dc/dc operation[1].

C. DC-AC Power converter space vector modulation Technique.

Nine power switches of inverter with 8 possible combinations shown in "Figure. 3" are corresponding to effective voltage space vector U1 – U_9 what is u1…….u9 is here if its vector then what is v1……v9 and 2 zero vector U_0,U_9. The phase angle between one effective voltage space vector and adjacent one is 40 degrees. They constitute 9 uniform segments. The three digits in brackets express the linking state between three-phase output A,B,C and the input DC, such as M=101 which represents the switching of the switches S_{ai},S_{bj} and S_{ck}
The output voltage space vectors and the corresponding switching states are represented"[1].

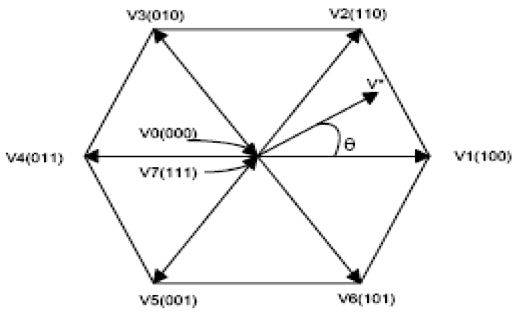


Fig.4 The composition of output voltage vector and Switching stages.

Any expected output voltage space vector U_j is formed by adjacent two basic output voltage vectors U_M, U_N,Uz t and zero output voltage U_0 orU_9. Suppose the angle between U_j and U_M is θ_j .

$$U_j = d_M U_M + d_N U_N + d_0 U_0 \qquad (11)$$

Whered_M, d_N and d_0 are the ratio cycles of U_M, U_N and U_0 respectively. And

$$d_M = T_M/T_\delta = m_v \sin(60^0 - \theta_j) \qquad (12)$$

$$d_N = T_N/T_\delta = m_v \sin(\theta_j) \qquad (13)$$

$$d_0 = 1 - d_M - d_N \qquad (14)$$

Where T_M, T_N is the switching time of vectors U_M and U_N respectively. T_δ is the switching period of PWM. m_v is the modulation index of output voltage. And

$$m_v = (2/3)^{1/2}\, U_{om}/(U_{im} m_c \cos\emptyset) \qquad (15)$$

Where U_{om} and U_{im} are the amplitude of output and input voltage, m_c is the input current modulation index, generally set $m_c = 1$, $\emptyset$is the input power factor angle. When the rotating space vector U_j locates in a segment, the local average of output voltage can be formed by two adjacent basic voltage space vectors constituting this segment and one zero voltage space vector.

D. SVM Techniques:

A different approach to SPWM is based on the space vector representation of voltages in the d, q plane. The d, q components are found by Park transform, where the total power, as well as the impedance, remains unchanged.Fig:9 space vector shows space vectors in according to 9 switching positions of inverter, V* is the phase-to-center voltage which is obtained by proper selection of adjacent vectors V1 and V2.

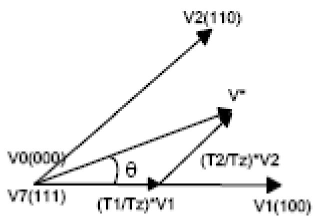
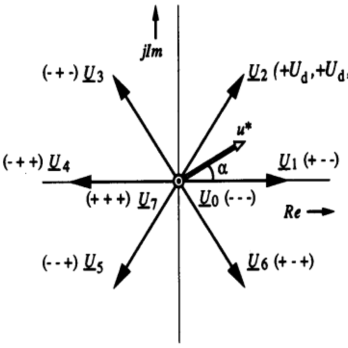


Fig.5.Determination of Switching times

The reference space vector V* is given by Equation (13), where T1, T2 are the intervals of application of vector V1 and V2 respectively, and zero vectors V0 and V7 are selected for T0.

