Sustainable Energy Generation By Integration Of RES With The Grid Through An Inverter Interface

Vedant A. Bhave, Anuprit Punse, Aakanksha P. Rao, Kshamta Mathur

Abstract*: Increasing the use of renewable sources of energy like solar and wind has become a necessity over the use of non-renewable resources, mainly due to the fear of these resources becoming scarce which will be insufficient to satisfy the needs of the ever increasing worldly population. This paper provides a method for synchronizing the renewable energy supply from solar and wind with the grid supply with phase locked loop (PLL) technique using MATLAB software. It also includes solar and wind separate power generating system. This synchronization is required because the renewable energy sources are variable in nature, therefore grid synchronized inverters are used as an interface for synchronizing and controlling the renewable sources of energy with the grid. This is a 3-phase inverter having multiply functions and is mainly used to inject the power produced by the renewable sources into the grid. The concept of renewable energy & synchronization is demonstrated using MATLAB/Simulink software which gives the accurate results & graphs. In the recent years, the renewable energy share in the total energy production has increased substantially and has now commenced its support to the distribution grids thus reducing the dependency on the polluting power plants.

Index Terms: Renewable Energy System, Solar & Wind System, Grid interfacing inverter, Synchronizm.

I. INTRODUCTION

Fossil fuels formation requires millions of years and require high pressure and temperature, thus cannot be created in laboratories. India's population is increasing at an alarming rate with the current population being approximately 1.37 billion. With a 1.19% growth rate, it might reach 1.53 billion by the year 2030 which makes it necessary to increase renewable energy consumption as fossil fuels are on the verge of depletion. Also about 93% of world's carbon capacity will be consumed by 2040 which leaves very less fossil fuels for future projects. The contribution of the fossil fuel in increasing the environmental effects like air pollution and greenhouse gas emissions is maximum, also the fear of their depletion leading to increase in their cost has made many countries to focus their attention in generating clean and sustainable power from the free abundant renewable energy sources (RES).

Renewable sources are variable in nature because they change as per the weather conditions, thus cannot provide continuous electricity [2]. This problem can be tackled if their energy is used to charge a battery bank which can be fed to a voltage source inverter (VSI) thus giving ac output [2]. The attempt of high penetration level of the RES with the grid, may cause issues in the stability of the network, voltage regulation and also affects network's power quality, therefore distribution systems need to keep a check on the safety, reliability and efficient operation of the entire network [1]. A voltage source inverter (VSI) is mainly used to interface the RES into the system [1]. PLL technique is used which matches the input signal with the output signal which not only help in synchronizing RES with the grid, but also takes care of the system stability, harmonics and the impact on power factor[3]. Sources such as solar and wind are weather dependent renewables which if utilized separately cannot provide continuous power. This problem can be solved if both these energy sources are hybridized as one system which can produce constant power [5]. This is done by incorporating photovoltaic (PV) system and wind turbine system together.

There are many villages in India which are still not powered and do not have proper electricity facility. This energy gap can be solved if such RES are used as a part of the main utility

