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Modelling and Simulation of Microgrid during Islanding and Optimization of Distributed Energy Resources

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ABSTRACT

This paper presents a simulation and mathematical model of Microgrid in Autonomous mode. A Microgrid consist of renewable energy sources such as Solar PV system , Fuel cell stack system , Battery energy storage system (BESS) and load. Comparative study of sinusoidal PWM and space vector modulation is done and SVPWM is preferred in controlling of inverter due to its advantage over SPWM. Optimization of DER'S is done to utilize the resources at most keeping the cost in mind.

Keywords : Microgrid, Solar PV system, space vector PWM, Sinusoidal PWM, Islanding operation and inverter.

I. INTRODUCTION

To reduce CO2 emission , main cause of Global warming , we need to switch to renewable energy sources from conventional sources. Microgrid is the main focus area and need of hour due to increase in global temperature and climate change. A Microgrid can be defined as a low voltage distribution system to which small modular generating systems are to be connected. It can be installed in a village or town. MG is intended to operate in the following two operating modes.

- GRID CONNECTED MODE: In this mode, MG is connected to main utility grid through a point of common coupling (PCC) switch. MG feeds the load connected to it, wherever MG supplies more than required then it can feed to main grid and when demand is more than the power supplied by Microgrid then main grid helps in satisfying the demand.
- EMERGENCY MODE: The MG operates autonomously , means whenever there is fault or black out condition occurs in main grid then MG is disconnected from main grid and MG alone feeds the local loads . Here islanding has been explained in detailed.

II. MODELING OF POWER SOURCES

DER'S used in Microgrid are Solar PV system and fuel cell system with BESS. Modelling of each component of Microgrid is explained in detail.

1. PV system modelling

The equivalent circuit of PV cell is shown in figure 1.

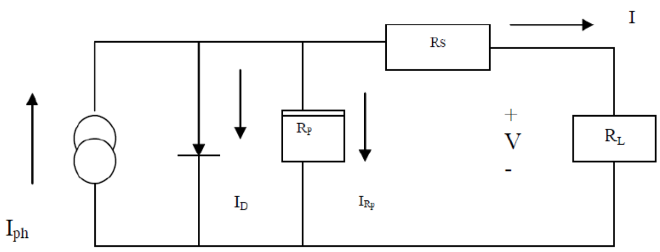

Fig. 1. PV cell equivalent circuit

Applying Kirchoff's current law (KCL), we get:

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$$I_{ph}=I_D+I_{Rp}+I \quad (1)$$

By rearranging the following equation we get photovoltaic current

$$I= I_{ph}-I_{Rp}-I_D \quad (2)$$

$$I = I_{ph} - I_o \cdot \left[exp\left(\frac{V+I.R_S}{V_T}\right) - 1\right] - \left[\frac{V+I.R_S}{R_P}\right] \quad (3)$$

Here Iph- Insolation current

I – Cell current

Io- Reverse saturation current

V- cell voltage

Rs- series resistance

Rp- parallel resistance

VT- Thermal voltage

k- Boltzman constant

T- Temperature in kelvin

q- charge of electron (C)

Simulation block of solar cell and its parameters are shown in figure 2 and figure 3 respectively.

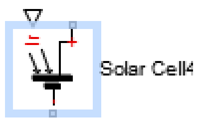


Fig. 2. Simulation block of solar cell

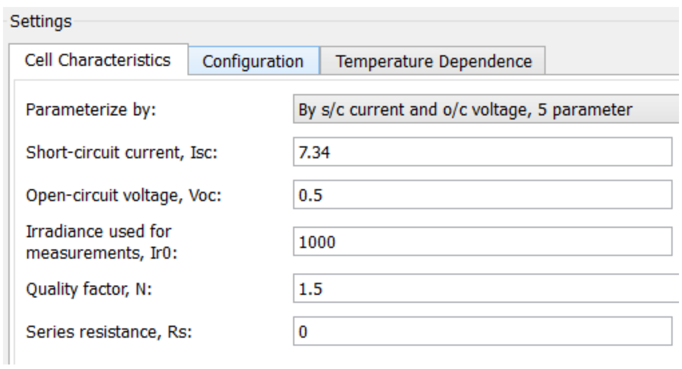
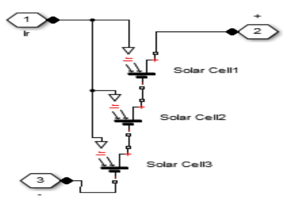


Fig. 3. Solar cell parameters

As one solar cell voltage is 0.5 V. Here each cell has 10 solar cells in built in it giving voltage of 5V. By connecting such 3 cells in series we will get 15V voltage. It can be understood by looking in figure 4 .



