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Power Management Strategies of Single-Stage Converters with Pv-Battery System Using Ann Technique

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Abstract: **This paper introduces a new converter called reconfigurable solar converter (RSC) for photovoltaic (PV)-battery application, particularly utility-scale PV-battery application. The main concept of the new converter is to use a single-stage three-phase grid-tie solar PV converter to perform dc/ac and dc/dc operations. 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. The output power induced in the photovoltaic modules depends on solar radiation and temperature of the solar cells. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the PV array. This paper presents a maximum power point tracker using Ann Technique. An advanced ANN controller is proposed as a new method gives a very good maximum power operation of any PV array under different climatic conditions such as changing insolation and temperature. The simulation studies show the effectiveness of the proposed algorithm.**

Keywords:-- Converter, energy storage, photovoltaic (PV), solar, ANN (Artificial Neural network).

I. INTRODUCTION

With the increasing fossil fuel deficit, global warming and damage to the ecosystem, renewable energy sources (solar, wind, tidal, and geothermal, etc.) are attracting more attention as alternative energy sources. Among the renewable energy sources solar photovoltaic (PV) energy has been widely utilized in small-sized applications. It is also the most promising candidate for research and development for large-scale uses as the fabrication of less costly photovoltaic devices becomes a reality.

Photovoltaic system as a number of applications such as water pumping, domestic and street lighting, electric vehicles, hybrid systems, military and space applications, refrigeration and vaccine storage, power plants, etc., all in either stand-alone or grid-connected configurations. A PV array is by nature a nonlinear power source, which under constant uniform irradiance has a current–voltage (I–V) characteristic like that shown in Fig. 1.

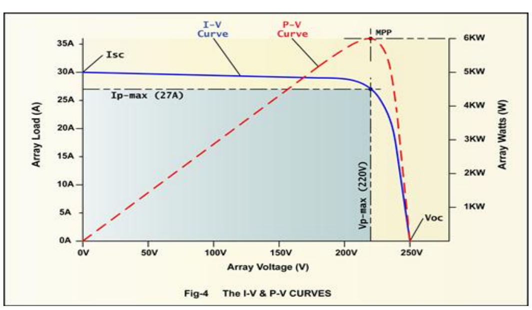


Fig.1. V-I & P-V Curve graph

There is a unique point on the curve, called the maximum power point (MPP), at which the array operates with maximum efficiency and produces maximum output power. As it is well known, the MPP of a PV power generation system depends on array temperature, solar insolation, shading conditions, and PV cells aging, so it is necessary to constantly track the MPP of the solar array. A switch-mode power converter, called a maxi-mum power point tracker (MPPT), can be used to maintain the PV array's operating point at the MPP. The MPPT does this by controlling the PV array's voltage or current independently of those of the load. If properly controlled by an MPPT algorithm, the MPPT can locate and track the MPP of the PV array. How-ever, the location of the MPP in the I–V plane is not known a priori. It must be located, either through model calculations or by a search algorithm. Fig. 2 shows a family of PV I–V curves under increasing irradiance, but at constant temperature. Needless to say there is a change in the array voltage at which the MPP occurs. For years, research has focused on various MPP control algorithms to draw the maximum power of the solar array. These techniques include look-up table methods, using neural networks [1], [2], perturbation and observation (P&O) methods [3]–[6], and computational methods [7]. For example, Hiyama et al. [1] presented a neural network application to the identification of the optimal operating point of PV modules and designed a PI-type controller for real-time maximum power tracking. Optimal operating voltages are identified through the proposed neural network by using the open-circuit voltages measured from monitoring cells and optimal operating currents are calculated from the measured short-circuit currents