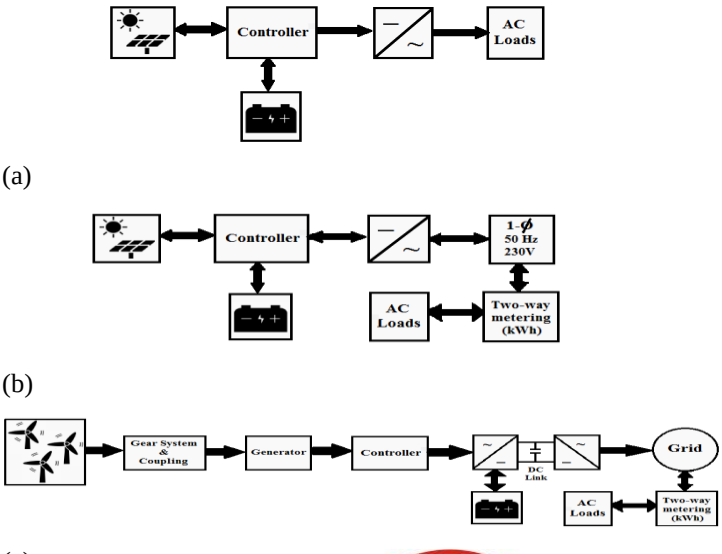

Fig 1. (a) Autonomous Solar PV System, (b) Solar PV

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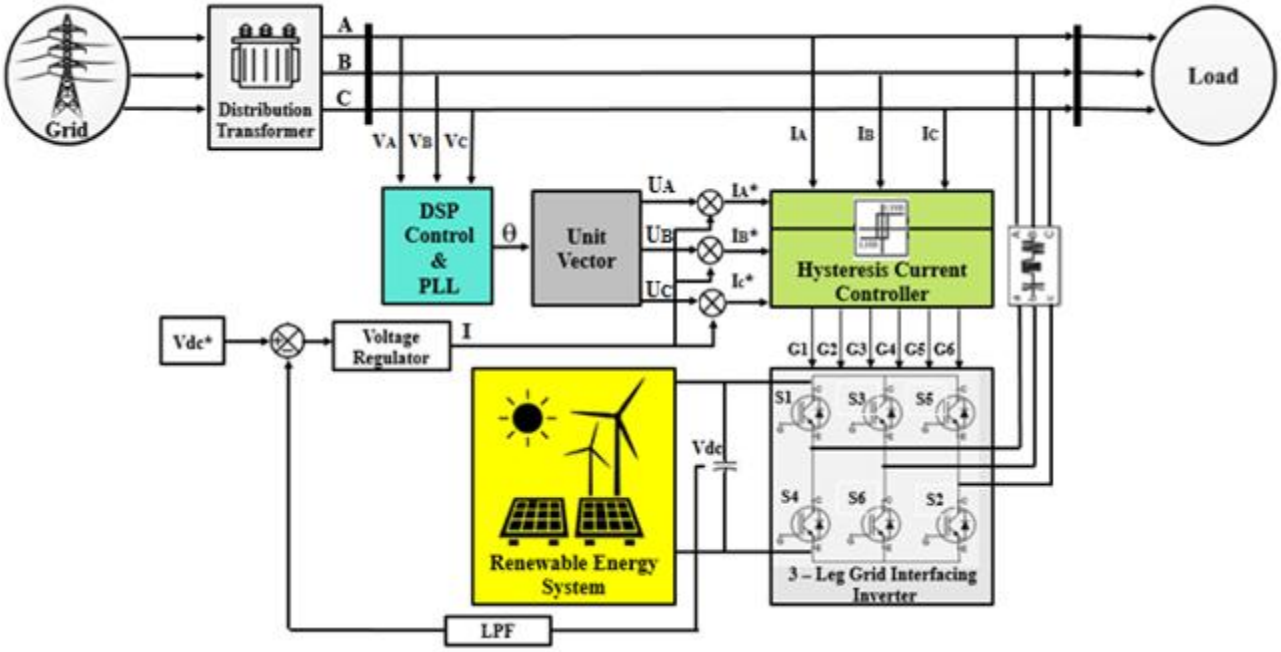
Vedant A. Bhave, Electrical Department, Mukesh Patel School Of Technology Management And Engineering, Mumbai, India.
Anuprit Punse, Electrical Department, Mukesh Patel School Of Technology Management And Engineering, Mumbai, India.
Aakanksha P. Rao, Electrical Department, Mukesh Patel School Of Technology Management And Engineering, Mumbai, India.
Kshamta Mathur, Electrical Department, Mukesh Patel School Of Technology Management And Engineering, Mumbai, India.



System connected to the grid, (c) Wind Turbine System with grid-connection.[2]

Fig 2. Schematic of grid interfacing system

grid or can also be a standalone system called as micro-grid [7]. By using renewables for power generation, we can not only improve the environment and health of people but also we can reduce the cost of electricity thus providing economical energy rates for the consumers [7].

This paper describes about the two RES which is solar and wind system and the synchronization between grid and RES which is simulated by using the MATLAB Software. The output from the RES is always intermittent and variable, therefore, an interface such as inverters are needed for synchronizing and controlling the RES to the grid which is accomplished by the PLL technique. Figure 1(a)[1] is commonly used when there is no grid and when a grid is present, we can improvise the utilization a RES by integrating RES with the grid as shown in Figure 1(b) [1].

