iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: VII Month of publication: July 2022

DOI: https://doi.org/10.22214/ijraset.2022.44874

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

# Review on Power Quality of Hybrid Renewable Energy System

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***Abstract:*** ***It is now essential for power and energy engineers to keep an eye out for sustainable, economical and environmental friendly alternatives to conventional energy sources, such as the sun, wind, geothermal, ocean, and biomass. However, these renewable energy sources are not always available throughout the year, so the hybrid renewable energy systems concept has come.***

***Hybrid renewable energy system is the best choice for power generation. However, In these kind of systems, stability issues may arise. This is a review of the hybrid power system's stability. This paper analyses the stability issue and discusses various controllers that have an impact on the hybrid power system's output power. Stability and power quality are the two main issues with hybrid systems.***

***Numerous fact devices and other techniques are used to improve these issues. The use of hybrid power systems is growing today. The majority of the work is based on using various controllers and controlling techniques to generate the most power possible from a hybrid system while maintaining power quality.***

***Keywords: MPPT, FACTS devices, Voltage source converter, Current source converter, Multilevel inverter, fuzzy logic, neural network.***

## I. INTRODUCTION

A hybrid energy system combines traditional energy sources with renewable ones, such as wind, solar, and hydropower. These offer energy that is eco-friendly and clean.

These hybrid systems can be grid-connected or stand-alone. Because the loads are directly connected to the grid, in the event that there is a power shortage or a problem with renewable energy sources, the grid connected hybrid system is more reliable to provide continuous power to the grid. Due to the fact that the wind and sunlight are not constant throughout the day, hybrid systems have stability issues.

For improving the stability problem in the system various types of FACTS devices, voltage source inverter and current source inverter are used.

The system's stability is maintained using tools like the UPFC, IPC, fuzzy logic, SVC, STATCOM, and others. Additionally, maximum power point tracking techniques are employed for maximum power generation and continuous operation, where the maximum amount of wind and sunlight are extracted to produce the greatest amount of power for hybrid systems.

## II. POWER QUALITY AND VOLTAGE STABILITY IMPROVEMENT METHODS FOR SOLAR AND WIND HYBRID POWER SYSTEM

Power quality and voltage stability are the two main problems with wind and solar hybrid power systems. Given that both sources are renewable, the output of each depends on its natural surroundings. The wind speed is not constant all the time and also the sunlight varies throughout the day. In rainy season the solar power system will not operate. Voltage will not remain constant as a result, and power quality will suffer. To maintain stability and enhance power quality, various controllers are used for this. Power stability and power quality are improved by using the UPFC, D-STATCOM, IPFC, SVC, SSSC, and fuzzy logic controllers. Due to voltage swell, sag, and harmonics generated within the system, the voltage stability of the power system is lowered. Before supplying power to the load, the FACTS devices are connected to the inverter's output terminal. By lowering the harmonics in the current waveform, these FACTS devices help to improve the power quality. The STATCOM used is a Static Synchronous Compensator used as a shunt compensating device for reducing reactive power compensation, improving the steady state of system and also transient stability. It is used for both reactive and active power compensation.

