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Integration Of Renewable Energy Sources With Power Management Strategy For Effective Bidirectional Vehicle To Grid Power Transfer

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Abstract

The high proportion of Electric vehicles (EV) escalates the demand for rapid charging stations, putting a strain on the present grid infrastructure. Installing charging stations can perform certain jobs, lowering grid effect and assisting the system in maintaining power balance for an extended period of time. The involvement among several sources of energy for powering an automobile is coordinated by a power management technique. Solar panels, wind turbines, and a bidirectional vehicle-to-grid interface comprise up the system. Vehicle to grid technology enhances the use of sustainable power while also assuring stability of the system and a transformation to a healthier atmosphere. Motivated by the growing development of electric cars (EVs) upon this market and indeed the lack of predictability of renewable generation.

This paper suggests a voltage stability design of a photo - voltaic (PV) array and wind turbine, storage facility of an electric car, as well as the grid via a controller to prevent voltage instabilities at the source. The power circuit consists of a dc-to-dc converter, a bidirectional ac-to-dc converter, a car battery, a load, and switches. The results of the generated computer simulation suggested synchronising the grid, batteries, wind, and solar electricity under various loading scenarios, solar irradiance conditions, and wind conditions.

Keywords: *Photovoltaic Array, Bidirectional Ac–Dc Converter, Closed Loop Control, Pitch Angle, Irradiance, Fuzzy Controller, Probability Density Function (PDF)*

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1. Introduction

The Sun is an enormous power source, and sunlight is perhaps the most intense active source of energy that Earth receives. Solar energy, which is generated from the sun, may very well be required to develop heat or electricity. Photovoltaic has become the most ubiquitous and reliable form of energy in the twenty-first era attributable to its great abundance, unending stream, and indeed the facts that it will not foul the environment, with exception of non-renewable energy sources. In addition to visible light, 45 percent of the solar radiation that surrounds the earth is infrared, and a small fraction of it is ultraviolet and some other types of electromagnetic radiation [17].

When developing and establishing a solar power plant, numerous parameters must be considered, including installation site, yearly solar installation, temperature. The performance of the solar power plant is determined by the number of panels employed. Their operating system will get even more complex because of the increasing number of nodes [16].

Human activity seems to have no influence on the amount of solar light that reaches the atmosphere. Even though this is considered, the cost of electricity transportation may still increase whenever the placement of the power plant is specified [18]. Among the most critical aspects influencing the efficiency of overall solar plant is the temperature of the panels. The depreciation of panels during functioning is hastened by increasing temperatures, involves determining all scientific outputs that cause the temperature to drop [16][17].

The functioning of the solar module is based on the operation of a semiconducting material, and the production parameters of the diode are approximated as: $I_d = I_{sat}[e^{\left[\frac{V_d}{mV_T}\right]} - 1]$ (1)

The vehicle to grid and grid to vehicle condition integrated with renewable energy should happen without any potential disturbances at the source end. In general flow of renewable to vehicle system, the source might fluctuate in between some limits. This problem can be avoided by using a proper controller. Out of many controllers, two controllers are used proportional-integral controller and fuzzy controller, the differences between the controllers in terms of peak time, settling time, rise time, overshoot is preferred for the system of power transfer from vehicle to grid and grid to vehicle.

The purpose of the research is to develop a power transfer between the utility grid and the battery in a bidirectional way. System is comprised of a bidirectional AC to DC converter, a DC to DC converter, and a vehicle battery. As in process of bidirectional transfer, the bidirectional ac to dc converter functions as a rectifier in G2V mode and an inverter in V2G mode. As a result, the dc to dc converter functions as a step down and step-up converter.

The Fig.1. depicts the block diagram of the system where the renewable energy system is integrated to the system and currently acting as the source for the grid to vehicle system. Grid is also a source to the system, starts supplying to the home and vehicle's battery. Home is a part of the system through which the vehicle can give power from vehicle to essential equipment's of the house.