II. DETAILED DESCRIPTION OF GRID INTERFACING SYSTEM

Fig 2 shows a schematic consisting of dc-link V_{dc} between the RES and a voltage source inverter, whose work is to deliver the power produced by the RES which may be a PV energy source generating variable dc voltage thus acting as a DC source or a wind turbine producing varying ac voltage thus acting as an AC source. The sunshine hours varies with the radiations of the suns falling on the solar panels and wind power obtained from turbine depends on wind speed, wind direction and the type of turbine we choose depending on application and area of installation.

The renewable energy sources used in this paper are solar and wind. For carrying out simulation easily we have considered a solar panel as a voltage source Vdc and a reference voltage Vdc*. The output voltage from the RES is filtered by a first-order low-pass filter (LPF) which helps to eliminates the voltage ripples and reference currents ripples and then regulated to get an active current I. The unity vectors are generated from the grid-synchronization angle θ is obtained from PLL. The unity vector block generates a unity grid voltage vectors (U_A, U_B and U_C) which when multiplied with I gives output as grid current references (I_A*, I_B* & I_C*).

$$U_A = Sin(\theta) \quad (1)$$

$$U_B = Sin\left(\theta - \frac{2\pi}{3}\right) \quad (2)$$

$$U_C = Sin\left(\theta + \frac{2\pi}{3}\right) \quad (3)$$

The output voltage obtained is the difference between Vdc & Vdc* which is then made unity.

$$V_{OUT} = V_{dc}^{*} - V_{dc} \quad (4)$$

The values of three phase reference grid currents obtained are

$$I_A^{*} = I.U_A \quad (5)$$

$$I_B^{*} = I.U_B \quad (6)$$

$$I_C^{*} = I.U_C \quad (7)$$

The reference grid currents (I_A*, I_B* and I_C*) are compared with the actual grid currents (I_A, I_B and I_C) to get the error currents as given below then fed to the hysteresis current controller which generates switching pulses that are fed into the 3-legged inverter.

$$I_{Aerror} = I_A^{*} - I_A \quad (8)$$

$$I_{Berror} = I_B^{*} - I_B \quad (9)$$

$$I_{Cerror} = I_C^{*} - I_C \quad (10)$$

This 3-legged inverter consists are total six IGBTs, with the three odd numbered IGBTs placed above in the sequence of S_1, S_3, S_5 with the three even numbered IGBTs placed below them in the sequence of S_4, S_6, S_2. The gate pulses

to the S_4, S_6, S_2 IBGTs are given by the logical NOT of gating pulses given to the S_1, S_3, S_5 IGBTs respectively. This mean when switch S_1 is ON then S_4 is OFF, when switch S_3 is ON then S_6 is OFF, when switch S_5 is ON then S_2 is OFF and similarly the other way round.

III. NEED OF INTEGRATING RES WITH THE GRID

Renewable energy sources are free, clean, sustainable, pollution free and abundant sources of energy which are the best replacement of fossil fuels. But since they are more variable and uncertain compared to the non-renewables, meeting such targets will require changes in the power system planning and operations. Grid integration is the best approach of delivering such renewable energies to the grid which not only helps to maximize the cost-effectiveness and also maintaining or increasing the stability and reliability of the system.

IV. PLL TECHNIQUE

PLL are widely used for synchronizing purposes which is an electronic circuit having a voltage-driven oscillator which adjusts itself so as to match the input signal frequency. PLL are mainly used in computers, radios, telecommunications and other electronic applications. The main functions of PLL are generation, stabilization, modulation, demodulation, filtering or recovering a signal from a "noisy" communications channel where the information has been interrupted. The figure Fig 3 below shows the block diagram of the PLL.