V* Tz = V1 *T1 + V2 *T2 + V0 *(T0/2) + V7 *(T0/2)……….(16)



The amplitude of u0 and u9 equals 0. The other vectors u1…u9 have the same amplitude and are 40 degrees shifted. By varying the relative on-switching time T_{on} of the different vectors, the space vector u* and also the output voltages ua, ub and uc can be varied and is defined as:

ua = Re (u*)

ub = Re (u* . a-1)

uc = Re (u* . a-2) …………(17)

During a switching period Ton and considering for example the first sector, the vectors u0, u1 and u2 will be switched on alternatively.

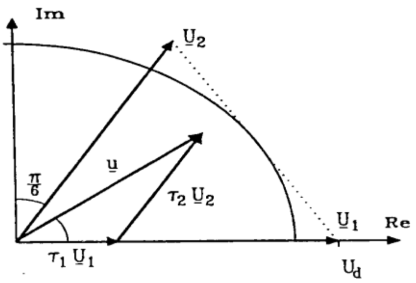


Fig.6. Definition of the Space vector

Depending on the switching times t0, t1 and t2 the space vector u* is defined as:

u* = 1/Ton . (t0 . u0 + t1 . u1 + t2 . u2)

u* = t0 . u0 + t1 . u1 + t2 . u2

u* = t1 . u1 + t2 . u2 ………….. (18)

Where

t0 + t1 + t2 = Ton and

t0 + t1 + t2 = 1

t0, t1 and t2 are the relative values of the on witchingtimes.They are defined as: t1 = m . cos (a + p/6) t2 = m . sin a t0 = 1 - t1 - t2

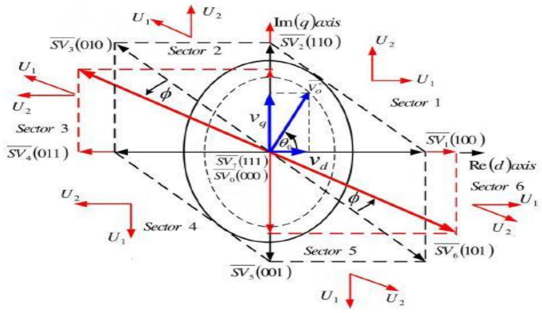


Fig.7. SVM Vector Diagram for New Switching Converter

Their values are implemented in a table for a modulation factor m = 1. Then it will be easy to calculate the space vector u* and the output voltages ua, ub and uc. The voltage vector u* can be provided directly by the optimal vector control laws w1, v_{sa} and v_{sb}. In order to generate the phase voltages ua, ub and uc corresponding to the desired voltage vector u* the above SVM strategy is proposed.

where n_3 is the introduced reset winding. Phase-shifted control is used for the converter where $Q_1$and Q_3form the leading leg

C.ZVS OPERATING PRINCIPLE

The proposed ZVS PWM full-bridge converter with reset winding is shown in Fig.8 switches operate first and Q_2 and Q_4 form the lagging leg. The converters in Fig. (1) and (2) are defined as Transformer Lead type and Transformer Lag type, respectively. The primary winding n_1 is connected with the lagging leg and the leading leg, respectively. The operation principle of the two types is similar. The difference is that the clamping diodes conduct only once in type while conduct twice in type. The following description will be focused on the type.

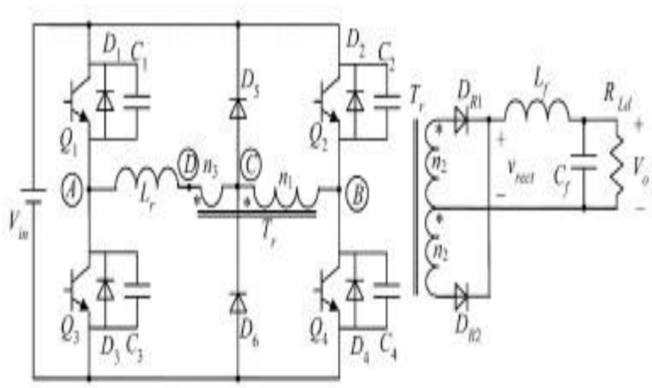


Fig: 8..Transformer-lag type ZVS PWM full bridge converter

SimulationModel:

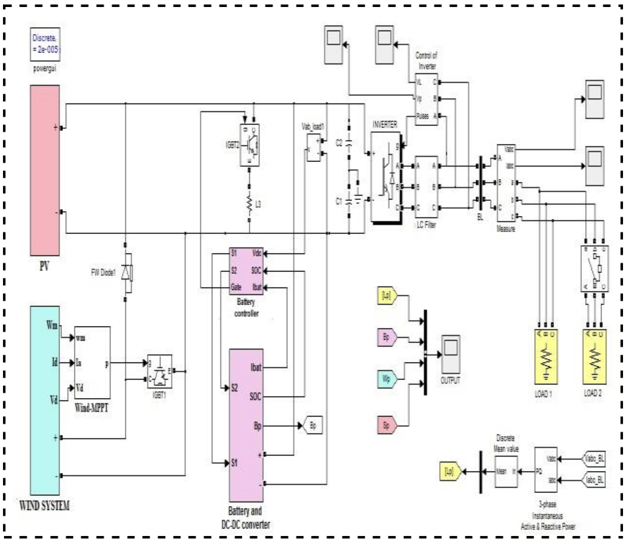


Fig. 9. Composite Simulation Model of Proposed Hybrid System

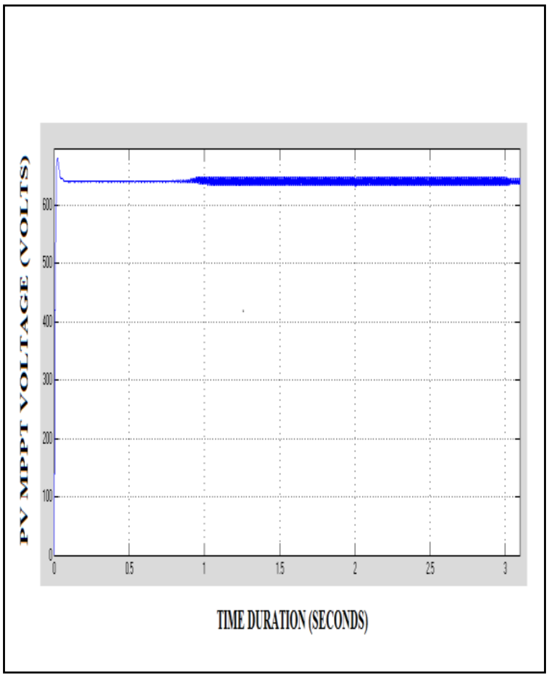


Fig .11 Phase Voltage observed at the PV array

Simulation Results:

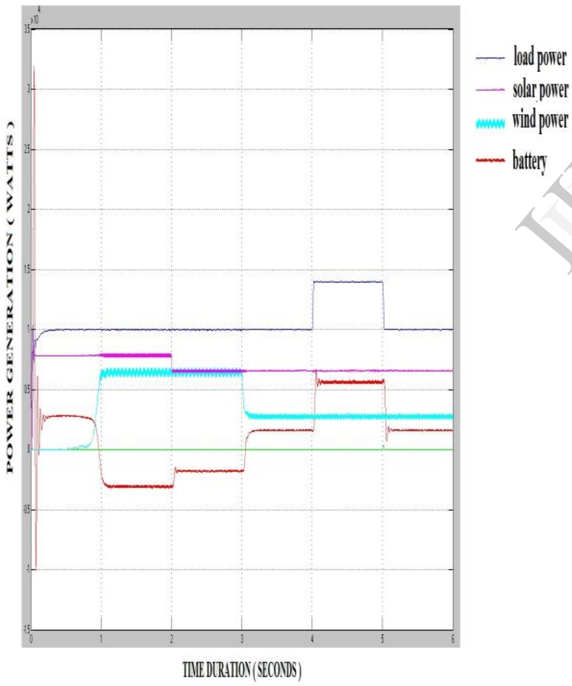


Fig .10 Load Sharing Action Performed by the Hybrid Energy Energy in Polycrystalline Solar ,wind and fuel Panel TSP 215