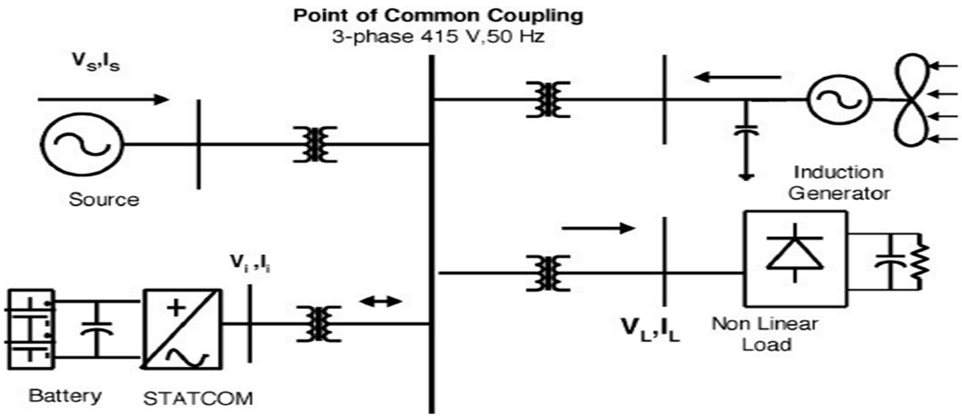


Figure 1: FACT Device system for power quality improvement connected to grid

## III. DIFFERENT KIND OF INVERTERS FOR POWER QUALITY IMPROVEMENT AND VOLTAGE STABILITY IN HYBRID POWER SYSTEMS

The number of levels determines the power quality of a multilevel inverter. The main advantage of a multilevel inverter is that low harmonic output voltages can be generated. These inverters are used in applications that require a lot of power. The harmonics cause an increase in current, which leads to an increase in neutral current. The sources in a hybrid system are first connected to a dc-dc converter, then to multilevel inverters. Two-Level Voltage Source Converters, Three-Level Diode clamped Voltage Source Converters, Four-Level Flying Capacitor Voltage Source Converters, Series Connected H-Bridge Voltage Source Converters, current source converter and voltage source converter using phase locked loop are among the converter topologies used. The diode clamped inverter is the most widely used multilevel converter topology, in which a diode is used as a clamping device to clamp the dc bus voltage in order to achieve steps in the output voltage level three, seven inverters can be considered. When the number of levels is increased, the amplitude of low order harmonics decreases. The inverter is usually followed by a low pass filter because high frequency harmonics are easy to filter. By reducing lower order harmonics, the performance of multilevel inverters can be improved. The PI controller can also be used to maintain a constant voltage on the DC bus. Voltage source converter/inverter with phase locked loop topology is used in grid connected hybrid energy system to maintain the voltage stability.

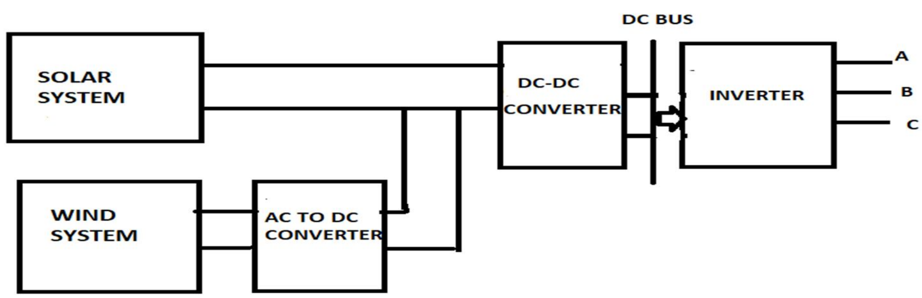


Figure 2: Block Diagram of Hybrid System with Multilevel Inverter

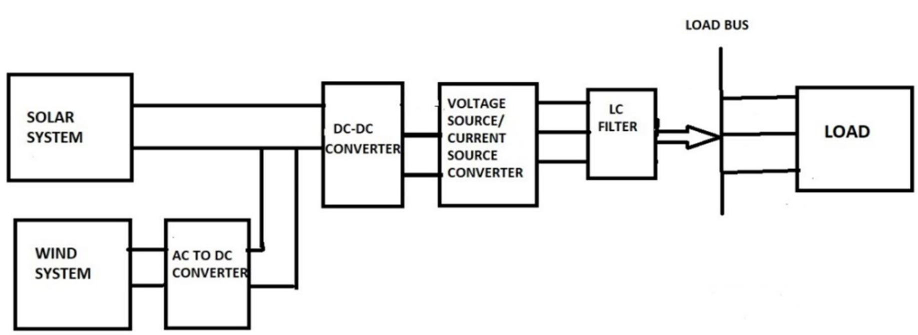


Figure 3: Block diagram of solar and wind hybrid system with voltage source converter/ current source converter

Power conversion systems, of which the voltage source converter (VSC) is typically the last stage for injecting power into the grid, are required in order to utilise the energy from renewable energy sources. The low-voltage distribution system's grid-connected VSC can add the capability of power quality conditioning at a reasonable cost. Inductive-coupling VSC and capacitive-coupling VSC, which are named after the fundamental frequency impedance of their coupling branch, are the two multifunctional VSCs that are examined in this paper. When used for the integration of renewable energy and power quality conditioning at the same time, the operation voltages of the two VSCs are contrasted. When reactive power is being used to compensate for inductive loads, the operation voltage of the capacitive-coupling VSC can be set much lower than that of the inductive-coupling VSC.

