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Power Quality Enhancement For a Grid Connected Wind Turbine Energy System

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Abstract:

Wind, a renewable energy source becomes a key contributor to our modern society, but there are some challenges. They are: 1. Voltage and frequency fluctuations are caused by non-controllable variability of wind energy generation. 2. Harmonics, which are caused due to power electronic devices. Maximum Power Point Tracking (MPPT) algorithms to achieve maximum power under all-weather situations. The paper consists of existing approaches to improve power quality. Four leg inverter is used to inject the available energy and also work as active power filter, decreasing load current disturbances and improving power quality. A four-wire system is introduced here, with three-phase and singe-phase linear and nonlinear loads. The utility side controller is designed, to compensate the disturbances caused in presence of reactive, unbalanced or nonlinear loads. This controller design also provides active and reactive power as required. DC link capacitor is used for continuous supply of wind energy to the grid. This paper mainly deals with proposed technology over existing one. Conservative Power Theory involved in the proposed technology. This provides decoupled power and current references for inverter control. This also offers flexible, selective and powerful functionalities.

Keywords: Wind Power, Power Quality, MPPT, Four-leg inverter, DC link capacitor, Conservative Power Theory.

01.INTRODUCTION

Energy is the basic input of life. Among all the different forms of energy, Electricity plays a key role. Today, meeting the world's constant increase in energy demand is a major concern. As the population is increasing day-by-day and people wanted to have luxurious life, which indirectly or directly includes electrical energy. As an electrical engineer, we need to generate electricity from many sources keeping in mind about environment. Furthermore, the rapid depletion and exhaustibility of existing energy sources has necessitated a thorough examination of renewable energy sources (RES) as another source of energy. Among renewable energy sources, solar photovoltaic (PV) and wind power have gained a lot of attention and are considered to be the most rising electricity-producing power technologies. Massive turbines with a large power capacity can be used to harness WE. As wind is gift from nature, it will not deplete. So, we can generate electricity from wind.

Past researcher given that by 2018 there were 600 GW of installed wind capacity. This development is due to advancement in electrical generation and power electronics devices. The main issues with this RES, is that, they are not continuous, i.e, we cannot get constant power. By using proper storage devices, we can store the energy, when wind is high & use it wherever necessary. Hence power production can be improved.

As the power generated by RES, we can integrate any number of RES & can get maximum power generation. Integration is simply a word, but it leads to many problems like voltage swells, voltage sag, frequency fluctuations & harmonics. There problem can be rectified or compensated by using power electronics inverters. Several other control approaches have also made.

In any situation our main aim is to get maximum efficiency or power. The machine side controllers are designed to extract max power point from wind using hill-climbing control, fuzzy based, and the adaptive controllers. Grid side controllers are designed to ensure active and reactive power is delivered to grid.

To analyze voltage current components theoretically, Instantaneous Power (PQ) theory for a 3phase system is given by Akagi. In PQ theory, 3 phase is transformed into a 2phase reference frame to extract active and reactive components in a simplified manner. Further implementation or advancement are made to this theory called as Conservative Power Theory (CPT). In CPT, current & voltage components are derived in the 3phase form, without requiring any reference frame

