Integration of Distributed Generation in Micro-Grid

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ABSTRACT : *This paper includes modeling of Solar and Wind Plants of Micro-grid. Paper includes mathematical analysis, modeling of solar, and wind source individual. And include modeling of simple P&O MPPT method. The interconnection of the small-distributed generation such as PV, Wind turbine is connected to the common bus to supply load.*

KEYWORDS - *DC-DC Converter, MPPT, PV, Wind.*

I. INTRODUCTION

In this paper, solar and wind plant is design for use of the common purposes and as one can utilize maximum power according to the Geo-graphical, situation and can generate power and make a micro grid for the local use for remote area like hill or tribal villages. The need of the energy is going to increases drastically in future years for which Micro-grid is a good solution for providing energy gap, which is not carried out by current fossil sources. Power generation community require to control it and use it optimally when required and also store extra power for future requirement, check islanding and grid connection mode of micro-grid as per criteria and requirement of the system. Micro-grid can play very important role in small-scale distributed energy source utilization [1], so that wheeling cost of energy reduces. By use of renewable energy distribution generation, we can reduce cost for providing economical rate of energy for consumer.

II. SOLAR PLANT

In solar plant, focus is generation of electrical energy, for that solar plant is simulated and modeled from equation. In simulation model as change in solar irradiance make different in solar array output. The change is in particular pattern, by understanding this pattern estimation of switching operation (from grid connection to islanded or islanded mode to grid connection) is easy. Design of Solar Plant include modeling of

a) Solar Cell
b) MPPT and Buck Converter

A. Solar *Cell*

$$I = Iph - Is\left\{e^{\frac{q(v+IRs)}{mKT}} - 1\right\} - \left\{\frac{(v+I*Rs)}{RL}\right\} \quad (1)$$

Characteristics equation is modeled into circuit form and Equivalent circuit is as fig.1 [2]

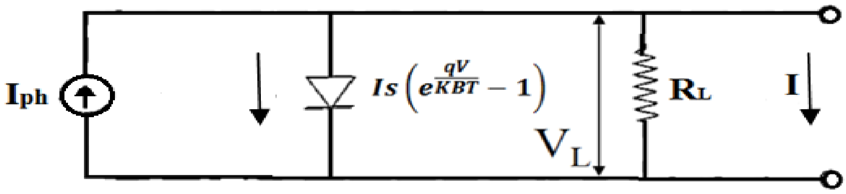

figure 1 equivalent model of solar cell [1]

Where,

I_{ph} = Photo Voltaic Current
Is = Saturation Current of the Diode
q = Electron Charge in Coulombs
= $1.602*10^{-19}$ C
K_B = Boltzmann Constant
= $1.380*10^{-23}$ J/K
m = Diode ideality factor
Rs = Series resistance
R_L = Parallel resistance
T = Temperature in Kelvin
V_{oc} = Open circuit Voltage

The array is formulated on following equation:

$$I = Is(e^{\frac{qV}{Kt}} - 1) - Iph \quad (2)$$

$$Voc = \left(\frac{KBT}{q}\right) * \ln[\frac{Iph}{Is} + 1] \quad (3)$$

The photo voltaic current I_{pv} is a function of the irradiance (G) and is formulated as:

$$Ipv = \{Ipv_{stc} + Ki\Delta T\}\frac{G}{Gstc} \quad (4)$$

Where

I_{pv_STC} = Light generated current under standard test Conditions (STC)
ΔT = (T-Tstc) Kelvin
G = Surface irradiance of cell (W/m^2)
G_{STC} = 1000W/m (Irradiance under STC)
Ki = Short circuit current coefficient

Diode Saturation current (I_s) is given in equation (5)

$$Is = Is\_stc(\frac{T}{Tstc})^3 e^{\{\frac{qEg}{MK}(\frac{1}{Tstc} - \frac{1}{T})\}} \quad (5)$$

Where

STC = Normal saturation current under standard test Conditions (STC)
TSTC = Temperature under standard test conditions
Eg = Band gap energy of the semiconductor

B. MPPT and Buck Converter

Conventional solar plant converts only 30 to 40 percent of the solar irradiance into electrical power. Maximum Power Point Tracking (MPPT) helps to improve the efficiency of solar panel. By maximum power transfer theorem, the power output of circuit is maximum when the thevenin impedance of the circuit match with the load impedance. Due to this by matching impedance, maximum power of solar panel is achieved. For matching impedance, buck converter is used to match source impedance with load impedance and for enhancing the output voltage.