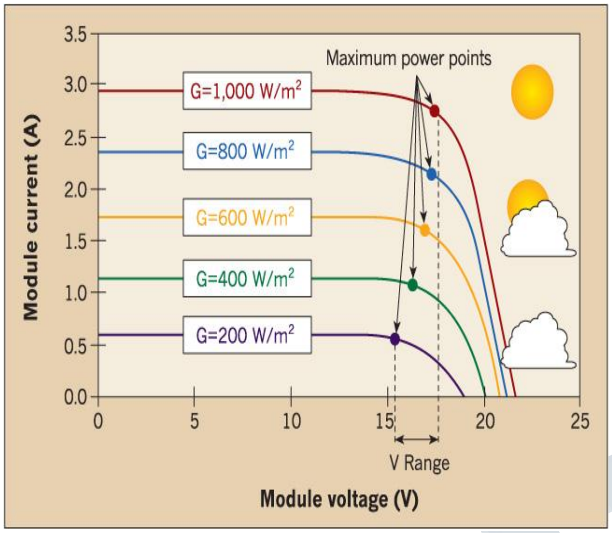


Figure 2: PV array (I –V) characteristics at various insolation levels

Solar Photovoltaic (Pv) electricity generation is not available and sometimes less available depending on the time of the day and the weather conditions. Solar PV electricity output is also highly sensitive to shading. When even a small portion of a cell, module, or array is shaded, while the remainder is in sunlight, the output falls dramatically. Therefore, solar PV electricity output significantly varies. From an energy source stand point, a stable energy source and an energy source that can be dispatched at the request are desired. As a result, energy storage such as batteries and fuel cells for solar PV systems has drawn significant attention and the demand of energy storage for solar PV systems has been dramatically increased, since, with energy storage, a solar PV system becomes a stable energy source and it can be dispatched at the request, which results in improving the performance and the value of solar PV systems [1]–[3].

There are different options for integrating energy storage into a utility-scale solar PV system. Specifically, energy storage can be integrated into the either ac or dc side of the solar PV power conversion systems which may consist of multiple conversion

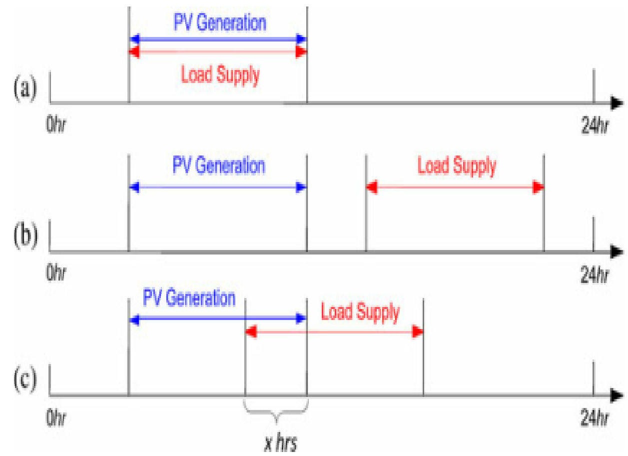


Fig. 3.Different scenarios for PV generation and load supply sequence. Stages [4]–[33].

Every integration solution has its advantages and disadvantages. Different integration solutions can be compared with regard to the number of power stages, efficiency, storage system flexibility, control complexity, etc.

This paper introduces a novel single-stage solar converter called reconfigurable solar converter (RSC). 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 RSC concept arose from the fact that energy storage integration for utility-scale solar PV systems makes sense if there is an enough gap or a minimal overlap between the PV energy storage and release time. Fig. 1 shows different scenarios for the PV generated power time of use. Incase (a), the PV energy is always delivered to the grid and there is basically no need of energy storage. However, for cases (b) and (c), the PV energy should be first stored in the battery and then the battery or both battery and PV supply the load. In cases (b) and (c), integration of the battery has the highest value and the RSC provides significant benefit over other integration options when there is the time gap between generation and consumption of power. The output of the neural network goes through the PI controller to the voltage control loop of the inverter to change the terminal voltage of the PV system to the identified optimal one.

ANN-based MPPT technique [8], [9] is one of the computational methods, which have demonstrated fine performances under different environmental operating conditions.

II. RECONFIGURABLE SOLAR CONVERTER (RSC)

A. Introduction

The schematic of the proposed RSC is presented in Fig. 2. The RSC has some modifications to the conventional

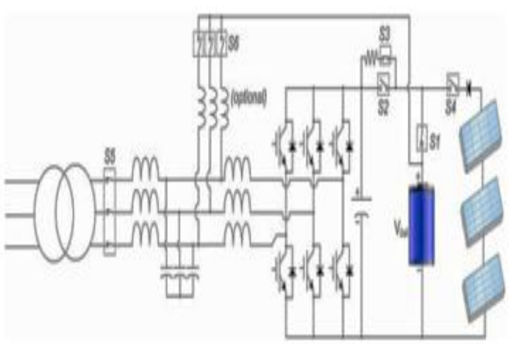


Fig. 4. Schematic of the proposed RSC circuit.