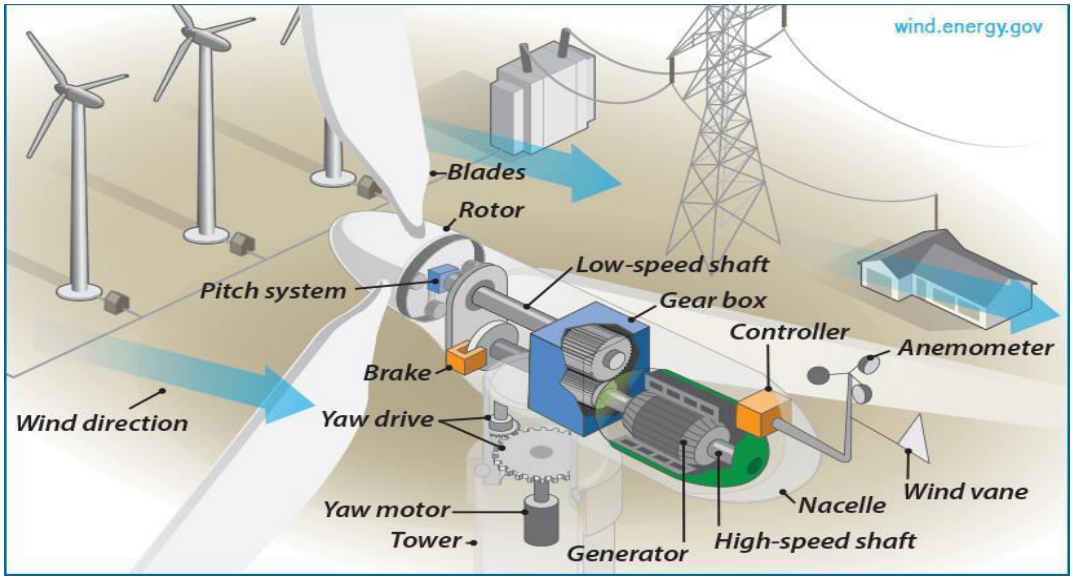
transformation.

This paper provides control structure in 3phase 4 wire system. It provides more functionality to the grid side converter of a wind turbine system using CPT, which help in particular current disturbance compensation. We can feed both single or 3phase loads. 3phase 4 wire inverters have been realized using conventional 3-leg converters with split capacitor or 4 leg converters. In a 3-leg conventional converter, one neutral wire in connected to the midpoint of DC between directly. In 4-leg converters, the ac neutral wire connection provided through the 4th switch leg. 4 leg converters method has more controllability than split capacitor topology.

The system that we have considered has both 3phase &1phase linear & nonlinear loads. CPT is used to identify & quantify the amount of resistive reactive liner & nonlinear characteristics of a particular load under different supply voltage condition for 4 wire system.

MPPT algorithms are employed on wind systems to extract the greatest feasible output power from systems during changes in atmospheric conditions. These changes lead to voltage and frequency fluctuations which affects the power quality and it is discovered that the control techniques efficiently keep the grid voltage constant.

02.WIND ENERGY CONVERSION SYSTEMS



Wind power is generated by wind power plants. It consists of wind blades, wind turbine, double fed induction generator which converts wind energy into electrical energy.

Wind first hits a turbine-blades, causing them to rotate and turn the turbine connected to them. Turbine converts kinetic energy to rotational energy, by moving a shaft which is connected to a generator, which in turn produces electrical energy through electro magnetism.