There are various MPPT methods like:

- Perturb and Observe (hill climbing method)
- Incremental Conductance method
- Fractional short circuit current
- Fractional open circuit voltage
- Neural networks
- Fuzzy logic

From the above-mentioned methods here Perturb and Observe (P&O) method has been adopted to simulate solar MPPT due to it is simplest method and requirement of only voltage sensor for algorithm because of which it is very simple to implement and less time complexity. But it has certain disadvantages, in which it reaches near to MPP (Maximum Power Point) it doesn't stop it and continues to perturbate in both directions. And it is not accounting continuous change in irradiance. Working of the P&O is explained in fig.3**.**Here in P&O method first V and I is measured from plant, that power is measured and checked whether it increases or decreases. This indication is observed by power of the plant.

- If power of the array is increased, then P&O checks whether voltage increases or decreases. If power is increased and voltage (V_k) also increases, then voltage of the array should increase to get maximum power. And if voltage (V_k) is decrease then array voltage should decrease.
- Now, if power is decreased, and voltage difference is also decreasing (V_k) then array voltage should increase. But if voltage difference is increased then array voltage should decrease and after that value of measured voltage V_k is updated to $V_{(k-1)}$ and power P_k is updated in $P_{(k-1)}$.

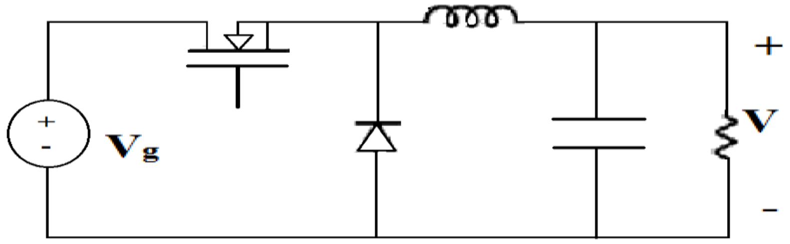

figure 2 basic buck converter [3]

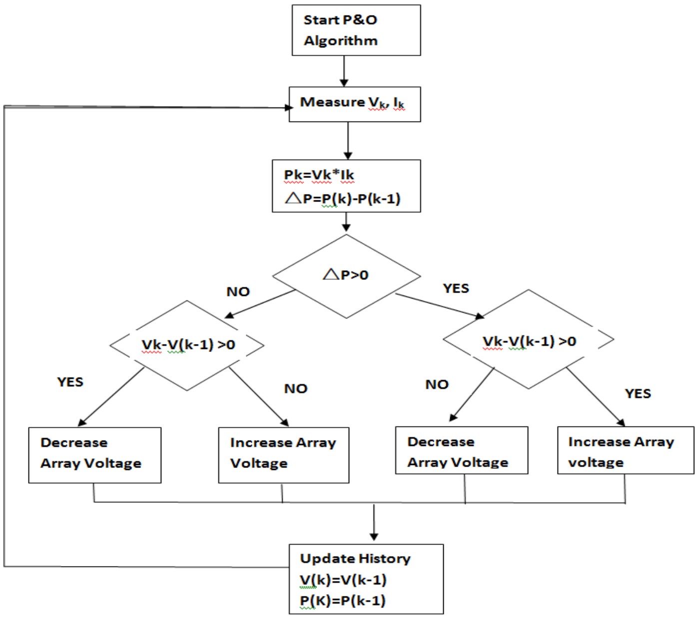

figure 3 p&o method flow chart [6]

Buck converter, is one that converts high voltage to low voltage by switching a thyristor. Theoretical arrangement of the buck converter is as shown in fig.2

Here V_g is solar array from that we are getting input and from converter we can convert that voltage into low level DC voltage. For method, we can use simple PWM method as comparing with the output, changes input. For that we can show simple method in fig.4