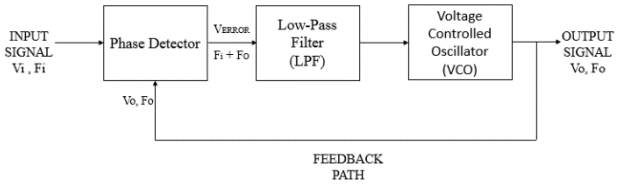


Fig 3. PLL Block Diagram

V. MATLAB SIMULATIONS

A. Solar PV Power System

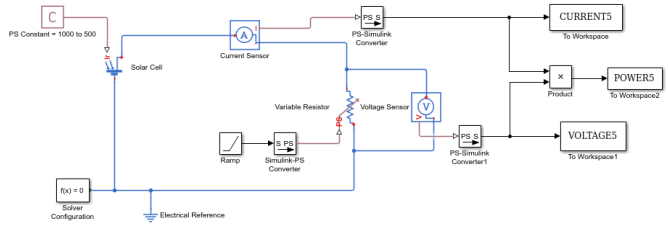


Fig 4. Simple PV Panel Simulation

Solar energy is a free, green, sustainable and an infinite energy source obtained from the sunlight or heat of the sun. The sunshine duration and its intensity in a day varies from time to time. The solar power is never constant because of its intermittent nature, thus solar irradiance varies. Fig 4 shows a simple solar PV panel consisting of series and parallel combination of many solar cells as per requirement.

The varying solar irradiance is shown by using a constant which varies from 1000 to 500 Wb/m^2.

B. Wind Power System

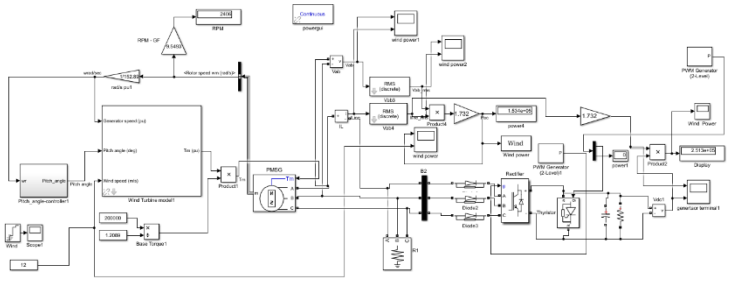


Fig 5. Wind Power System Simulation

The power obtained from the wind is the use of air flow through wind turbine that provides mechanical power to turn the electric generators. They are in abundance, free and produces less greenhouse gas emissions. The velocity of the wind flow is caused by the air moving from high to low pressure usually, due to temperature changes.

The various wind parameters to be looked into are the wind turbine blade design, height of wind turbine, rated turbine mechanical power output, rated generator mechanical input torque, air density, turbine rotor radius, rated turbine speed, rated wind speed, pitch angle control and rated generator speed. The generator used in Fig 5 is permanent magnet synchronous machine (PMSG).

VI. SIMULATION RESULTS

The output curves obtained from the two renewable energy sources are mentioned in the simulation results. Different voltage, current and power outputs are generated by different irradiance values of the sunlight by using workspace arrays in MATLAB. This will help to obtain P-V and V-I curves as shown in Fig.7. The wind turbine power output is generated using a PMSG which is shown in Fig.8. The output of these two sources will be supplied to the grid by a 3-legged inverter.