CHARACTERISTICS OF WIND ENERGY SYSTEM

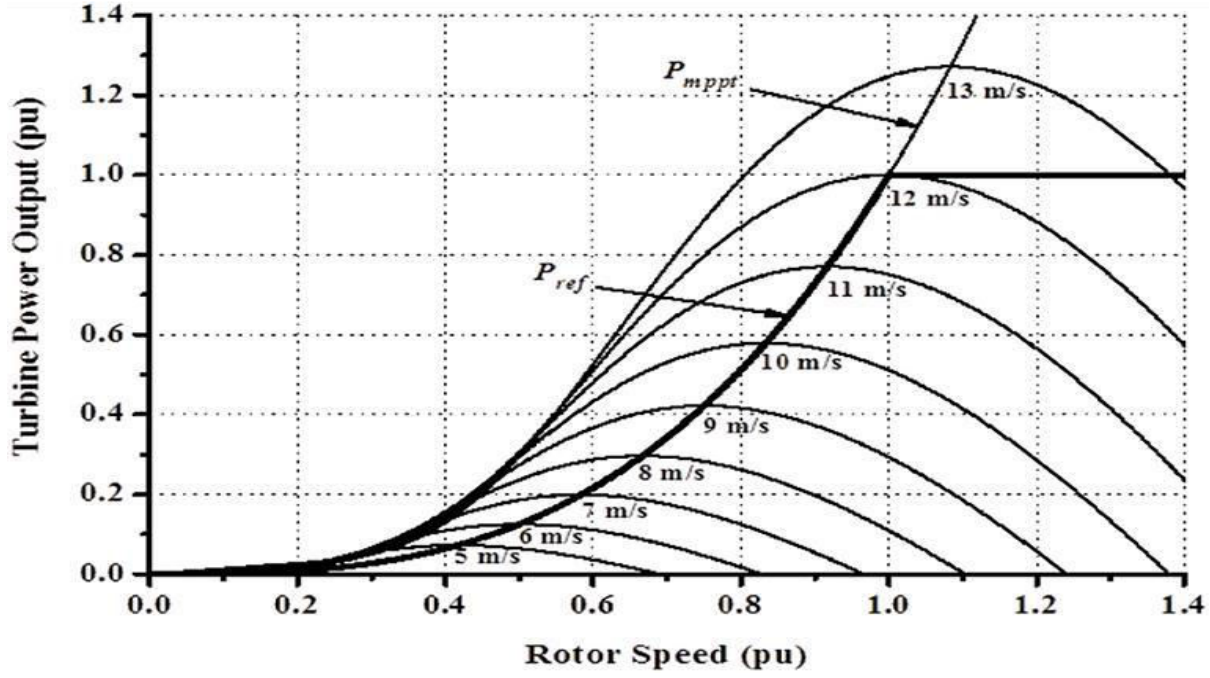
Let us assume that the wind reaches the turbine at a constant velocity, with uniform attributes (temperature and density), and without any disturbances, to understand how a wind turbine works and what its features are. The power coefficient of a real wind turbine can be defined as the power extracted by the wind turbine multiplied by C. A wind turbine's real power P is calculated as follows:

$$P_m=C_p(\frac{1}{2}\rho A v_w^3)=\frac{1}{2}\rho\pi R^2 v_w^3 C_p(\lambda,\beta)$$

(4.1)

Where, ρ-- air density; R-Wind turbine's blade radius; V-speed of the wind;

C, changes according to the wind speed, turbine blades and the rotational speed of the turbines. Thus, the power coefficient denoted as C, is represented as a function of blade pitch angle ß and tip-speed ratio λ



03.INCREMENTAL CONDUCTANCE MPPT TECHNIQUE

Maximum power point tracking (MPPT)or sometimes just power point tracking (PPT), is a technique used with variable power sources to maximize energy extraction as conditions vary. The technique is most commonly used with photovoltaic (PV) solar systems, but can also be used with wind turbines, optical power transmission and thermophotovoltaics.

MPPT is the process of adjusting the load characteristic as the conditions change.

MECHANICAL POWER MEASUREMENT-BASED MODIFIED MPPT TECHNIQUE:

Maximum - power is extracted from the wind turbine at the rotor's ideal rotational speed. By detecting the best rotational speed during wind speed variations, the MPPT method recovers maximum power from the wind turbine. While most MPPT strategies focus on wind turbine parameters and wind speed, flaws in wind turbine modelling and sensor inaccuracy would influence the MPPT technology's performance. The research suggests utilising a modified MPPT control technique to establish the best rotation speed based on mechanical power measurement.

i. First, the MPPT control establishes the fundamental values for mechanical power (P) and rotational speed (...).