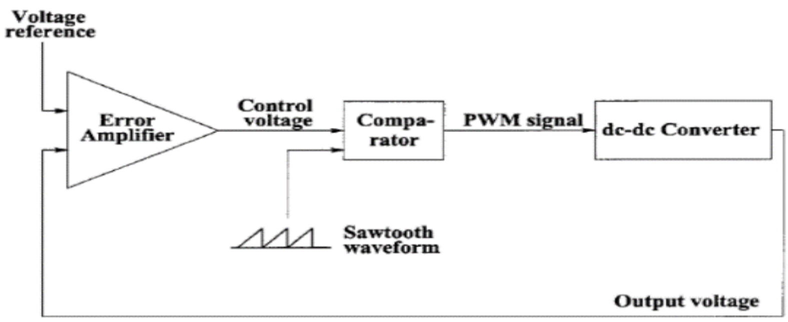

figure 4 controlling of buck converter according to p&o algorithm [3]

As indicated in fig.4 error amplifier (PI controller) is used to analyze error and after analyzing error it generates control signal to maximize power.

III. WIND PLANT

In wind turbine, power of wind is converted into electrical power that can be done by using various generators. In this case, we have used PMSG (permanent magnet synchronous generator) to convert wind power into electrical power and by using Buck converter, generated power is converted into DC power to make micro-grid a common DC Grid. The main advantage of the surface-mounted SG (synchronous generator) is its simplicity and low construction cost in comparison to the inset PMSG. However, the magnets are subject to centrifugal forces that can cause their detachment from the rotor and therefore the surface-mounted PMSGs are mainly used in low-speed applications. In a direct-driven WECS (wind energy conversion system), the synchronous generator with a high number of poles is used. The surface-mounted PMSG can have an external rotor in which the permanent magnets are attached to the inner surface of the rotor. In this case, the centrifugal forces help to keep the magnets attached to the rotor core.

Kinetic energy

$$KE = ½ * m * v^2 \quad (6)$$

$$P = ½ * m * v^2 \quad (7)$$

Fluid mechanics gives mass flow rate

(Density * volume flux)

$$dm/dt = \rho * A * v \quad (8)$$

$$\text{Total} \quad P = ½ * \rho * A * v^3 \quad (9)$$

Form this equation we can calculate input power of wind turbine. Here for simulation purpose MATLAB model of wind turbine with PMSG is used and after getting output from wind model, it is converted into DC so that power can be controlled easily and also stepped down to 200 V to match up the PV voltage level by Buck converter as shown in simulation & result.

IV. SIMULATION AND RESULT

Here solar and wind plant is discussed. The solar power plant is modeled using mathematical equations which is shown in fig.5

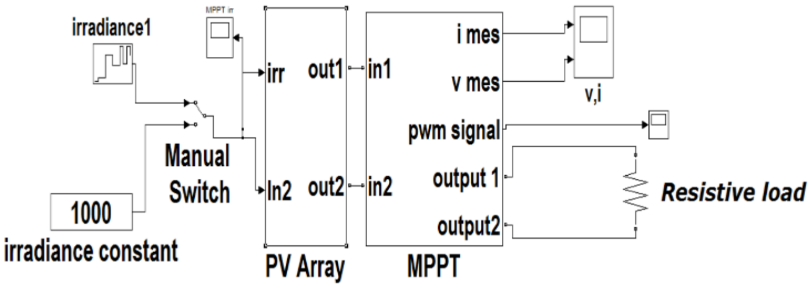

figure 5 solar plant overall layout

Here from PV array electrical energy is generated, that energy is supplied to MPPT for maximization. After that energy is supplied to simple resistive load. Results of Final voltage and current are shown in fig.9 and 10 respectively. Simulation model of the solar cell according to equation (1), (2), (3) is formed as fig.6

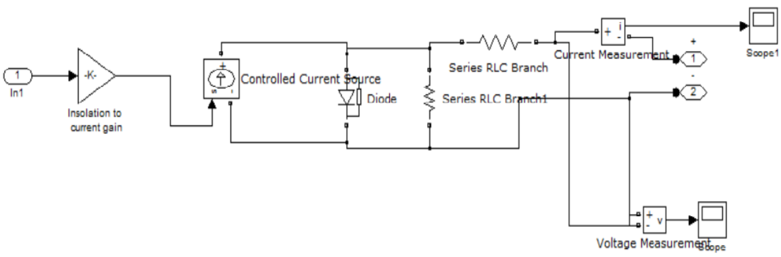

figure 6 solar cell simulation

Input from the solar irradiance can be calculated as area of the solar at fix Irradiance of 1000 W/m^2