## IV. NEURAL NETWORK CONTROL FOR HYBRID SYSTEM

Artificial neural networks can help improve the efficiency of solar energy renewable energy systems. In time series forecasting for solar energy, neural networks are used for prediction of solar irradiance as well as sizing applications. Maximum power point tracking (MPPT) and applications for PV power systems are also done with artificial neural network (ANN) systems. Artificial neural networks are used in wind energy conversion systems, which are heavily reliant on wind turbine pitch angle control. These are used in the propeller of a wind turbine to get the most out of wind energy. Wind speed and direction are predicted using ANN applications in wind turbines. The input layer, hidden layer, context layer, and output layer make up the architecture of an ENN.

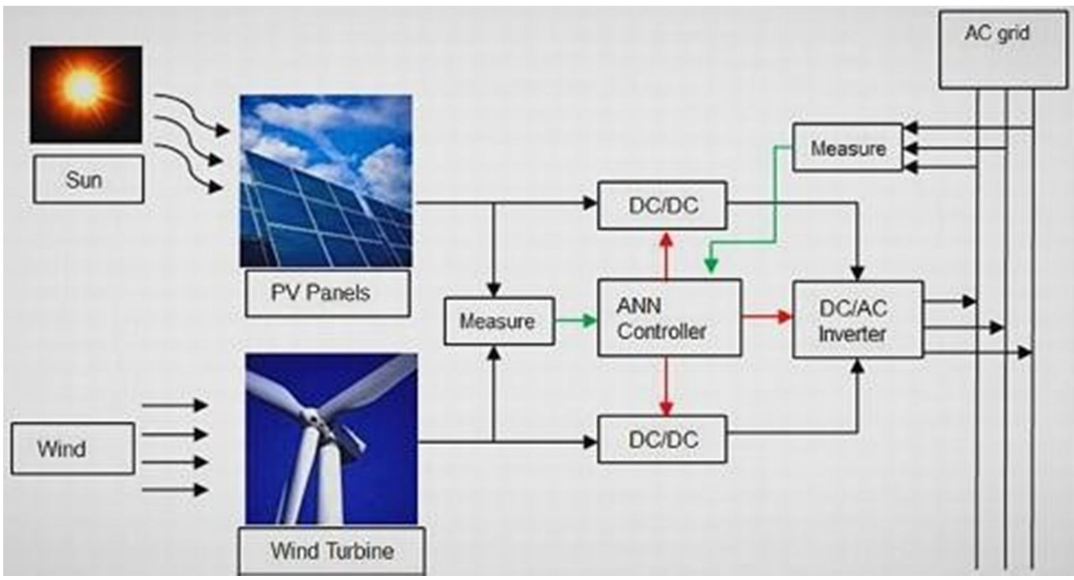


Figure 4: Neural network controller for Hybrid power systems

## V. MAXIMUM POWER POINT TRACKING FOR WIND AND SOLAR HYBRID POWER SYSTEM

Due to the limited use of conventional energy sources, renewable energy sources are becoming more popular. Wind and solar power are the most commonly used sources in a hybrid energy system. These energy sources are inherently variable. The wind speed and sun light do not remain constant throughout the day; they fluctuate constantly. As a result, getting the most power out of these sources is a challenge. We use a maximum power tracking system to extract the most power from wind and solar. As a result, the hybrid system's electrical power output has increased. The MPPT in solar energy sends a control signal to the dc-to-dc converter, which then sends the controlled outputs to the grid or to the load. Maximum power point tracking is also used in wind energy to get maximum power by controlling wind speed. The MPPT maximises the system's efficiency. There are a number of algorithms that can assist in determining the maximum power point of a PV module.

These are following:
*1)* P&O algorithm
*2)* Parasitic Capacitance
*3)* IC algorithm
*4)* Current based peak power tracking
*5)* Voltage Based peak power tracking