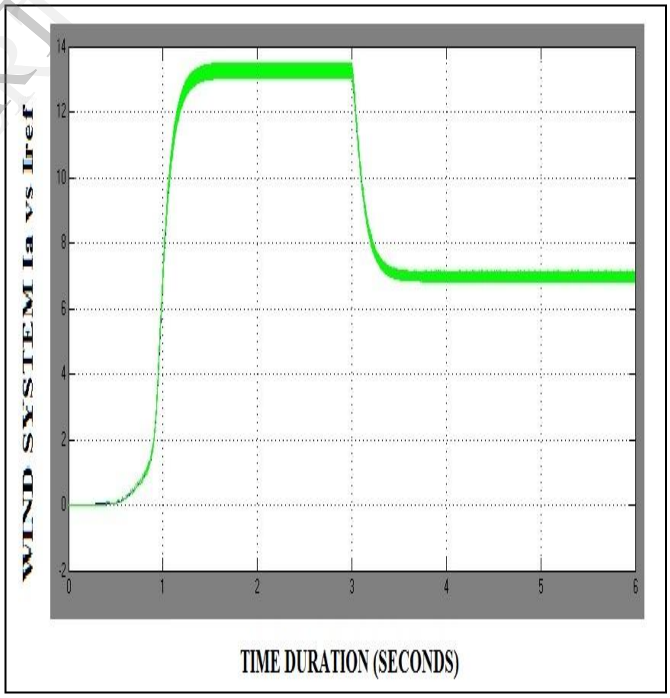


Fig. 12 The relative variation curve of Actual Current (Ia) and Reference Current (Iref)

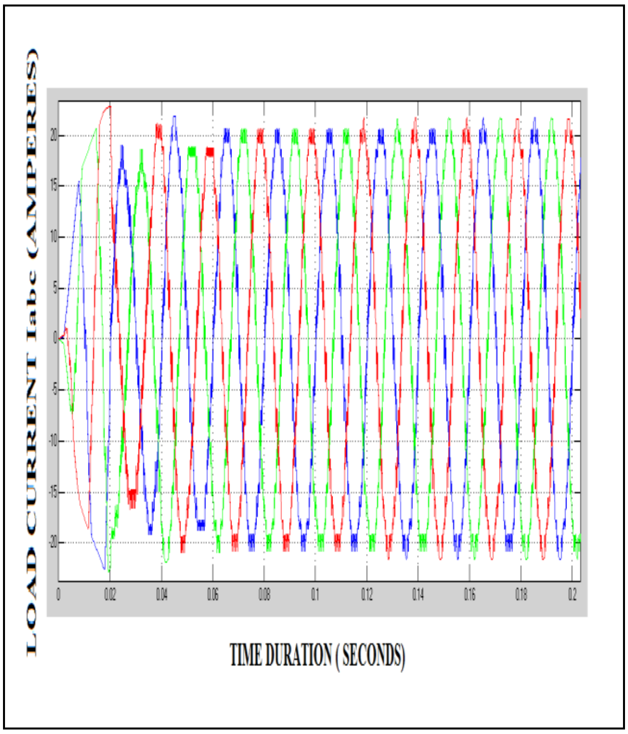


Fig.13 The load current supplied to the load is sinusoidal in nature as depicted in the simulation