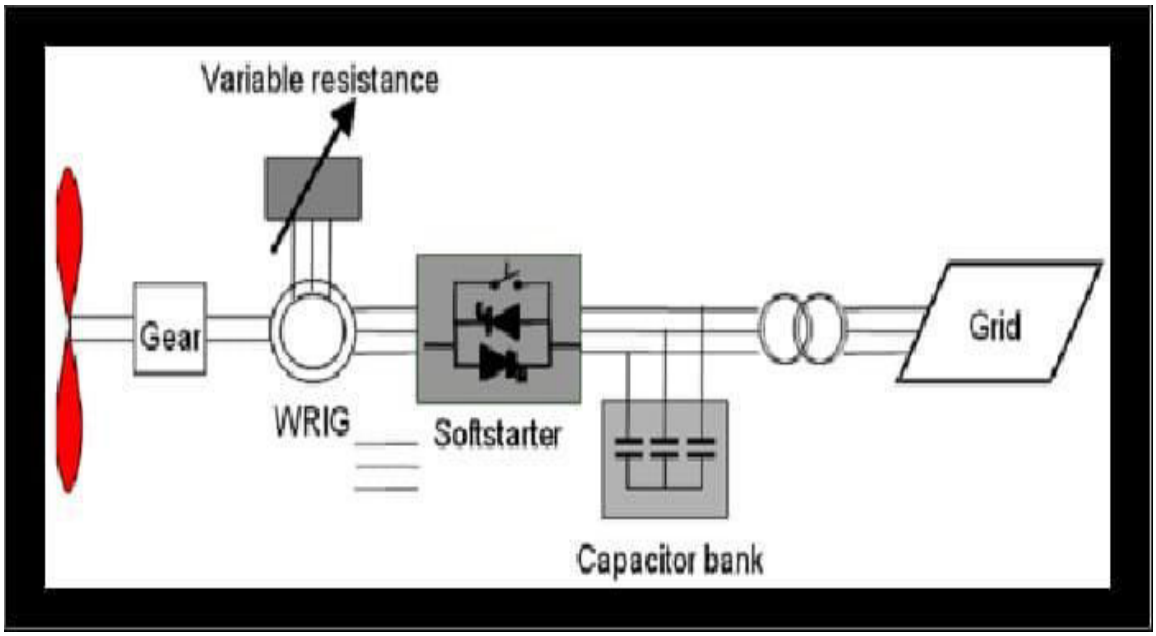
ii. The real mechanical power is then estimated using the MPPT method to determine the suitable rotation speed ().

iii. The best rotational speed is usually 1.2 p.u. while the mechanical power (P) is greater than 0.75 p.u. which corresponds to the maximum wind energy capacity (9 MW).

iv. Determines the ideal rotational speed if the mechanical power (P) is less than 0.75 p.u.

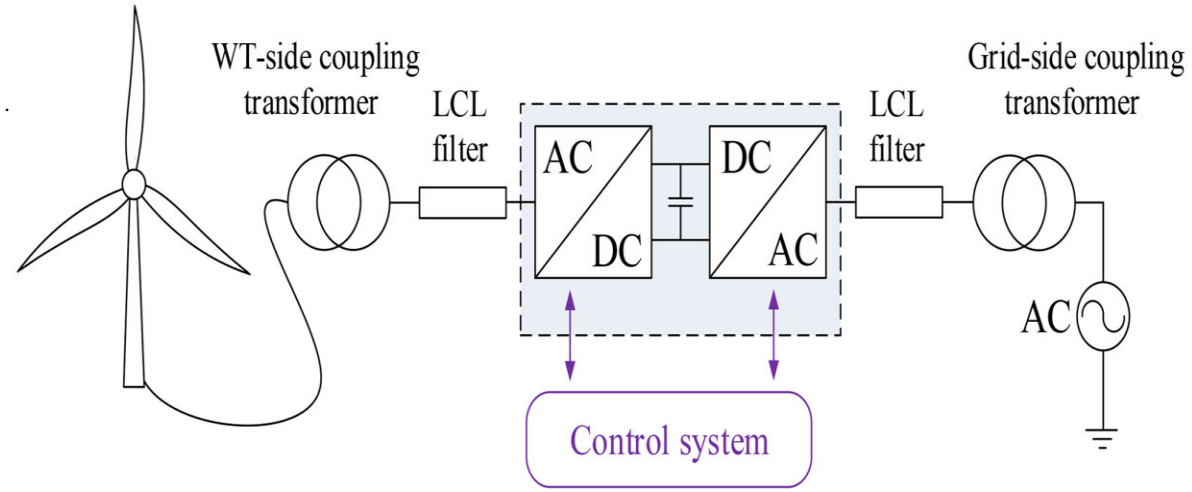
Without sensing wind turbulence, the enhanced MPPT technique easily specifies the best rotational speed for calculating maximum power.