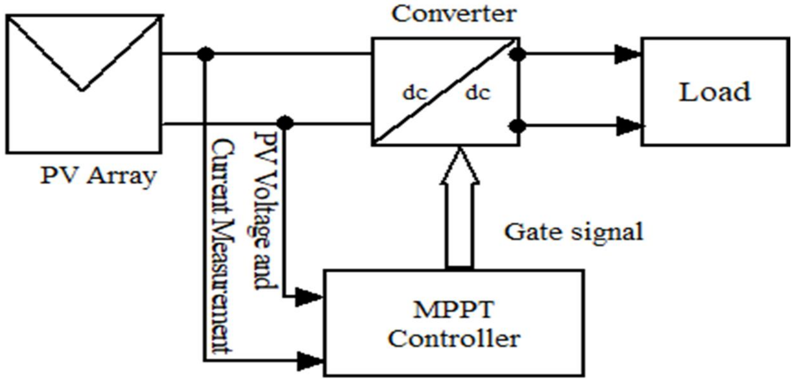


Figure 5: MPPT for solar energy system

Tip speed ratio (TSR) control, power signal feedback (PSF) control, and hill-climb search (HCS) control are three ways to control MPPT for wind energy conversion. The TSR control method of a wind energy conversion system regulates the generator's rotational speed in order to keep the TSR at an optimum value, which maximises the power extracted. The PSF control method necessitates knowledge of the wind turbine's maximum power curve, which must be tracked through the control mechanisms. The third method, the hill climb search control algorithm, searches for the peak power of the wind turbine in the system on a continuous basis.

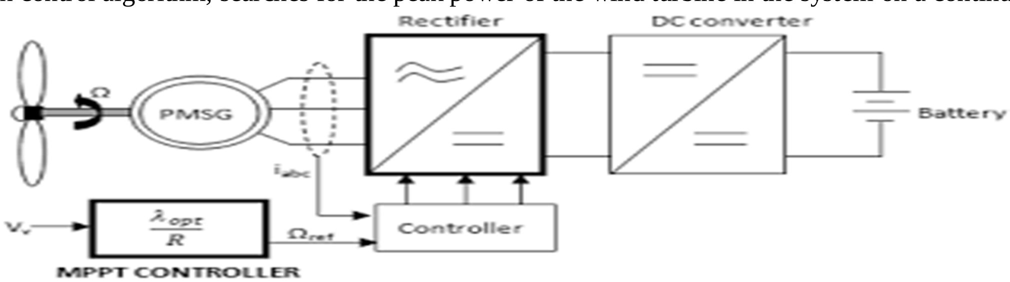


Figure 6: Tip speed ratio control of WECS with MPPT

## VI. USE OF POWER FILTERS

The use of Power filters can improve the power quality. A dc-dc converter and power filter are used to connect the renewable energy sources to the grid. Hysteresis controllers are used to control the hybrid system's gate pulses. The reference current for the hysteresis controller is obtained using the synchronous reference frame. The hybrid controllers are employed not only for the reduction of harmonics but also for the compensation of reactive power in the positive and negative directions. Different types of hybrid filters exist, including shunt active power filters and passive filters that function as hybrid filters. It makes sure that source current harmonics are compensated. This hybrid configuration eliminates series and parallel resonance. The arrangements are connected parallel to the grid and the active and passive filters are connected in series. These filters help to reduce the non-linear loads that generate harmonics.

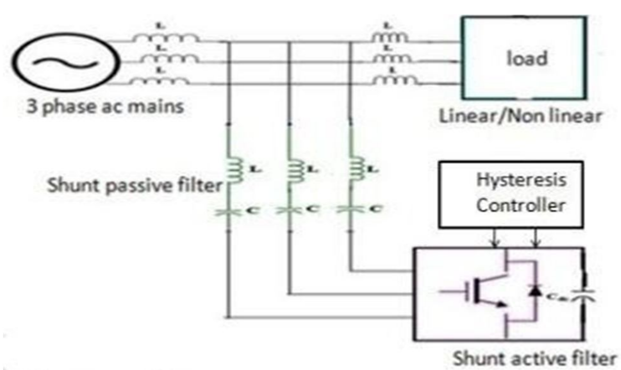


Figure 7: Hybrid filter connected to grid

## VII. ECONOMIC ANALYSIS OF THE HYBRID SYSTEM

The capital cost, maintenance cost, and replacement cost are all maintained by the hybrid system cost. Lower negative environmental effects are achieved by using renewable energy sources, primarily wind and solar. The hybrid wind and solar power plant that is connected to the entire network is evaluated. HOMER software performed all analysis. The life cycle cost method is used to conduct the economic analysis. This approach includes all costs incurred over the course of the life. The hybrid power system employs this technique. As a result, the hybrid power system is economically evaluated.