A. V-I and P-V Curves for Solar PV System Simulation

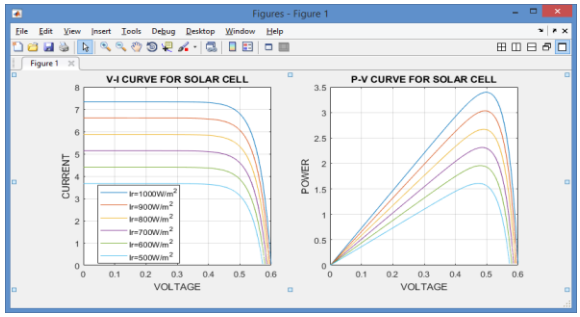


Fig 7. V-I and P-V Curves of solar panel

C. Synchronization of RES with Grid

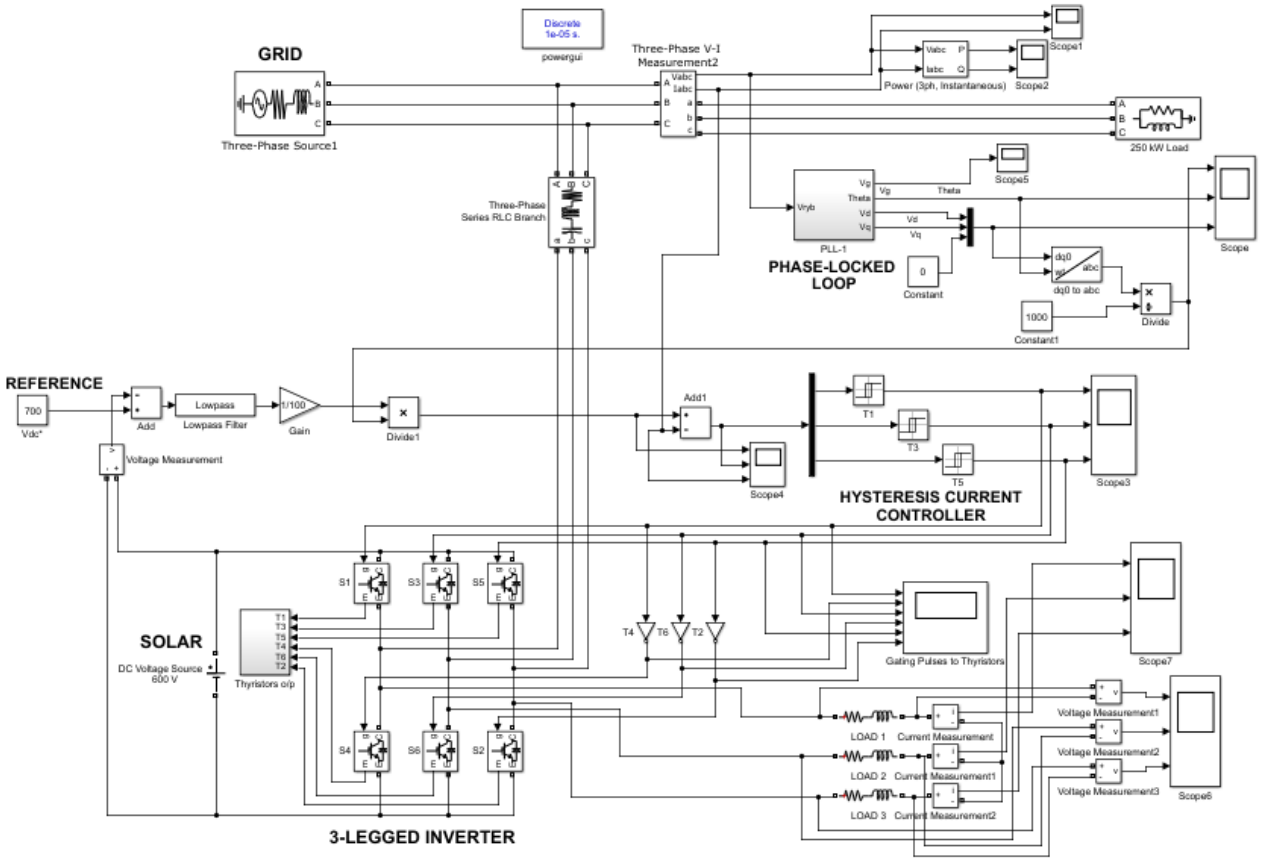


Fig 6. Modelling of RES synchronization with grid in MATLAB

B. Wind Turbine Output Waveform

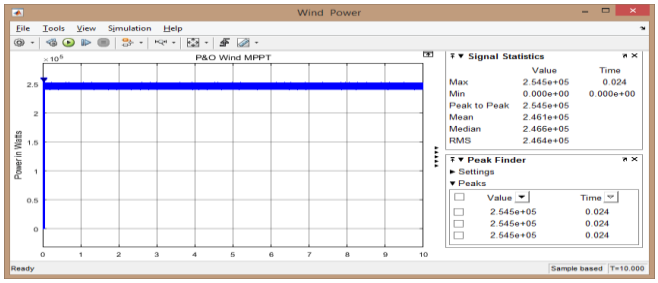