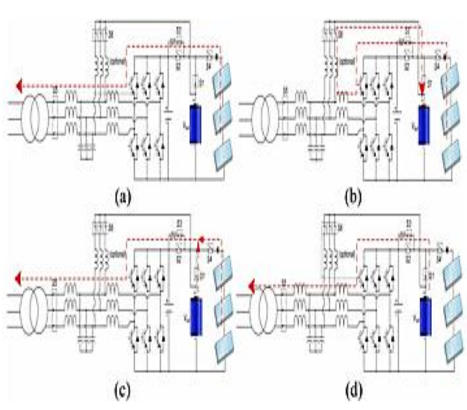


Fig. 5. All operation modes of the RSC. (a) Mode 1—PV to grid. (b) Mode 2—PV to battery. (c) Mode 3—PV/battery to grid. (d) Mode 4—battery to grid.

Three-phase PV inverter system. These modifications allow the RSC to include the charging function in the conventional three- phase PV inverter system. Assuming that the conventional utility-scale PV inverter system consists of a three-phase voltage source converter and its associated components, the RSC requires additional cables and mechanical switches, as shown in Fig. 2. Optional inductors are included if the ac filter inductance is not enough for the charging purpose.

B. Operation Modes of the RSC

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.

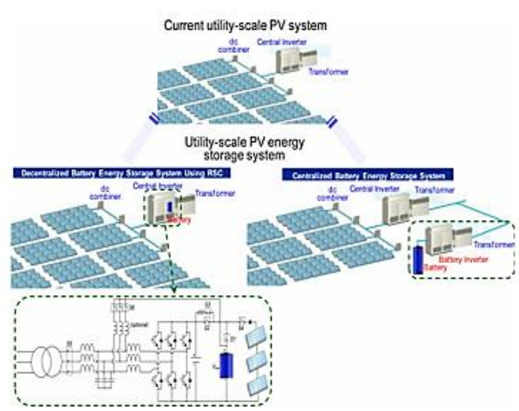


Fig. 6. Utility-scale PV-energy storage systems with the RSC and the current state-of-the-art solution.

C. System Benefits of Solar PV Power Plant with the RSC Concept

The RSC concept provides significant benefits to system planning of utility-scale solar PV power plants. The current state of-the-art technology is to integrate the energy storage into the ac side of the solar PV system. An example of commercial energy storage solutions is the ABB distributed energy storage (DES) solution that is a complete package up to 4 MW, which is connected to the grids directly and, with its communication capabilities, can be utilized as a mean for peak shifting in solar PV power plants [33]. The RSC concept allows not only the system owners to possess an expandable asset that helps them to plan and operate the power plant accordingly but also manufacturers to offer a cost-competitive decentralized PV energy storage solution with the RSC. Fig. 4 shows examples of the PV energy storage solutions with the RSC and the current state-of-the-art technology.

The technical and financial benefits that the RSC solution is able to provide are more apparent in larger solar PV power plants. Specifically, a large solar PV power plant using the RSCs can be controlled more effectively and its power can be dispatched more economically because of the flexibility of operation. Developing a detailed operation characteristic of a solar PV power plant with the RSC is beyond the scope of this paper. However, different system controls as shown in Fig. 5 can be proposed based on the requested power from the grid operator Preq and available generated power form the plant Pgen. These two values being results of an optimization problem (such as unit commitment methods) serve as variables to control the solar PV power plant accordingly. In other words, in response to the request of the grid operator, different system control schemes can be realized with the RSC-based solar PV power plant as follows:

1) System control 1 for Pgen> Preq;
2) System control 2 for Pgen< Preq;
3) System control 3 for Pgen= Preq;

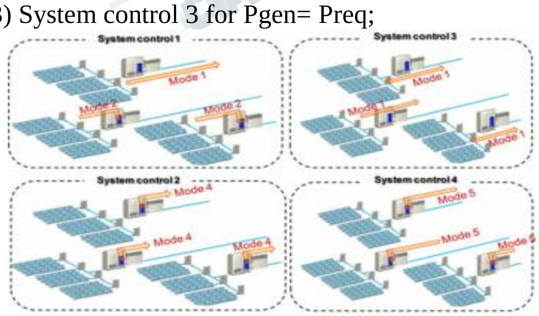


Fig. 7. Example of different system operation modes of a RSC-based solar PV power plant.