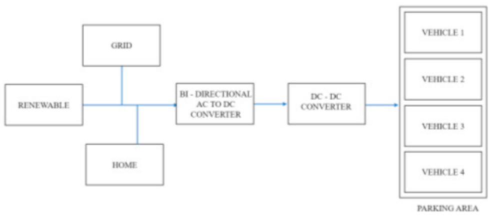

Fig.1.Block diagram of bidirectional power transfer from grid to vehicle with renewable integrated

The Fig.2. depicts the block diagram of the source i.e., Renewable system that consists of solar and wind system, the amount of dc at the output of the solar is boosted through a boost converter and similarly the ac output of the wind system is converted to dc though a rectifier and further boosted to the same potential that of the solar boost converter. The intermediate battery is used for storage purpose where the excess amount of renewable energy is stored and further used if required. The system is linked to the vehicle to grid system as depicted in the illustration.

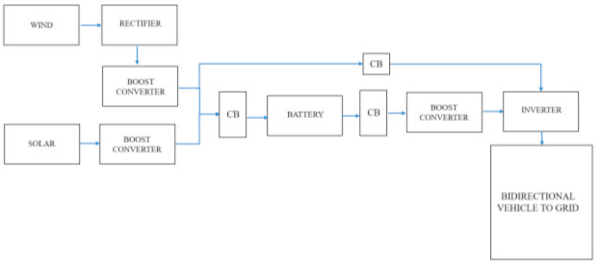

Fig.2.Block diagram of Internal structure of Renewable Energy conversion system

An ideal design of determining the energy storage system capacity is presented in this paper, and the factors like power rating of the solar panel and depending on the customers load profile, the G2V and V2G is initiated [21]. When the maximum power is same as the load, there won't be any power transfer between the grid and vehicle battery [22]. However, if the grid fails to give electricity to the load, the charged batteries will supply the surplus power. Nonetheless, when grid power is unavailable, electricity is given to the load.

The battery in an electric car pack stores a significant quantity of energy. A normal car may produce more than 10 kW, which is about equivalent to the electricity consumed by ten households. The precise timing of V2G grid power generation to meet time-sensitive power "dispatch" requirements of the electric distribution system while meeting driving needs is the the secret to using V2G to create economic value. Grid power is used by PHEVs to offset transportation fuel usage [23].

The energy stored in battery can be used to charge the homes and this is referred as vehicle to home. The influence of V2G in the Indian context is discussed in [24].[25] presents the converter types and their functions. [26] describes the architecture of an AC to DC converter for a plugged-in hybrid electric vehicle. [27] outlines the topologies for the AC to DC converter and the DC-to-DC converter accompanied by a capacitor that shares a DC link voltage.

The DC link voltage is always greater than the traction battery voltage, the reversible DC-DC converter acts as a buck converter during G2V operating mode. Most manufacturers recommend two charging stages to conduct the charging process: constant current and constant voltage The first phase is to recharge the battery with a constant current until the voltage reaches an acceptable maximum voltage, and the second stage is to keep the voltage constant until the current absorbed by the batteries reaches a residual value [28].

The traction batteries in electric vehicles are made up of a series and parallel connection of individual cells. A Battery Management System (BMS) is often used to monitor each cell independently. The charging and discharging of the vehicle in battery to source and utility to battery system consists of two stages are bidirectional ac to dc conversion and bidirectional dc to dc conversion.

1.1. Electric vehicle Charging

The process of charging electric vehicles starts from the grid, it passes through the filter. The filter removes the harmonics of the grid. The grid voltage is ac in nature, it passes through the ac to dc converter (rectifier), the output will be a dc voltage. according to the charging requirements of the vehicle, the obtained dc waveform will be converted to a dc voltage of different magnitude and charges the vehicle.

1.2. Electric vehicle discharging

The process of discharging is initiated from the vehicle with the vehicle owners' interest, the vehicle voltage is dc in nature, the vehicle voltage starts from the bidirectional dc-to-dc converter (boost converter), and the voltage boosted to meet the vehicle specifications of the voltage levels. and the voltage is inverted through an ac to dc converter circuit (inverter) and passes through the grid through a filter circuit.