## VIII. CONCLUSIONS

This paper reviews and discusses the hybrid power system's improved power quality utilising various FACTS device types. The system's power consumption is managed by the fuzzy logic controller, which also stabilises the system. The maximum power point tracking method of the maximum wind and sunlight for hybrid power systems is also covered in this paper. The use of multilevel inverters reduces harmonics in hybrid power systems and enhances power quality. The artificial neural network is used to increase the system's effectiveness. Utilizing hybrid filters is another way to enhance the power quality in hybrid power systems.

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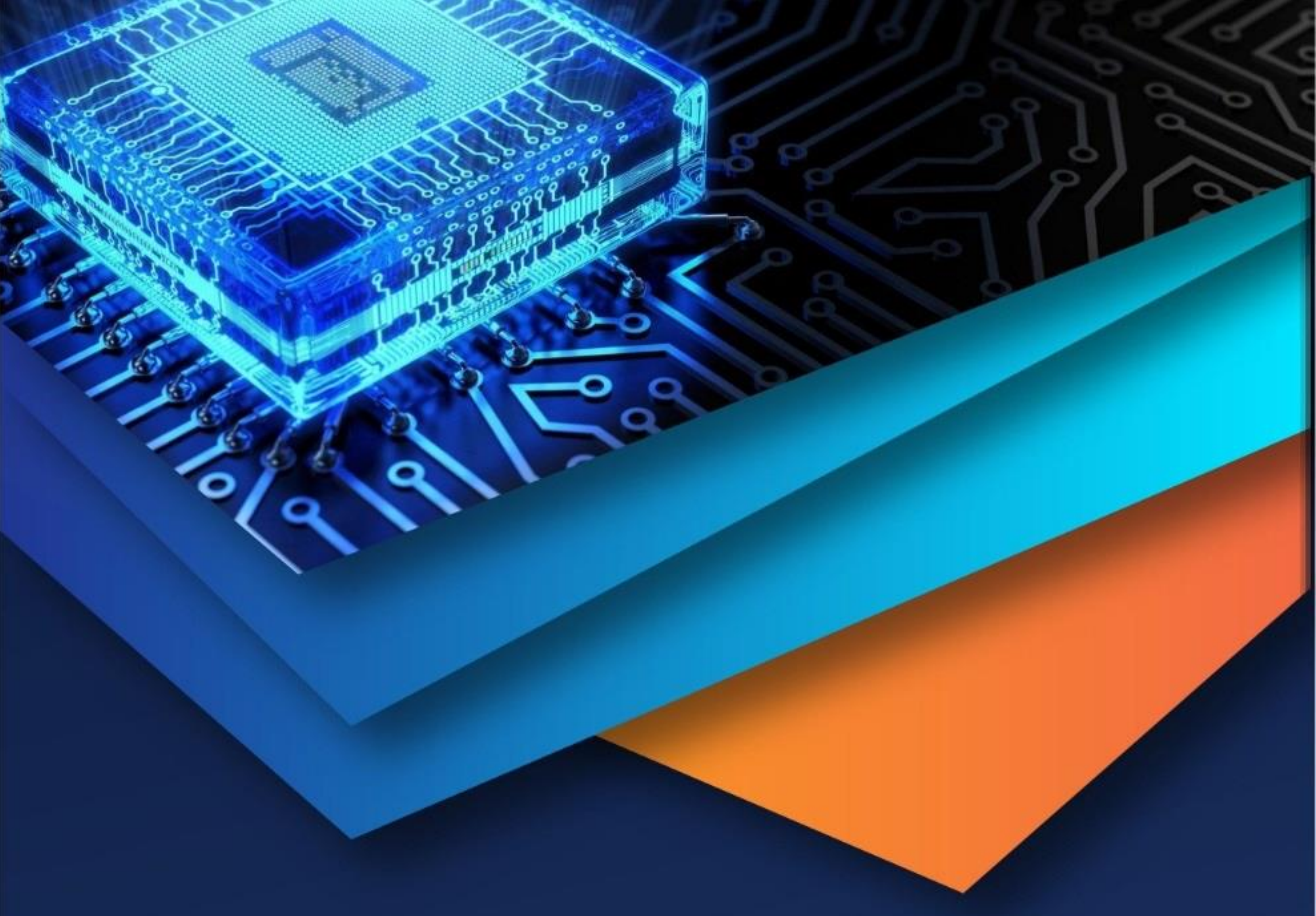


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