04. EXISTING BLOCK



In system, there are many disadvantages. Like, no continuous power supply and high reactive power generation and power quality issues. In order to overcome those, a new system is developed**.**

05. SYSTEM CONFIGURATION



This structure has back-to-back connected converters of wire turbine with permanent magnet synchronous generator (PMSG), both these are connected to same bus with loads. The loads are combination of linear and highly inductive loads causing harmonics at the PCC (point of common coupling).

CONSERVATIVE POWER THEORY

The CPT is used to identify and to quantify the amount of resistive, reactive, unbalanced and nonlinear characteristics of a particular load under different supply voltages condition for four-wire system.

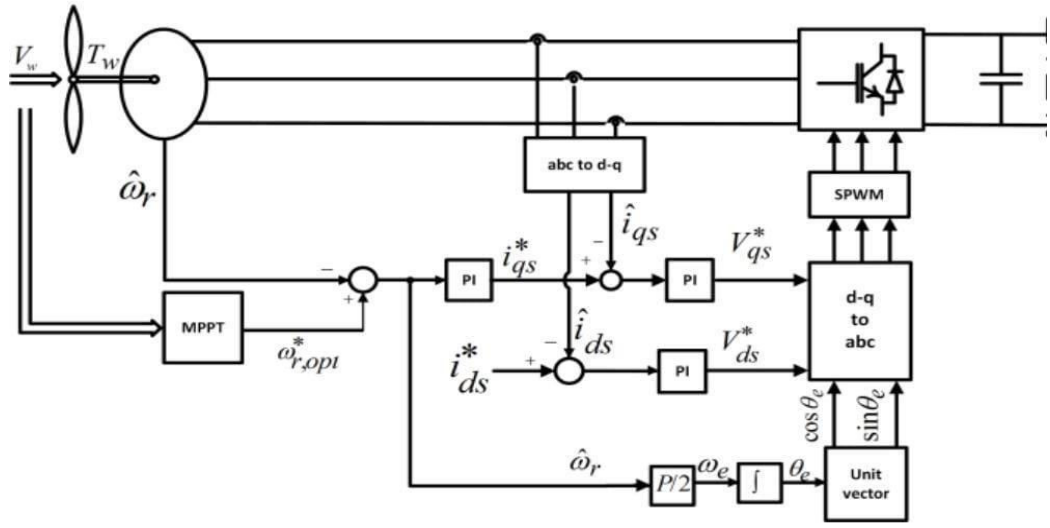
It decomposes the power and current in the stationary frame, according to terms directly related to electrical characteristics, such as average power transfer, reactive energy, unbalanced loads & nonlinearities.

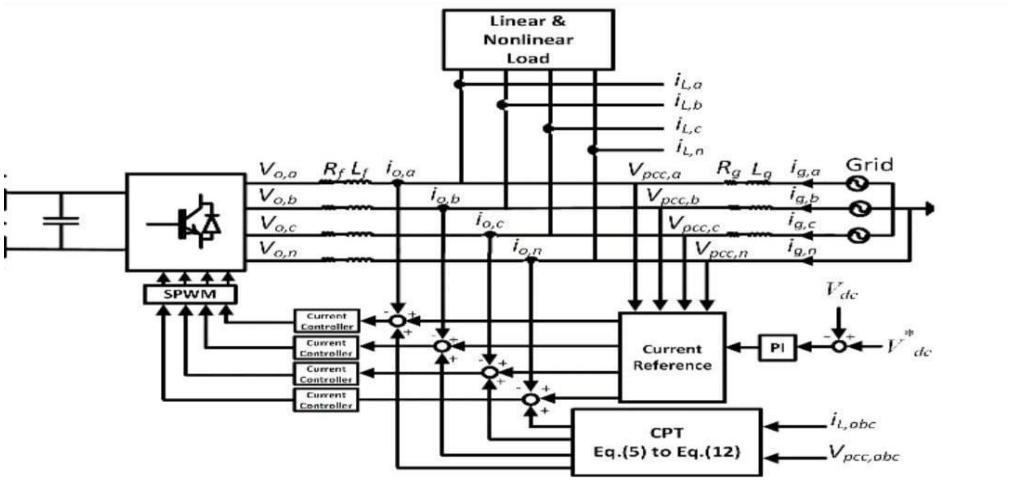
POWER QUALITY ISSUES:

Power electronic converters are the heart of renewable energy system. These devices are responsible for harmonic injection in the system. Operation of these converters highly dependent on quality of voltage signal. To improve power quality of RES's different measures are taken. Due to non-controllable variability of renewable energy sources, we observe voltage and frequency fluctuations such as voltage sag, voltage swell, voltage flickering. And harmonics occur due to power electronic devices. These can be compensated by using various FACTS devices. These can be compensated by using conservating power theory and four-leg inverter control.

06. CONTROL DESIGN

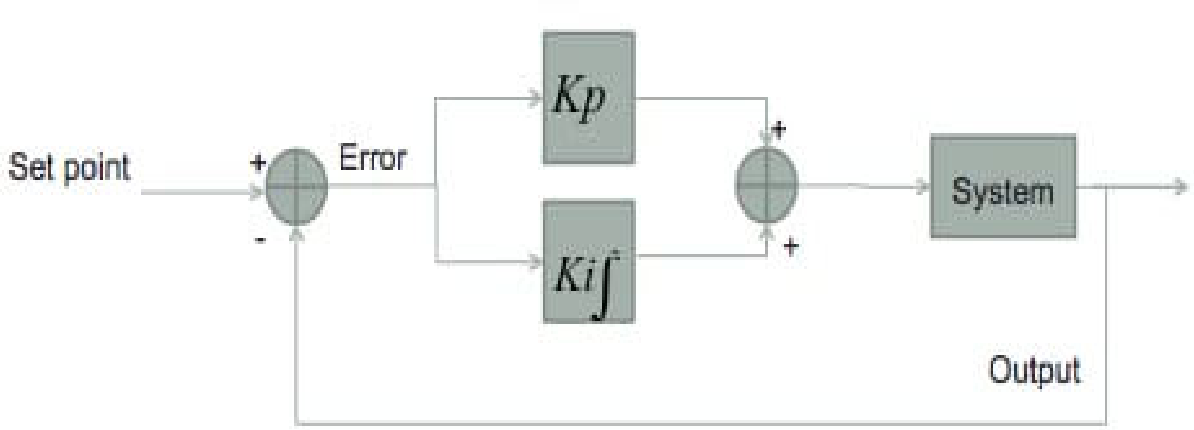
Machine Side Controller:





The machine side controllers are designed to extract max power point from wind using hill-climbing control, fuzzy based, and the adaptive controllers. Rotor speed control is designed to generate the quadrature current reference to the internal current controller.

Grid Side Controller:

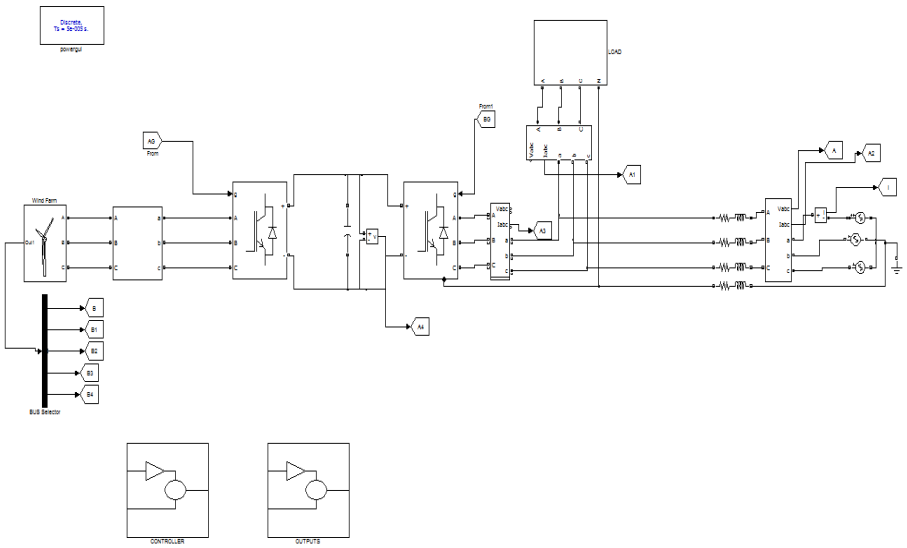


Grid side controllers are designed to ensure active and reactive power is delivered to grid. The above diagram tells us about control scheme for the four-leg grid side inverter. It consists of current-controlled voltage source inverter and also contain linear and nonlinear loads. In this case study, the four-leg inverter is configured to provide the load with active power generated by the wind and the remainder of the active power is sent to the grid with a power factor of one without compensating strategy.

PI CONTROLLER

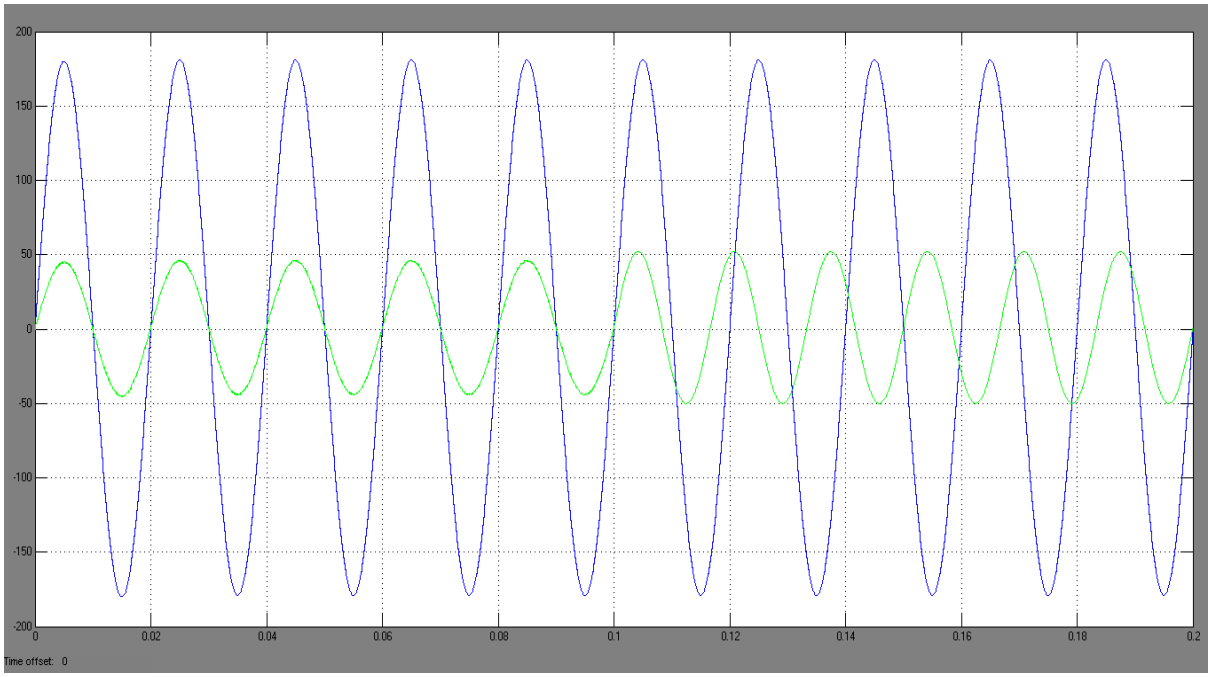
A PI Controller is a feedback control loop that calculates an error signal by taking the difference between the output of a system. It has more stability. Flexible and also withstand for large disturbances.