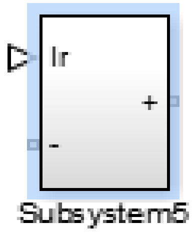


Fig. 4. Series connection of solar cell in equivalent subsystem in matlab

Now by connecting four such subsystem in series a voltage of magnitude 60 V can be obtained as shown in figure 5.

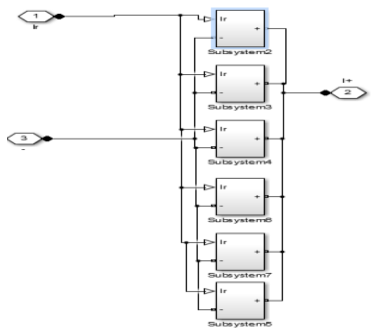


Fig. 5. Series combination of solar subsystems

Simulation model of solar PV system can be obtained in Matlab simulation using the subsystem of solar cell which is shown in figure 6.

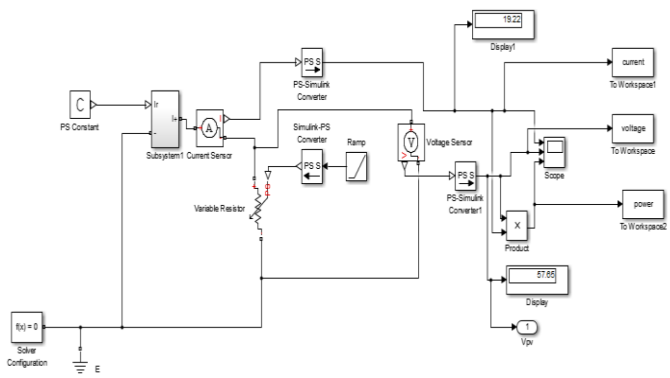


Fig. 6. Simulation model of solar system

After simulating solar pv system model the we get desired voltage , current and power waveform which are shown below .

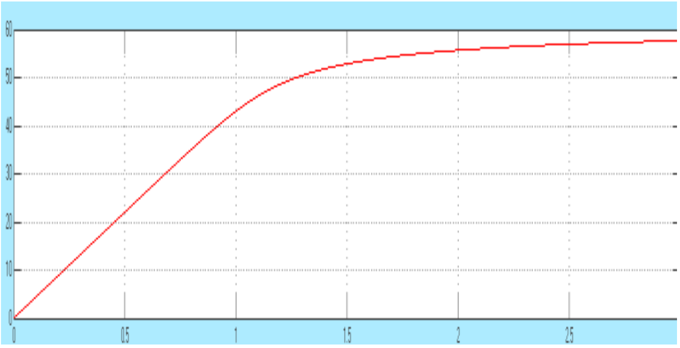


Fig. 7. Voltage waveform of solar panel

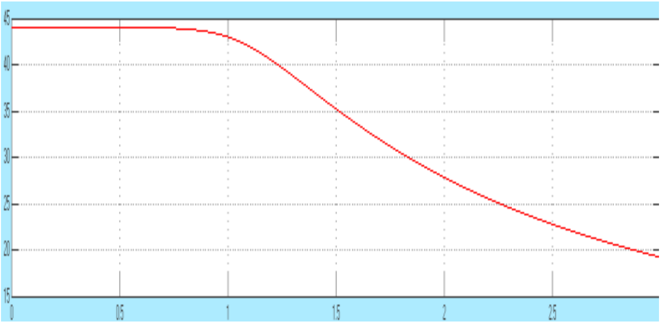


Fig. 8. Current waveform of solar panel

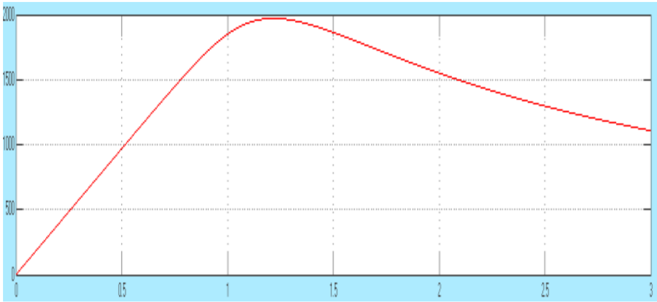


Fig. 9.power waveform of solar panel

P-V And V-I characteristics of solar system is shown in figure 10 and figure 11 respectively.