1.3. Filter

The presence of a ripple or a distorted signal in the output signifies that there is the presence of ac in the waveform. this ac component has to be removed to get a pure dc waveform. For this purpose, a filter circuit is required. A filter represented in Fig.3. is a circuit that removes the ac signal present in the dc output and there are different types, series inductor filter, shunt capacitor filter, LC filter can be used.

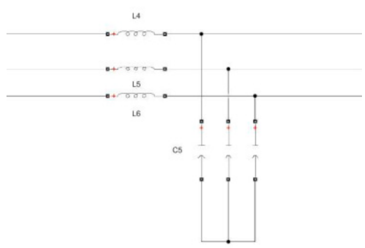

Fig.3.Simulation circuit of LC Filter

1.4. Bidirectional DC-DC Converter

A dc-to-dc converter is a power electronic circuit that takes dc voltage as supply and converts it from one voltage level to a higher or a lower level of voltage i.e., Step up or step down. When the Vo is greater than the Vin it is termed a boost converter and when the Vo is less than the Vin is called a buck converter.

Buck mode Duty Cycle [$D_{buck} = \frac{VI}{VH}$] (2)

Boost mode Duty Cycle [$D_{boost} = 1 - \frac{VI}{VH}$] (3)

Inductance [$L = \frac{VI}{VH} * \frac{RI}{2/f}$] (4)

Capacitance at low voltage side [$\mathrm{Cl} = \frac{\frac{VI}{VH}}{8/L/f^2}$] (5)

Capacitance at High voltage side [$\mathrm{Ch} = \frac{1-\frac{VI}{VH}}{RI/0.01/f}$] (6)

1.5. Bidirectional AC – DC Converter

The process of converting ac voltage to dc voltage is called rectification. Rectifiers are divided into Uncontrolled rectifiers and Controlled rectifiers, it generally flows in one direction. when it reverses the process is called inversion, it is the process of converting the dc voltage into an ac voltage.

$$Vs = \frac{V_{L(peak)}}{\sqrt{3}} \quad (7)$$

$$Vdc = \frac{3*\sqrt{3}}{\pi}\mathrm{Vs} \quad (8)$$

The Equations represent the output voltage of rectifier in bidirectional ac to dc converter.

1.6. PV Module

PV Module can be referred to as a large solar cell, generally used for boosting the output power of the Photovoltaic cells. A solar module is series connected, a finite number of cells to provide the required amount of voltage and current and are connected according to the requirement, PV modules range from 3 watts to 300 watts, and solar modules can be rated from several megawatts to several terawatts [2][18].

A series and parallel interconnection of photovoltaic modules is being used. To augment the voltage rating and quality, a series connection is established. Fig.4. represents the voltage current characteristics of a solar array.

Voltage at maximum Power Point = 30.12 v
Series connected Modules = 10
Terminal Voltage = 10 x 30.12 = 301.2 v
Current at the maximum power point = 7.3 A
Power = 100Kw
Number of parallel Strings = $\frac{\text{Power}}{(\text{Series connected Modules} \times \text{Terminal Voltage}) \times \text{Current at the maximum power poin}}$ (9)

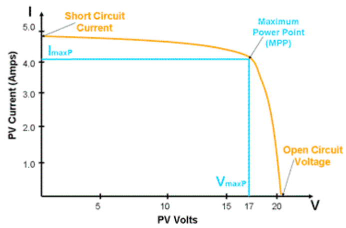

Fig.4. Voltage – Current Characteristics of a solar PV Array

The flowing air is termed as Wind. The Wind energy is from the sun [3]. The resources like coal, gas, oil is limited to certain extent. In the days when the fossil fuels are depleted, the renewable energy resources must play vital role in maintaining and fulfilling the needs of a human being. Considering the environment renewable resources play a vital role making society a better place to live [3] [17].

Windmills have been in use for centuries and centuries and are being used for pumping the water. The wind turbine is perhaps the most advanced technology equipment, and so its primary purpose is to transform energy of Wind turbine into electricity [16].