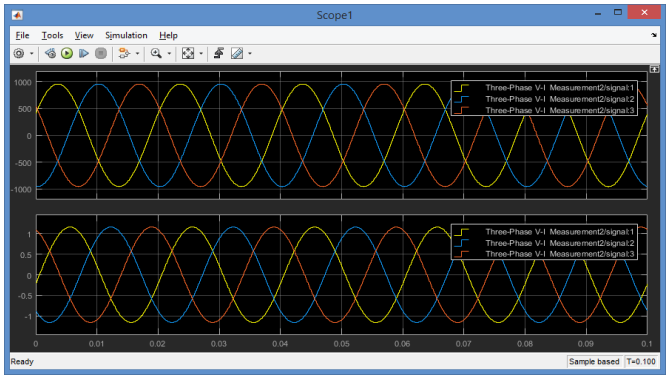
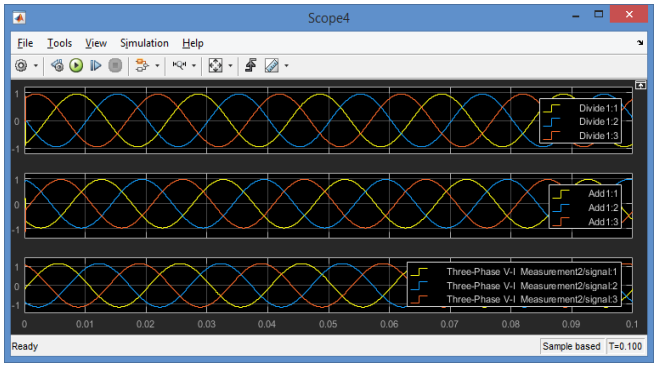


Fig 8. Wind power output

C. Synchronization Result



(a)



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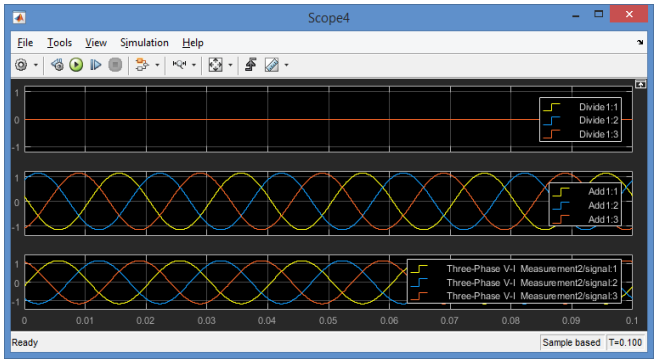
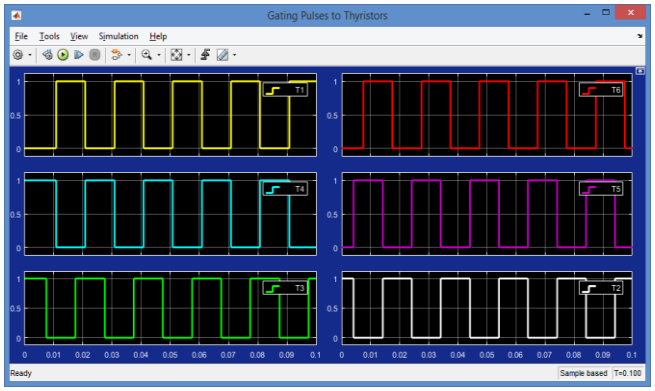
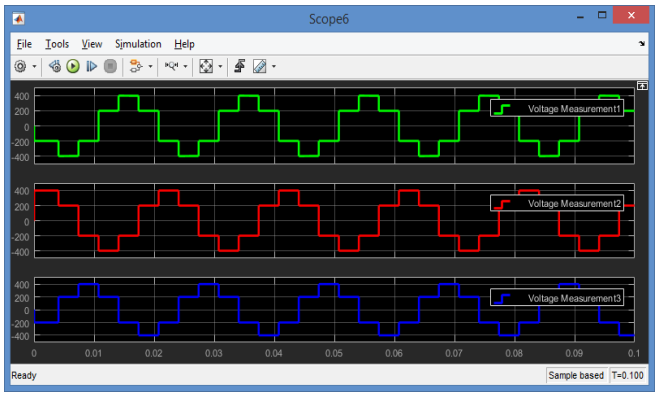