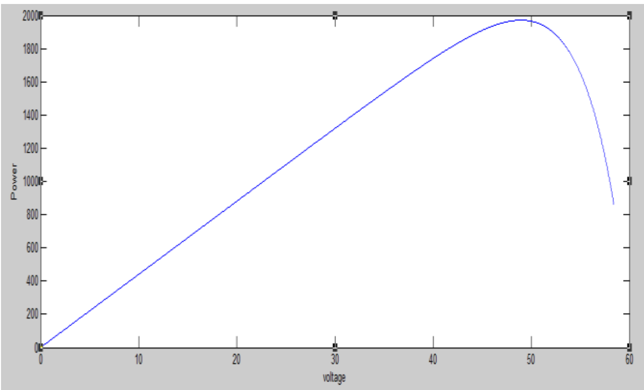


Fig. 10.P-V characteristics of solar panel

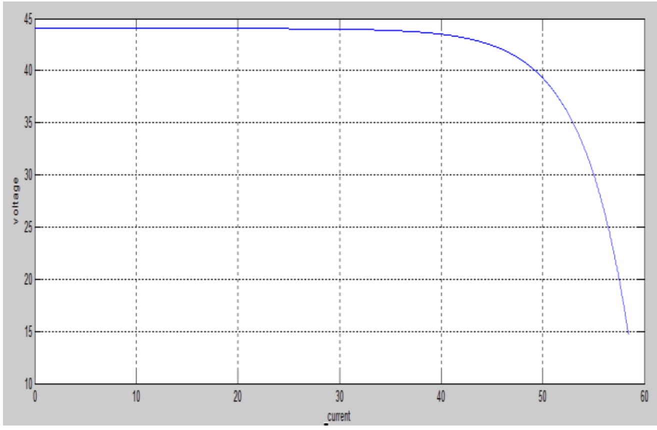


Fig. 11.V-I characteristics of solar panel

2. Fuel system modelling:

A fuel cell is an electrochemical device which converts chemical energy into electrical energy. It takes energy from a fuel and produce water and heat. It combines hydrogen and oxygen without any type of combustion.

SIMULATION MODEL OF FUEL CELL:

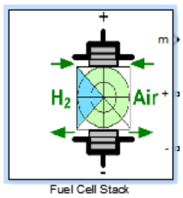


Fig. 12. Fuel Cell simulation block

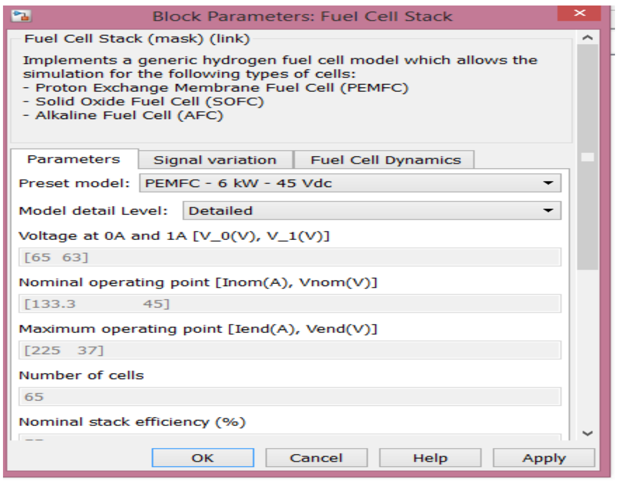


Fig. 13.Fuel cell parameters

3. Boost converter modelling:

It is a step up or PWM boost converter. It comprises of a Dc voltage source Vg, Boost inductor L, Diode D, a controlled switch S, Filter capacitor C and the load resistance R.

- When switch S is closed (ON STATE) current starts flowing through inductor and increase linearly. Diode D is reverse biased .
- When switch S is open (OFF STATE), The energy which is being stored in inductor during on state, get released to the output RC circuit through diode or we can say L is discharged through D.

SIMULATION MODEL OF BOOST CONVERTER

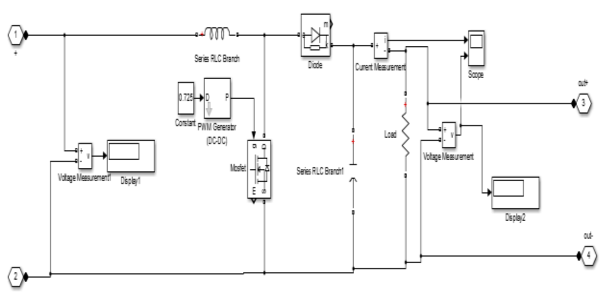


Fig. 14.Internal diagram of boost converter and subsystem of boost converter

VALUES OF DIFFERENT PARAMETERS IN BOOST CONVERTER:

Inductor L	**100mh**
Capacitor C	100µF
Duty cycle of MOSFET	0.725

4. PWM Inverter :

Here in this study two PWM schemes are used which are SPWM and SVPWM and both are compared on the basis of THD.