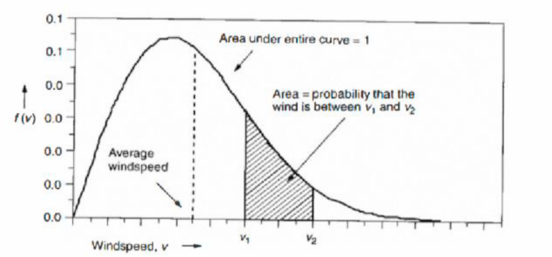

Fig.5. The Weibull Probability density function [4]

The speed alters from one instant to another instant. The PDF is

$$f(v) = \frac{2v}{c^2} e^{v/c^2} \tag{10}$$

Output Power of a Turbine:

$$Pm = \frac{1}{2} * C_p(\delta, \beta) * \rho * A * V_w{}^3 \tag{11}$$

$$C_p(\delta, \beta) = C_1\left(\frac{C_2}{\delta_I} - C_3 * \beta - C_4 * \beta^x - C_5\right)e^{\frac{-C_6}{\delta_I}} \tag{12}$$

$$\frac{1}{\delta_I} = \frac{1}{\delta + 0.08\beta} - \frac{0.035}{1+\beta^3} \tag{13}$$

$$\delta = \frac{W_r * R}{V_w} \tag{14}$$

Control system of WECS [4] is made up of three components.

- Controlling the aerodynamics (Pitch control)
- Control on the machine side (active power control, MPPT).
- Controlling power on the grid

2. Design

2.1. PI Controller

Proportional functions are used to determine the difference between desired and actual values. By using Integral, all previous errors are calculated and integrated to find out the integral term [20]. After an error is removed from the system, this integral will stop increasing.

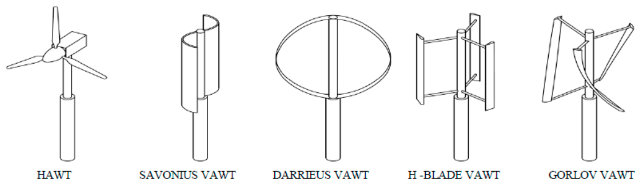

Fig.6. Different types of wind turbine blades [5]

The linear PID controllers with fuzzy logic control have variable control gains. The above variational variable gains are governed by the inaccuracies and the pace over which the error change.

$$u(t) = k_p e(t) + k_I e(t) + k_D \frac{d}{dt} e(t) \tag{15}$$

Often, "tuning" is employed iteratively to achieve the desired closed-loop dynamics with Kp, KI, and KD, without having specific knowledge of the plant model. In many cases, the proportional term is sufficient to ensure stability.

$$u(s) = k_p e(s) + k_I \frac{1}{s} e(s) + k_D s e(s) \tag{16}$$

$$u(t) = [k_p + k_I \frac{1}{s} + k_D s] e(s) \tag{17}$$

$$c(s) = [k_p + k_I \frac{1}{s} + k_d s] \tag{18}$$

The Input to the P, I, D is given at a same instance and the output of the system is summed up with an adder block. [20] Through this sum, it is applied to system and constantly based on the error signal the duty cycle will be changing to produce the output with less steady state error and less settling time through the parameters fed to the system.

2.2. Proportional term

The term proportional is sometimes called as Gain, which changes the output by constantly maintaining the relation of being directly in relation with error value. The response is then multiplied the difference of actual output and desired output by constant Kp. Kp is referred to as Proportional Gain.

$$Pout = K_{p*}e(t) \tag{19}$$

If the gain is very small, the system will suffer from noise or lag. Tuning is very necessary for a system to build a responsive output the proportional term acts on the steady state error mechanism which is inversely proportional to the proportional gain [20].

2.3. Integral Term

Integral being dependent on the magnitude, the error, which is the subtraction between the observed and anticipated result, would then be amplified by an integral gain and appended to the controller output via the summation component. [20].
The integral term is given by:

$$I_{out} = K_i \int_0^t e(\tau)d\tau \tag{20}$$

2.4. Derivative Term

Derivative term is also referred to as rate, is therefore determined by multiplying the steep of errors throughout period by both the derivative gain Kd, subsequently scaling that outcome by error changes that occur. Kd is a measurement as to how much the derivative term lends to a total control action.

$$D_{out} = K_d \frac{d}{dt} e(t) \tag{21}$$

The PID controller's result is computed by summing the proportionality, continuous output, and derived output.