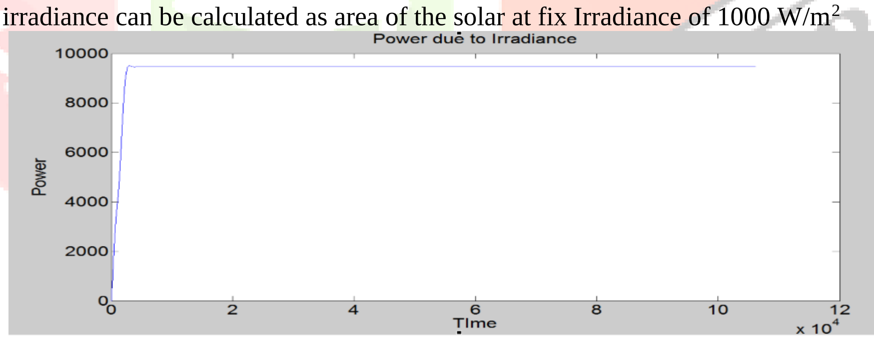

Figure 7 Power input due to Irradiance

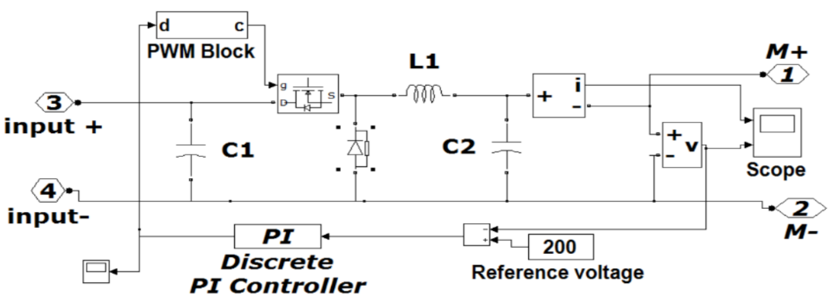

figure 8-buck converter with p&o algorithm

Simulation of Buck converter & MPPT is shown in fig.8 that shows when change in voltage is taken place, it changes input signal to PWM generator, which gives signal to thyristor to change output of the solar array. Here difference of signal is taken by PI controller. Values of all parameters are shown in Table 1,2and 3 respectively.

table-1: input value of solar plant

Input power from sun	4732 Watts
Solar array output	1350 Watts
Current	7.85 A
Voltage	170 V

table-2: data of the buck converter

$C_1 = 1.79*10^{-3}$ F	$C_2 = 120*10^{-6}$ F
$L_b = 1.53*10^{-6}$ H	R = 125 Ω
Duty ratio = 0.125	F = $20*10^3$ Hz
Input voltage = 1600 V	Output voltage = 200 V
Input current = 2.5 A	Output current = 19.4 A

table-3: final output value

V out_pv	130 V
I out_pv	10.0A
P out_pv	1350 W
Overall plant efficiency	(1350/4732) = 28.52%

As shown in figure.8 for making BUCK converter to convert voltage to 200V for generating common DC bus the values of L, C and D are calculated as depicted in table-2.