- Sinusoidal PWM :-

In sinusoidal PWM several pulses are produced per half cycle. The width of pulses varies as the amplitude of sine wave. The pulses near the edge of half cycle are narrower than the pulses near the centre of the half cycle.

- Space Vector PWM :-

It is an algorithm which is used to control pulse width modulation i.e. PWM. Major benefit of using this technique is the reduction in Total Harmonic distortion. To implement space vector modulation, we need to have a reference signal Vref which is to be sampled at a frequency fs (Ts = 1/fs).This reference signal is generated by using αβγ transformation of three reference phases.

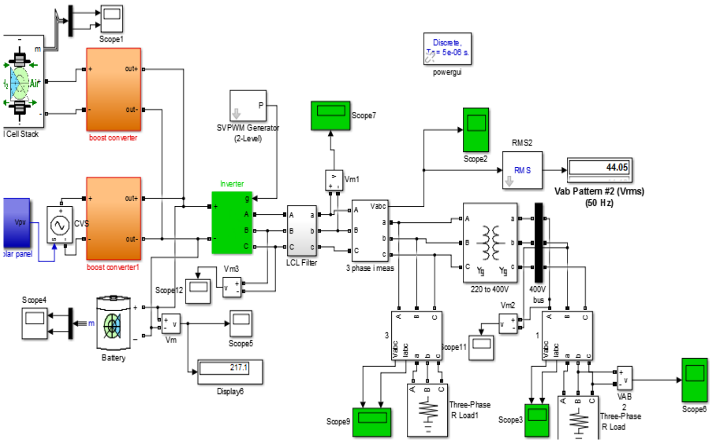


Fig. 15.MIicrogrid simulation model in island model

III. OPTIMIZATION OF DISTRIBUTED ENEGRY SOURCES

Designing of Microgrid is a very important phase as we have to consider cost of every component used in system. So to get optimised value of power of each source we have assumed cost of each source. It can be changed depending upon market values.

As the cost of 1 KW of solar panel is between Rs. 55000 to 60000 .
Fuel cell stack cost is Rs. 10,000 per KW.
Battery cost around Rs. 7600 for 1 KW .

Depending upon these cost value of sources , a constraint equation can be formed. Let us assume power generated by solar panel is x KW, Fuel cell generate y KW power and power generated by battery is z KW.

Total load we are taking is 10 KW. So we need to generate 10 KW of power. As cost of solar panel is very high so minimum power generated by it is taken as 2 KW . The limit of fuel cell is 10 kw and that of battery is 2 kw. The equations finally formed are:

C= 57.5 x+ 10 y+ 7.6 z; (4)

x+y+z= 10; (5)

2≤x≤10; 0≤y≤10; 0≤z≤2.

(6)

By solving these linear equations in MATLAB we get optimum value of all the resources which is as follows:

X= 2.0

Y=6.0

Z= 2.0

It states that solar panel should produce 2.0 kw of power. Fuel cell should produce 6.0 kw of power and battery should give 2.0 kw of power. So we will put these values in our model to have optimum utilization of resources.