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau) + K_d \frac{d}{dt} e(t) \tag{22}$$

2.5. Fuzzy Controllers

Generally triangular membership function has been found very helpful. The fuzzy rule base is considered from the fig.5. below and inferred that if there is any change in parameter with the corresponding parameter, and suitable action is taken place. Two inputs are generally considered and there are change in error and error. Considering the error here the output will be sent as a duty cycle to the power switching devices.

For few inputs the output is zero because we use a sum block, and the inputs are positive big and negative big that sums up to zero. Similarly for other inputs if it is Positive medium and negative small the duty cycle is approximated to be 5 and similarly 50 and 100 and their negative duty cycles based on the inputs fed to the error and change in error [19]. The Triangular membership functions are considered for the system, seven membership functions considered, PB, PS, PM, Z, NS, NM, NB. For the duty cycle output seven membership functions are considered, -100, -50,0,50,100. Renewable energy conversion system is incorporated with both pi system and fuzzy system.

e' \ e	PB	PM	PS	Z	NS	NM	NB
NB	0	-5	-50	-100	-100	-100	-100
NM	5	0	-5	-50	-100	-100	-100
NS	50	5	0	-5	-50	-100	-100
Z	100	50	5	0	-5	-50	-100
PS	100	100	50	5	0	-5	-50
PM	100	100	100	50	5	0	-5
PB	100	100	100	100	50	5	0

Fig.7. Tyrus - Luybent Modelling Tabular Data [32]

3. Results

From the Fig.8. Fuzzy controller is reaching the desired value fast when compared to the PI and fuzzy controller seems to be best controller for the present system.

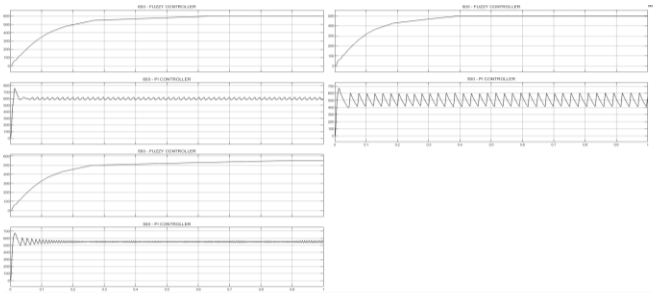

Fig.8. Output Voltage Waveform Renewable Energy Generation System with PI Controller and Fuzzy Controller

The above table 2 represents the parameters of the system with Fuzzy controller having same input voltage and varying the reference voltage, the Table.1. displays the peak overshoot of the system rise time, peak time, settling time.

Table.1. Output Waveforms of Renewable Energy Generation with Fuzzy Controller

Input	Reference Voltage	Peak Overshoot	Rise Time (mS)	Peak Time (mS)	Settling Time (mS)
250,250	500	0.1074	0.2328	0.9262	0.3610
250,250	550	0.1012	0.2428	0.8951	0.7360
250,250	600	0.0370	0.2434	0.6501	0.5550

Table.2. Output Waveforms of Renewable Energy Generation with PI Controller

Input	Reference Voltage	Peak Overshoot	Rise Time (mS)	Peak Time (mS)	Settling Time (mS)
250,250	500	15.5225	0.0056	0.0136	0.0997
250,250	550	25.3455	0.0048	0.0144	0.9976
250,250	600	24.8882	0.0068	0.0136	0.99882

The above Table.2. represents the system parameters with Pi controller having same input voltage and varying the reference voltage, the table delivers the peak overshoot of the system rise time, peak time, settling time for a simulation time of 1 second. The results of the SOC, current of the Electric Vehicle and voltage waveforms of the converter during the vehicle and grid mode and grid to vehicle mode using PI Controller are displayed in the Fig.9.