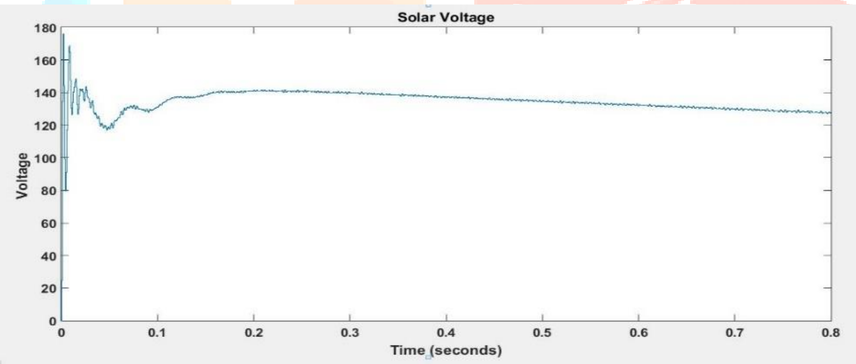

figure 9 output voltage of solar plant

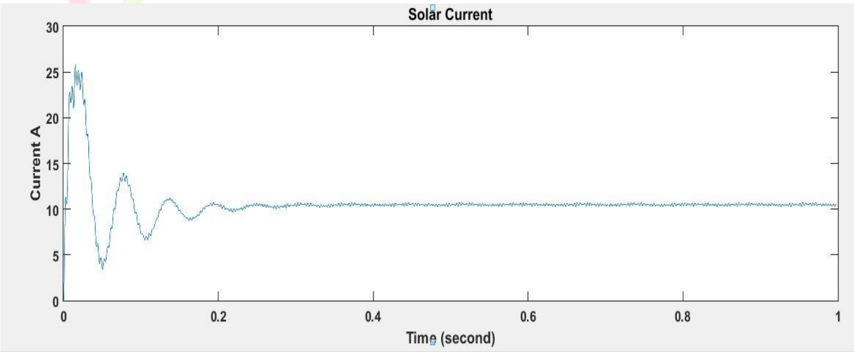

figure 10 output current of solar plant

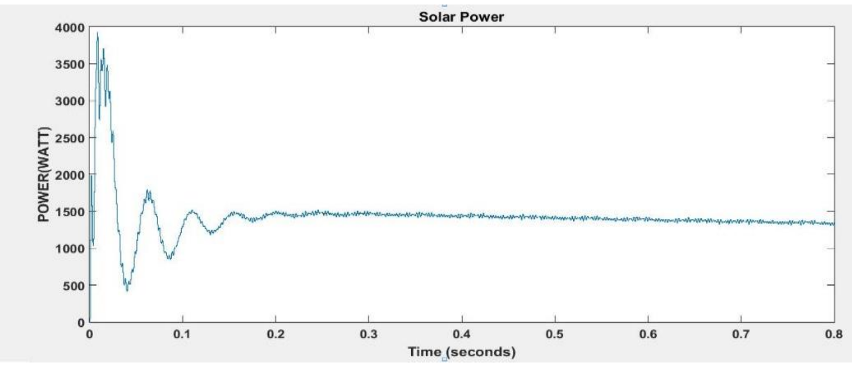

figure 11 output power from solar plant

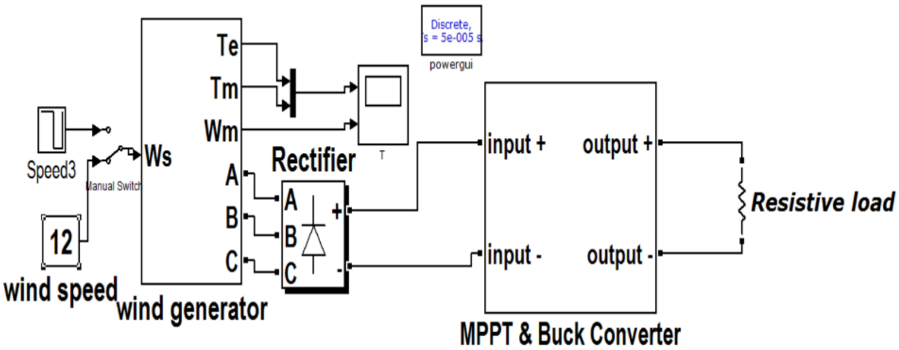

figure 12 overall wind simulation

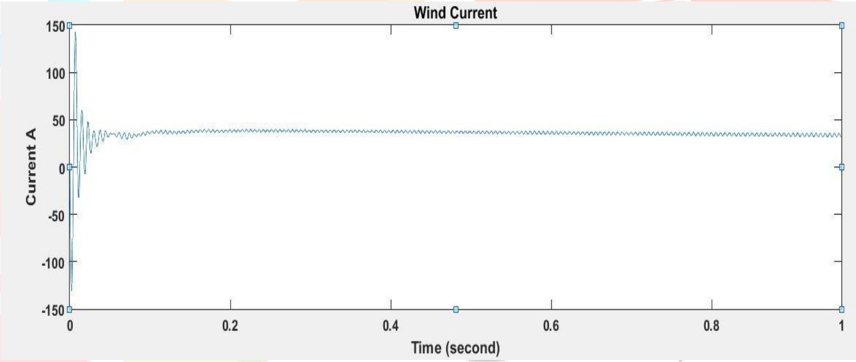

figure 13 output current from wind plant

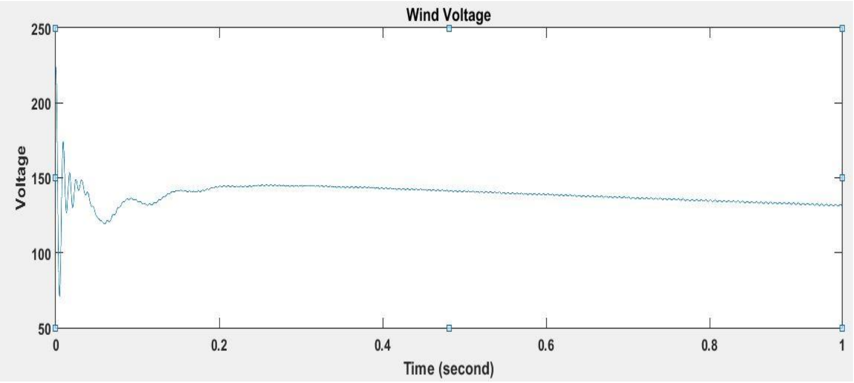

figure 14 output voltage of wind plant

<u>table-4: wind turbine data</u>

Input Quantity	Value	Output Quantity	Value
Wind 8 m/s	3500 Watts	Power	800 Watts
Blade Length	9 Meter	V out_Wind	130 V
		I out_Wind	35 A

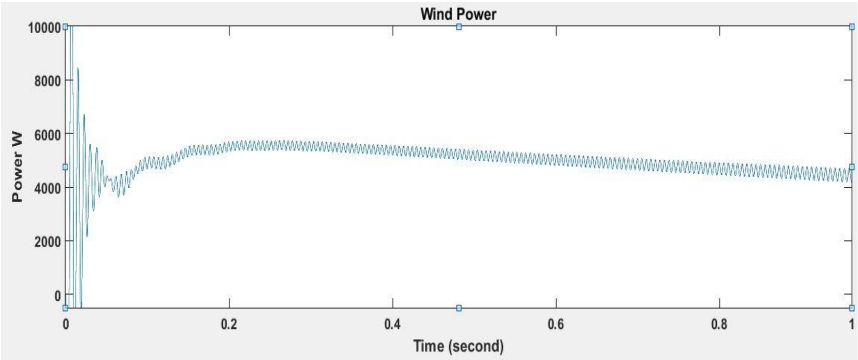

figure 15 output power of wind plant

V. Combination Of wind and solar

Two or more power supplies can be connected to supply higher voltages or current. The simplest method to create higher current is to connect the power supplies in parallel and leave only one supply in constant voltage mode. Some power supplies are equipped with analog control signals that allow auto-parallel or auto-tracking, a more elegant way to control multiple power supplies. Auto-parallel supplies can be controlled with a single master supply; a second advantage is that all of the master power supplies features can be used. E.g. remote sense, CV or CC mode, even analog programming. Auto tracking allows multiple supplies to track the master; the slaves can have the same output characteristics or can be configured to be proportional to the master.