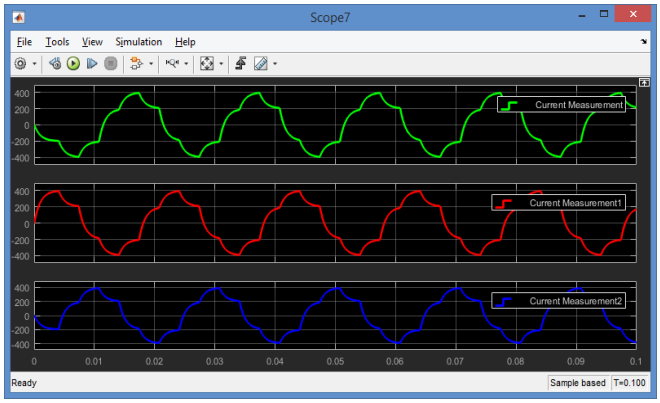
(c)



(d)



(e)



(f)

Fig 9. Synchronization Results (a) Grid voltages and currents, (b) Voltage when Vdc*=700V, (c) Voltage when Vdc*=600V, (d) Gating Pulses to 3-legged inverter, (e) Load voltages, (f) Load currents.

Fig 6 shows the integration of a solar panel represented by a 600V voltage source with the grid via a 3-phase inverter interface. The reference voltage is set to 700V. The difference between these voltages gives the error output voltage which is converted into unity by a unit vector template which is compared with the grid output. The hysteresis current controller is a way to control a VSI so that the obtained output current follows the reference current waveform. The generated output from the hysteresis current controller is given as a gating pulses to the odd numbered switches which will be logical NOT and then given to their respective even switches.

The results obtained after the RES synchronization with the grid is shown in Fig 9.

VII. CONCLUSION

This study has presented RES simulations for solar and wind system along with the method of synchronizing the RES with the grid. This synchronization is required because the renewable energy are always fluctuating, therefore grid synchronized inverters are used as an interface for synchronizing and controlling the renewable sources with the grid. The inverter between RES and grid is mainly used to inject the power produced by the renewable sources into the grid. The RES power output is given to the inverter which then feds this into the main utility. Fossil fuels are a finite source of energy whereas renewables are an infinite energy source. Power plants utilizing fossil fuels burns oil, gas or coal to generate steam which is passed through large turbines to produce electricity. This produces large quantity of carbon dioxide in the air which not only causes climatic changes and gas emissions, but also affects the health of many life. By replacing fossil fuels with RES, will not only improve the environmental conditions but also reduce the burden on fossil fuels to generate electricity.

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AUTHORS PROFILE

Vedant A. Bhave was born in Nashik, India, in 1997. He is currently pursuing his B.Tech from 2015-2019 & is in the final year of B,Tech degree in Electrical Engineering from Mukesh Patel College Of Management Studies & Engineering (MPSTME), India, in 2019. He has competed in project competitions & has made electrical & electronics project during his B.Tech years. His current research interests include hybrid electric vehicles, flexible ac transmission system (FACTS) & smart grids. He has been the technical head & research & development (R&D) head of the Electrical Engineering Students Association (EESA) in MPSTME.

Anuprit Punse was born in Mumbai, India, in 1997. He is currently pursuing his B.Tech degree from 2015-2019 in Electrical Engineering from Mukesh Patel College Of Management Studies & Engineering, India, & is currently in the final year. He has competed in project competitions & has made electrical & electronics project during his B.Tech years. His current research interests include hybrid electric vehicles, electrical circuit designing & smart grids.

Aakanksha P. Rao was born in Mumbai, India, in 1997. She is currently pursuing her B,Tech degree in Electrical Engineering from Mukesh Patel College Of Management Studies & Engineering, India, from 2015-2019 & is in her final year. She has competed in project competitions & has made electrical & electronics project during her B.Tech years. Her current research interests include hybrid electric vehicles, flexible ac transmission system (FACTS) & smart grids. She has been the technical head & creatives head of the Electrical Engineering Students Association (EESA) in MPSTME.

Kshamta Mathur is working as an Assistant Professor in the Narsee Monjee Group of colleges, Mumbai. India. She has 7 years of total work experience and has done her Bachelor of Engineering in Electrical with 76% and M.Tech in power system from National Institute of Technology, Jaipur in Power Systems with 8.6 cgpa. She has also done her PGDBA with specialization in human resources and has published 2 research papers in international conferences, also attended various summer schools, training programs, etc.

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