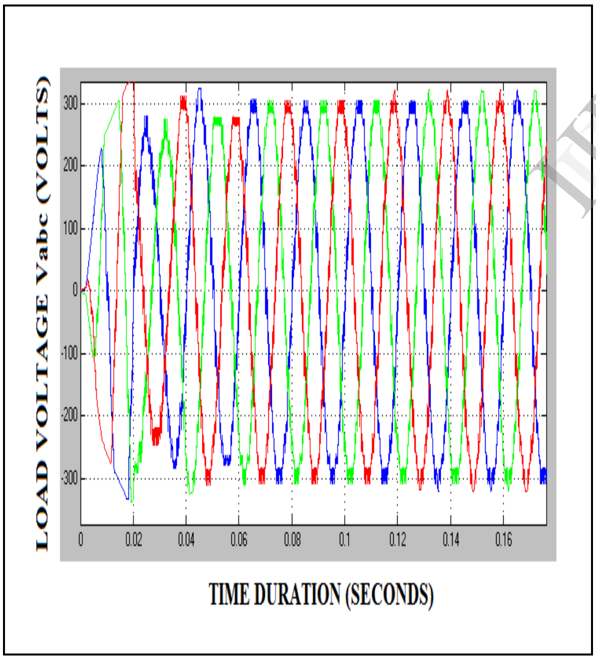


Fig. 14 Three Phase Voltage Supplied To The Load. By The Inverter

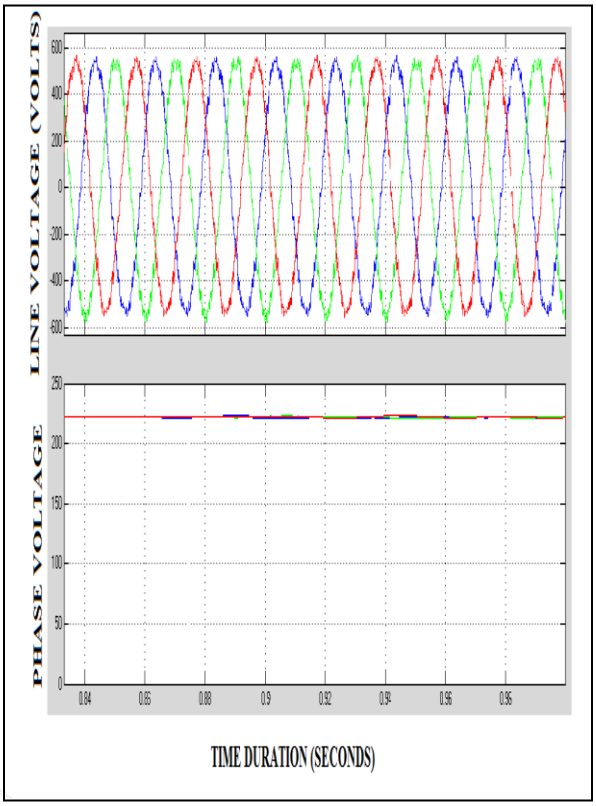


Fig. 15 AC Line Voltage and Phase Voltage Given By the Inverter

V. CONCLUSIONS AND FUTURE SCOPE

This paper introduced a new converter called RSC for PV-battery application, particularly utility-scale PV-battery application. The basic concept of the RSC is to use a single power conversion system to perform different operation modes such as PV to grid (dc to ac), PV to battery (dc to dc), battery to grid (dc to ac), and battery/PV to grid (dc to ac) for solar PV systems with energy storage. The proposed solution requires minimal complexity and modifications to the conventional three-phase solar PV converters for PV wind -battery systems.

In The Proposed Paper Load Demand Is Met From The Combination Of PV, WIND and FUEL CELL Array, Wind Turbine And The Battery. An Inverter Is Used To Convert Output From Solar Systems Into AC Power Output. Circuit Breaker Is Used To Connect An Additional Load Of 5 KW In The Given Time. This Hybrid System Is ANN Controlled To Give Maximum Output Power Under All Operating Conditions To Meet The Load. Either Solar System Is Supported By The Battery To Meet The Load. Also, Simultaneous Operation Of Wind And Solar System Is Supported By Battery For The Same Load. The Importance Of Single-Stage Converter Systems For SE (PV, WIND Arrays And Fuel Cells) Applications Has Been Presented. Several Topologies Were Reviewed, And A Novel Switching Pattern Has Been Proposed Based On The VSI Topology. The Simulation Setup Constructed For The Proposed Switching Pattern Had Promising Results And Verified Its Capability. 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.

FUTURE SCOPE

1) The losses incurred at the initial working stage of PV, WIND and FUELL CELL can be controlled through optimum modeling of essential parameters.
2)Dump Load can be used to dispose excess power.
3)Transformer can be added to distribute supply variedly to the load..
4)A current controller is designed to react to and absorb unanticipated Power disturbances in the utility grid.

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