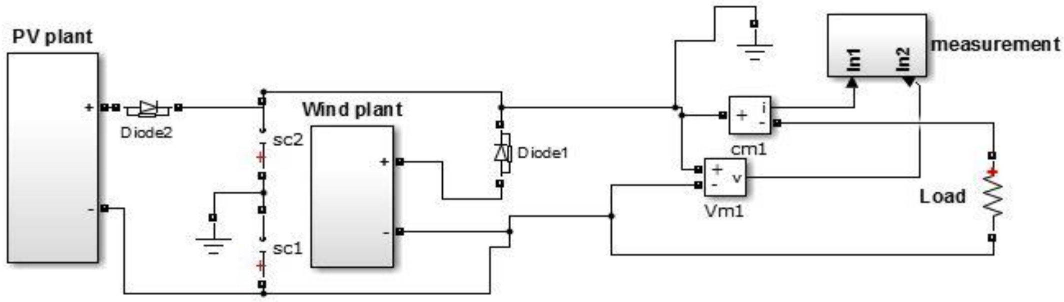

figure 15 lay out of combine wind & solar

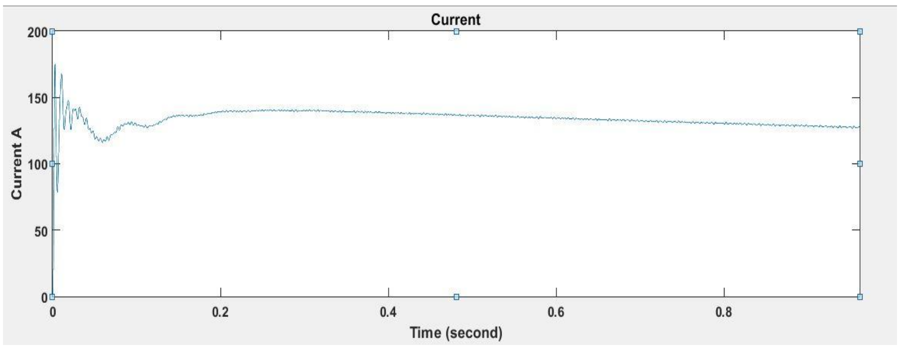

figure 16 output current of combine plant

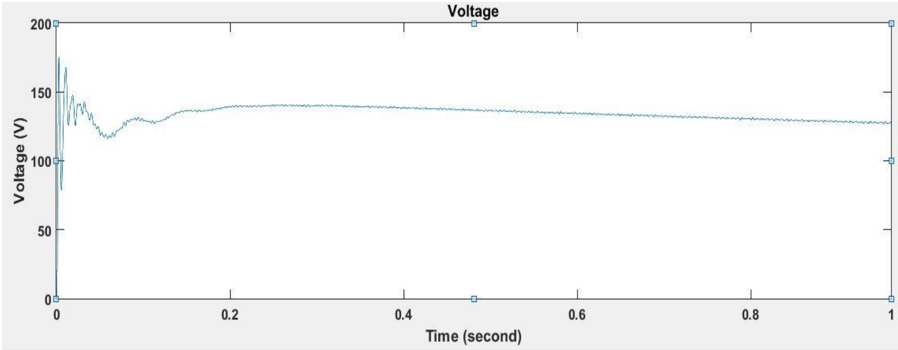

figure 17 output voltage of combine plant

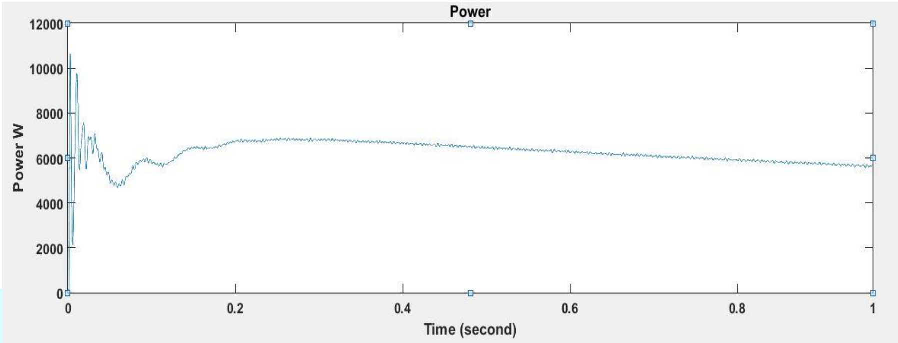

figure 18 output power of combine plant

table-5: final output value

V out	140 V
I out	48.3A
P out	6720 W

Since the voltage sources share common nodes, the only time two or more voltage sources are allowed in parallel is when they have exactly the same voltage, polarity in dc sources.

VI. Conclusion

By modeling of the solar and wind plant, we get detailed idea about how these Distributed Generation sources change its generation according to solar irradiance and wind speed at standard temperature and pressure. By modeling we can get idea about change in generation in different condition from, that we can determine whether system should operate in islanded or grid connected mode.

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