PROPOSED SYSTEM SIMULATION USING PI CONTROLLER:

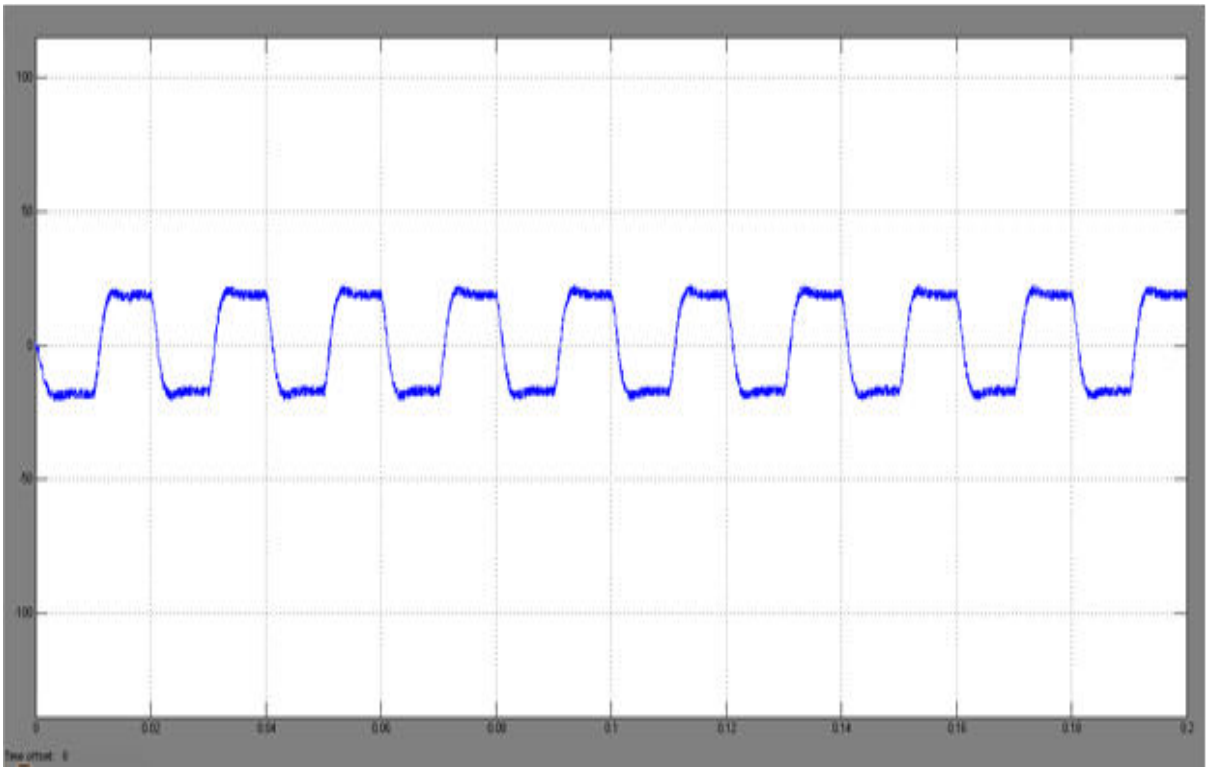


SIMULATION RESULTS

VOLTAGE AND CURRENT WAVEFORMS:



DC LINK RESULTS:



CONCLUSION

This paper discusses about the renewable energy sources into a microgrid with power quality improvement features, with an emphasis on Indian conditions. As the fossil fuels are depleting and also due to increase in population, there is urge of electricity. In order to satisfy the customer's demand, renewable energy sources are used. Power quality improvement is done using conservative power theory, PI controller and four-leg inverter.

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