4) system control 4 for charging from the grid (Operation Mode 5).

III. 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. 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. 6 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), which is not shown in Fig. 6.

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. Fig. 7 shows the overall control block diagram of the RSC in the dc/dc operation. In this mode, the RSC control should be coordinated with the BMS, which is not shown in Fig. 7.

IV. DESIGNING & TRAINING OF ANN

An ANN is essentially a cluster of suitably interconnected non-linear elements of very simple form that possess the ability of learning and adaptation. These networks are characterised by their topology, the way in which they communicate with their environment, the manner in which they are trained and their ability to process information [18]. Their ease of use, inherent reliability and fault tolerance has made ANNs a viable medium for control.
An alternative to fuzzy controllers in many cases, neural controllers share the need to replace hard controllers with intelligent controllers in order to increase control quality [19]. A feed forward neural network works as compensation signal generator. This network is designed with three layers. The input layer with seven neurons, the hidden layer with 21 and the output layer with 3 neurons. Activation functions chosen are tan sigmoidal and pure linear in the hidden and output layers respectively.

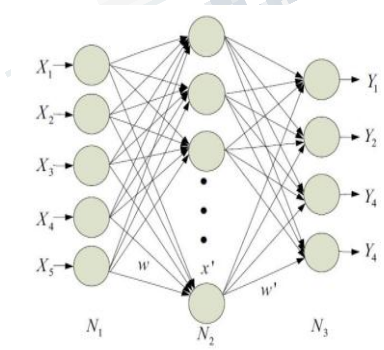
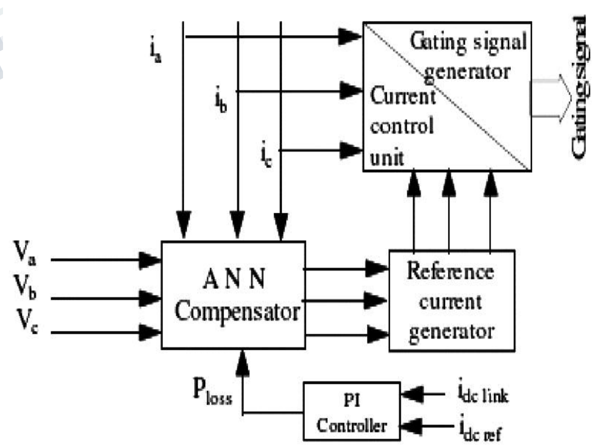


Figure.II Network Topology of ANN

The training algorithm used is Levenberg Marquardt back propagation (LMBP). The Matlab programming of ANN training is as given below:

```
net=newff(minmax(P),[7,21,3],
{‘tansig’, ‘tansig’, ‘purelin’}, ‘trainlm’);
net.trainParam.show = 50;
net.trainParam.lr = .05;
net.trainParam.mc = 0.95;
net.trainParam.lr_inc = 1.9;
net.trainParam.lr_dec = 0.15;
net.trainParam.epochs = 1000;
net.trainParam.goal = 1e-6;
[net,tr]=train(net,P,T);
a=sim(net,P);
gensim(net,-1);
```

The compensator output depends on input and its evolution. The chosen configuration has seven inputs three each for reference load voltage and source current respectively, and one for output of error (PI) controller. The neural network trained for outputting fundamental reference currents [20]. The signals thus obtained are compared in a hystersis band current controller to give switching signals. The block diagram of ANN compensator is as shown in Figure.III Block diagram of ANN-based compensator



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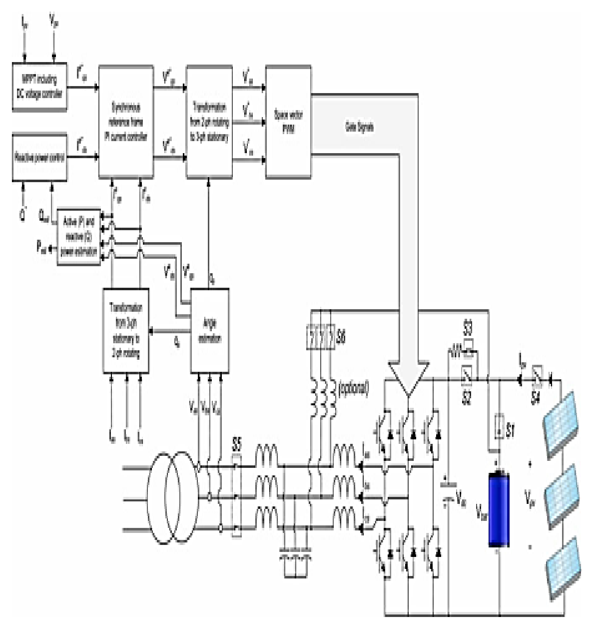