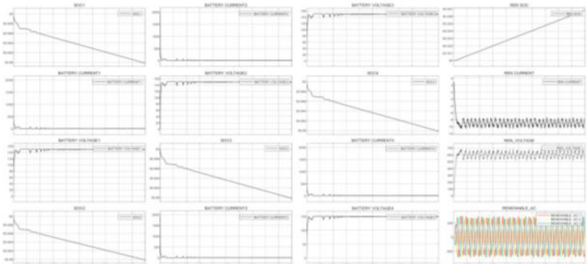

Fig.9. State of charge waveforms of batteries during vehicle to grid mode using PI Controller

The results from the vehicle to grid using fuzzy controller is proved an effective way because from Fig.9. the renewable ac voltage is fluctuating beyond the limit, this can be avoided by using a fuzzy controller as depicted in Fig.10.The ac voltage is steadily increasing without any fluctuations.

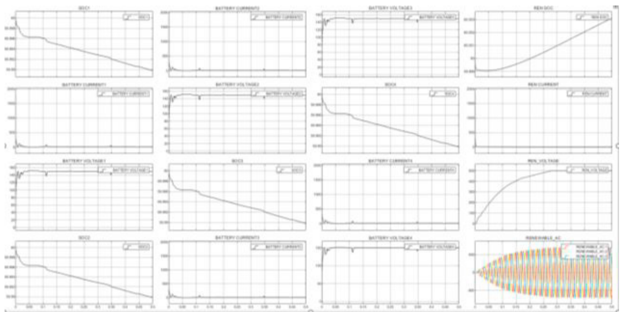

Fig.10. State of charge waveforms of batteries during vehicle to grid mode using Fuzzy Controller

Similarly, during the vehicle to grid the voltage waveforms of the converters i.e., the dc link voltage, the voltage input and output of the boost converter and the voltage and current waveforms of the grid are displayed in Fig.11.

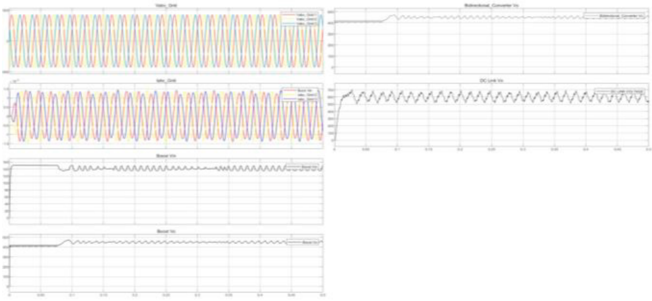

Fig.11. Voltage waveforms of converters during vehicle to grid mode using PI Controller

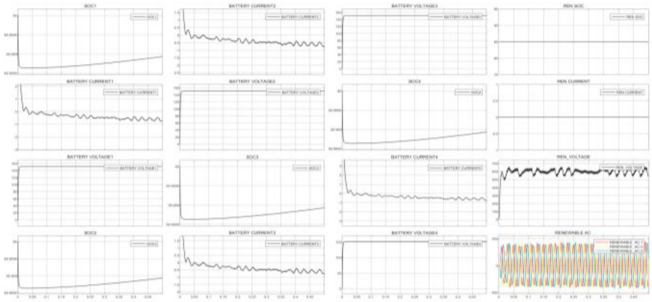

Fig.12. State of charge waveforms of batteries during renewable to vehicle mode using PI Controller

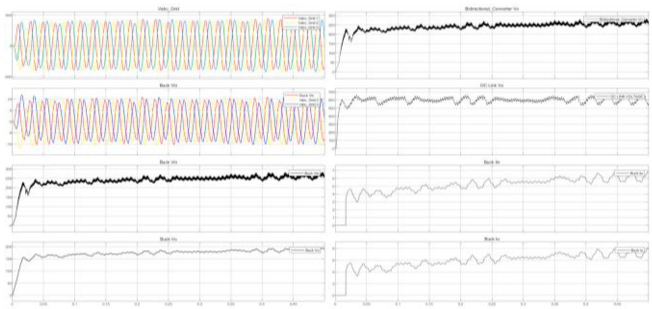

Fig.13. Voltage waveforms of converters during renewable to vehicle mode using PI Controller

Similarly, the results for renewable to vehicle are displayed in the fig.14 and fig.15, fuzzy controller is effective during the vehicle charging from renewable, from the fig.14 the dc link voltage i.e., at 600v do not have any disturbances and is also generating the required three-phase ac voltage.