IV. SIMULATION RESULTS

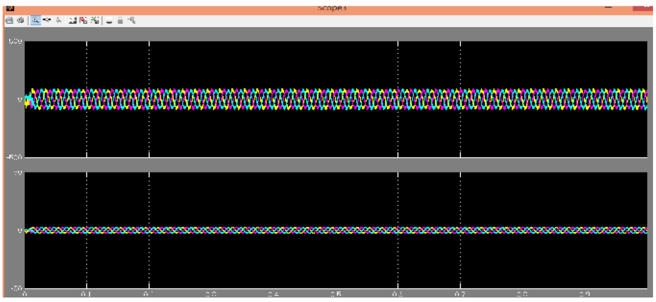


Fig. 16. Voltage and current waveform of R load

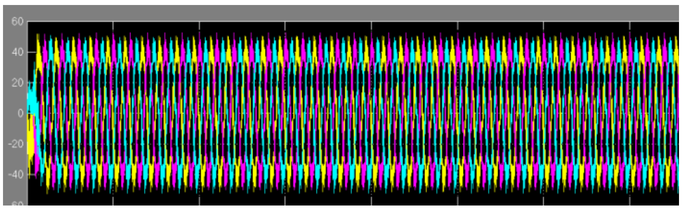


Fig. 17.Voltage waveform of R load1

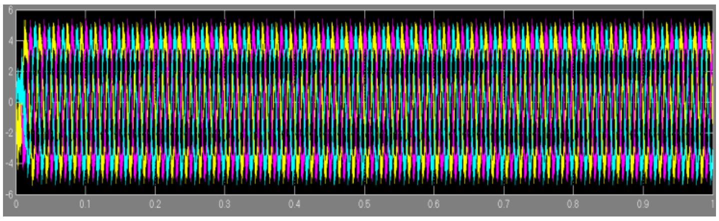


Fig. 18.Current waveform of R load1

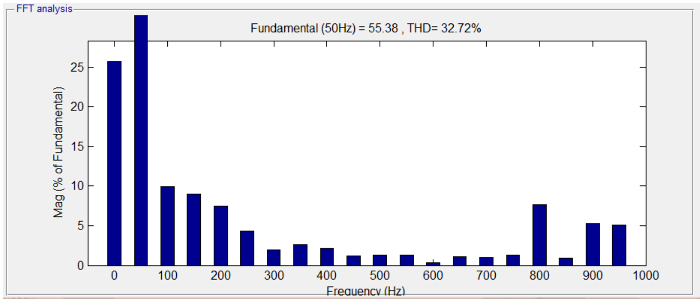


Fig. 19. THD of Rload using SPWM

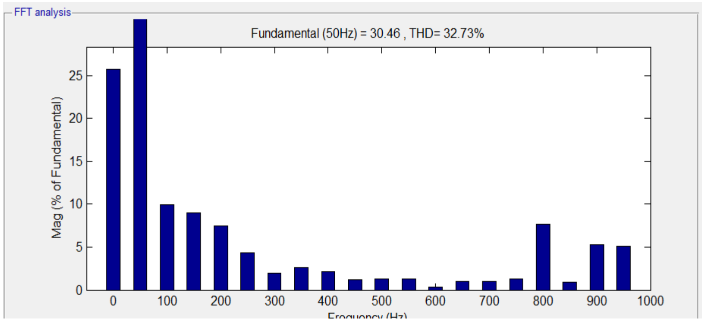


Fig. 20.THD of R load1 using SPWM

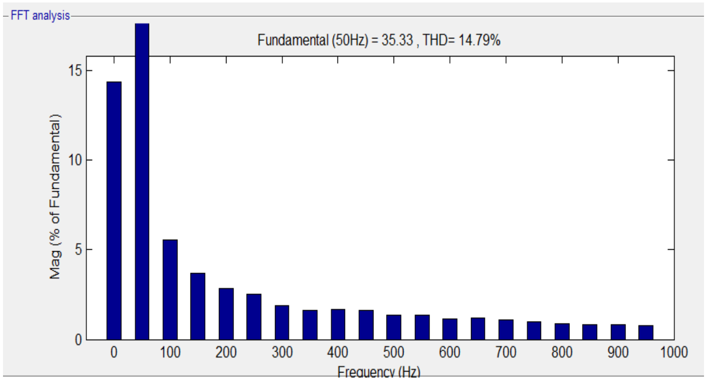


Fig. 21.THD of R load1 using SVPWM

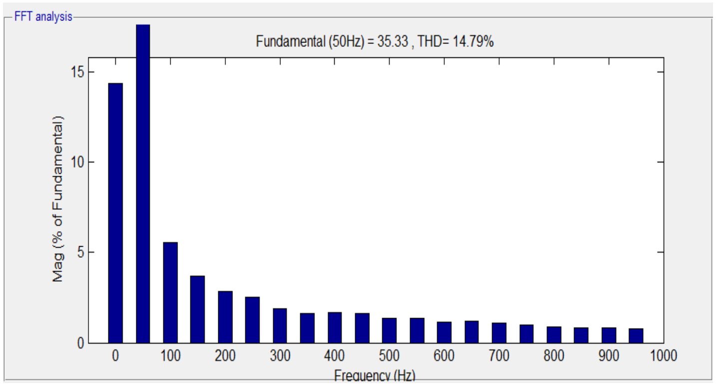


Fig. 22.THD of R load using SVPWM

V. CONCLUSION

As per the simulation results it can be concluded that the THD during SPWM is around 32.72% and with SVPWM it is reduces to 14.79%. So depending upon the results it is preferred to use SVPWM over SPWM for controlling of output voltage of inverter. Here Microgrid is working efficiently and feeding a load of 10 KW. Detailed study of each renewable source is shown in this paper. Further optimization of DER'S is also studied and done using MATLAB.

VI. ACKNOWLEDGEMENT

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