Fig. 8. Overall control block diagram of the RSC in the dc/ac operation

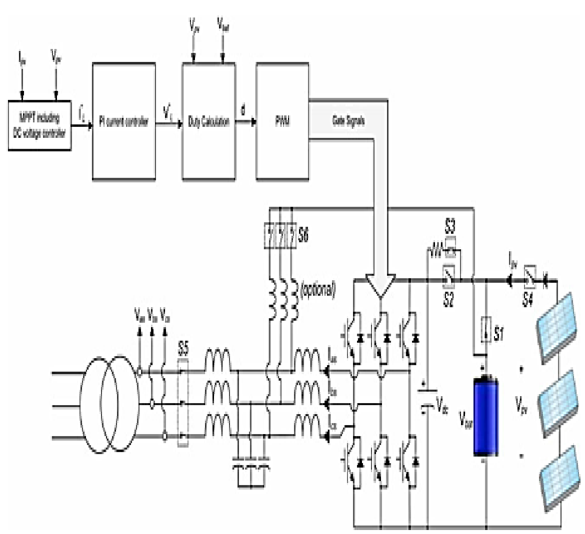

Fig. 9. Overall control block diagram of the RSC in the dc/dc operation.

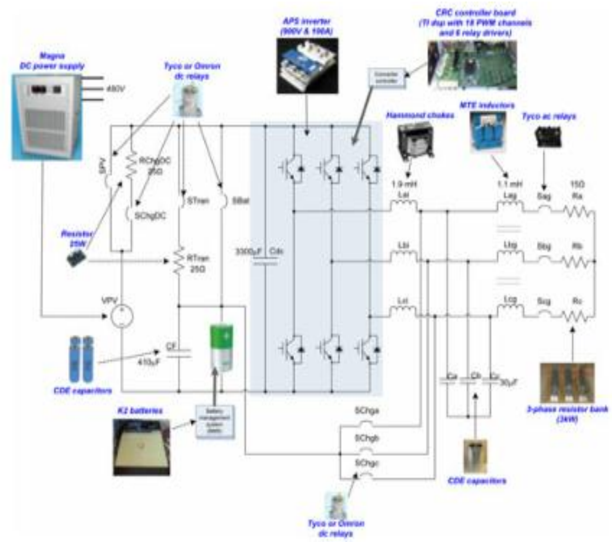

Fig. 10. Components used in the proposed RSC and a photograph of the test setup.

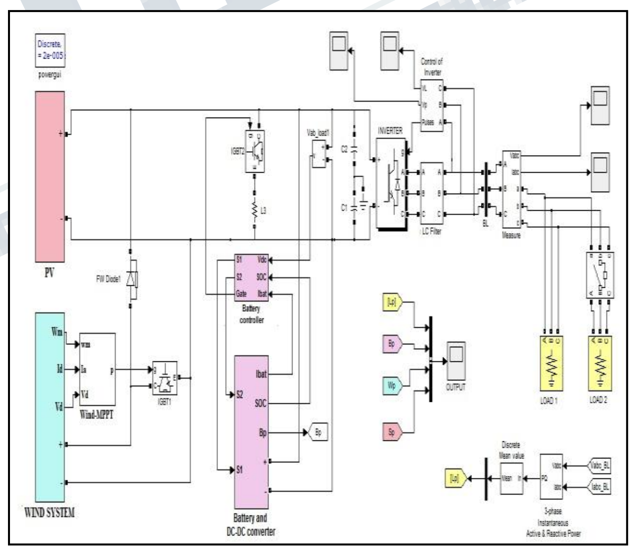

Fig 11 Composite Simulation Model of Proposed Hybrid System

SIMULATION RESULTS:

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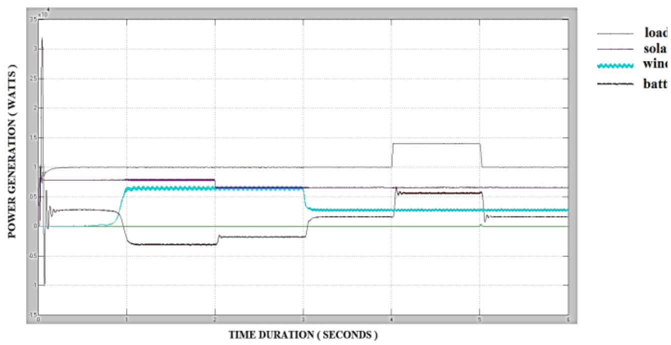

Fig 12 Load Sharing Action Performed by the Hybrid Energy Energy in Polycrystalline Solar Panel TSP 215

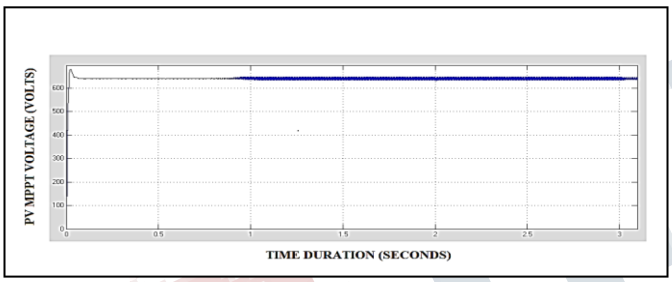

Fig 13 Phase Voltage observed at the PV array

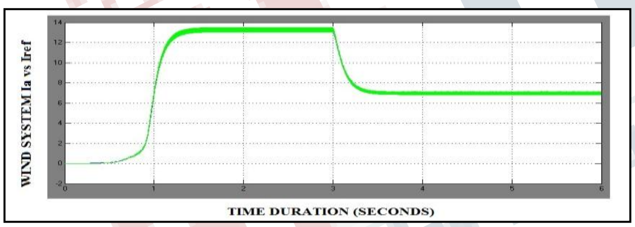

Fig 14 The relative variation curve of Actual Current (Ia) and Reference Current (Iref)

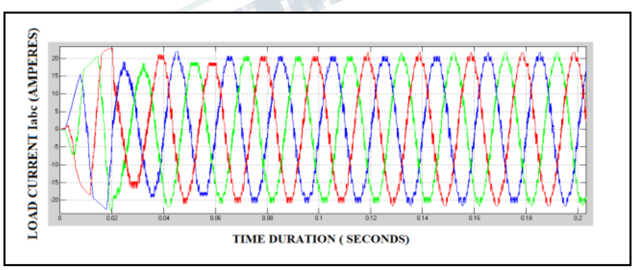

Fig 15 the load current supplied to the load is sinusoidal in nature as depicted in the simulation

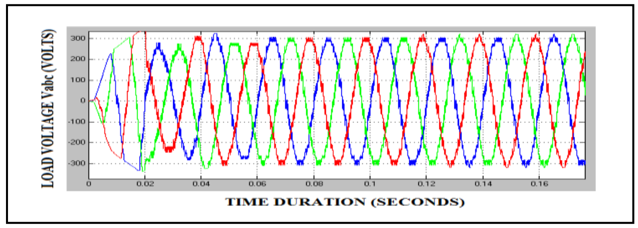

Fig 16 Three Phase Voltage Supplied To The Load By The Inverter

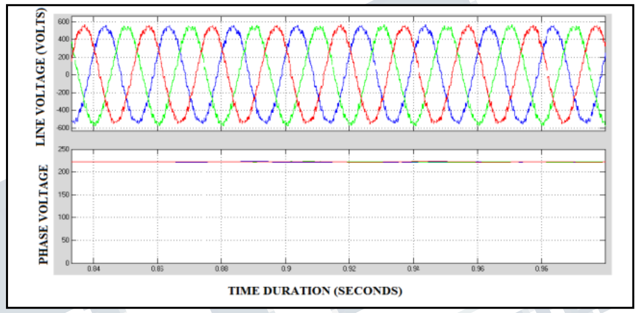

Fig 17 AC Line Voltage and Phase Voltage Given By the Inverter

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-battery systems.

In The Proposed Paper Load Demand Is Met From The Combination Of PV 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

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Systems For SE (PV 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 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)PID controllers with SVPWM can be used to control current in required circuit.
5)Other methods of MPPT can be implemented and compared
6)A current controller is designed to react to and absorb unanticipated Power disturbances in the utility grid

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