Power Management Strategy For Effective Bidirectional Vehicle To Grid Power Transfer

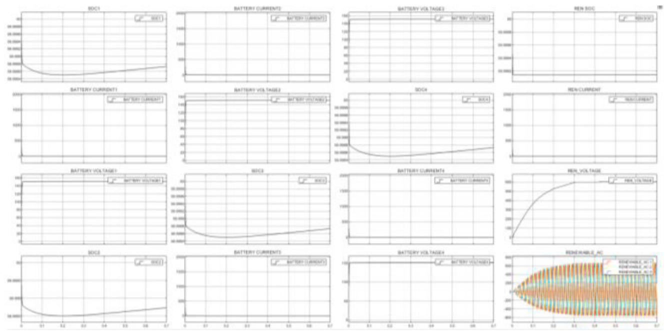

Fig.14. State of charge waveforms of batteries during renewable to vehicle mode using Fuzzy Controller

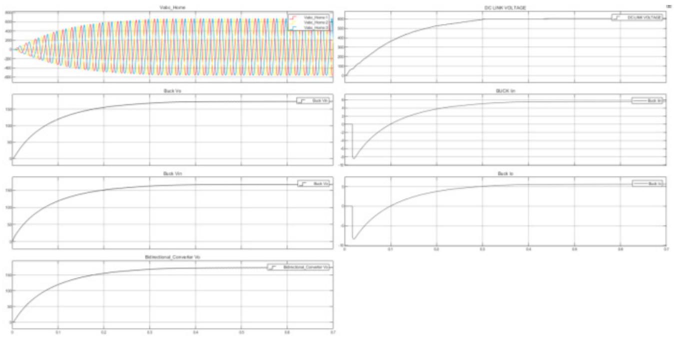

Fig.15. Voltage waveforms of batteries during renewable to vehicle mode using Fuzzy Controller

The three-phase ac voltage at the grid side, generated by the renewable energy system is stable through fuzzy controller than by using a pi controller, using fuzzy controller is more effective and will yield best results.

The Renewable system is acting as a source in renewable to vehicle which is similar to grid to vehicle, without a proper controller, the voltage the source side will fluctuate. From the Table.3. the controller with less settling time and less overshoot would definitely produce best results. Renewable system with fuzzy controller would produce a stable voltage because of less settling time and less overshoot.

Table.3. Comparison of Fuzzy Controller and PI Controller

Parameters	Fuzzy controller	Pi controller
Settling time	0.550	0.9982
Overshoot	0.1012	25.3455
Peak Time	0.8951	0.0144
Rise Time	0.2428	0.0048

4. Conclusion

Electric power generation from renewable energy resources is increasing substantially throughout every country across the entire globe, whether planned or unplanned. The research evaluated two renewable resources and even the strategies used to produce power. There are numerous benefits of renewable energy technologies, they likewise have had several shortcomings. The primary responsibilities involve energy discontinuities as well as unpredictability nature, high generation costs, and control-schemes.

In this paper, a model of bidirectional vehicle to grid is developed integrated with the renewable energy including solar and wind energy conversion system and addressed the issue of voltage stability through controller. From the analysis fuzzy controller yields best results in terms of settling time, overshoot, peak time and rise time. The settling time and overshoot of fuzzy controller is less than the settling time of pi controller. The bidirectional vehicle to grid system with renewable as source do not have any fluctuations at the input end when fuzzy controller is used, thus improving the power flow from renewable to vehicle.

Poor quality or fluctuating source supply may tend to cause power surges and power cuts. This may lead to flickering of lights, interference, and failure of electric equipment. Sensitive electronic components may damage when exposed to interrupted power supplies, this causes overheating, and this may lead to failure of components.

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