Comparative Analysis of Droop Control and PWM with VSI for Islanded Microgrid

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Abstract- **Present energy demands are supplied by fossil fuel. It has negative impact on environment, therefore the renewable sources are the best solution for energy supplies. PV array and VSI can employed in distributed manner to collect energy from solar irradiation. It can design at small scale according to site requirement. Collection of distributed generators build microgrid. Microgrid is able to supply power to local area, and it can supply power to the main grid or receive power from the main grid. Main issue with microgrid is power regulation. Communication based system is able to regulate microgrid power, but it is suffered from single point failure. VSI can control through PWM technique, but its performance is not compatible with system. Droop Control can control system parameter and improve system performance, and it control each VSI individually. In faulty condition controller cut off only faulty unit from system. Model is design and simulated in MATLAB/Simulink 2017a and results are discussed.**

Index Terms- Droop Control, PWM, VSI, Microgrid, MATLAB/Simulink.

I. INTRODUCTION

The conventional energy sources are main source of energy in today's energy system. It has a negative impact on the environment and the demand is growing day by day [1], [2]. We have to be aware that the reserves of fossil fuels on the earth are limited and will be deplete soon. The decay of environment is a clear warning that the present impacts of human progress have its limitations [3]. If we will not use renewable energy, it will waste.

Photovoltaic (PV) cell can direct convert solar irradiation to DC electrical power. Combination of PV cell create PV array. It can employ in small area with sun light exposure. By connecting VSI with PV array we can get three-phase output power. This combine unit known as Distributed Generator (DG). Many DGs can connect in single system and it is known as microgrid. Microgrid is a combination of DGs, storage units, load, etc. Microgrid can work in islanded mode or grid connected mode. A large number of inverter based Distributed generation (DG) units have been installed in traditional low voltage distribution system [4], [20]. DG has advantages of pollution reduction, high-energy utilization rate, low-power transmission losses and adaptable installation location. With compare to conventional generator DG provide a good controllability and operability [30]. In microgrid system regulation, the communication based system is used. Its performance is good, but suffering from single point failure and provides communication delay in system operation. Droop control is faster and it can control VSI without communication system. It work as single DG unit and if any fault occur, it will disconnect particular unit. Droop control is unable to control the VSI single handedly. We can control VSI with the help of PWM technique, but it performance is poor. If droop control and PWM use together, droop control can improve system performance.

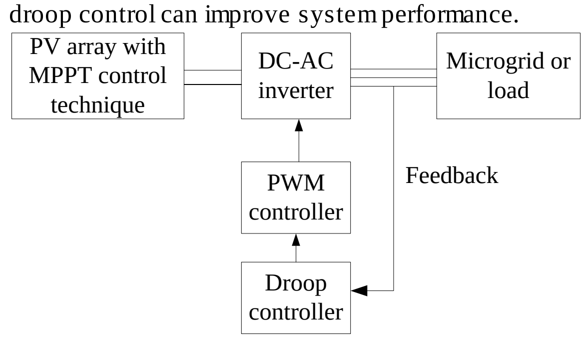

Fig. 1 Conceptual block diagram of proposed system

II. MATHEMATICAL MODELING

A. PV array

A solar cell is basically a p-n junction semiconductor, fabricated in thin wafer size. The radiation of the sun can directly convert to electricity because of photovoltaic effect. Typically, a PV cell generates a voltage around 0.5 to 0.8 volt depending on the semiconductor and the built-up technology [49]. We can observe that voltage is low as it cannot be used. PV cells are connected in series and parallel combination. This series and parallel combination of PV cells forms a PV array. It is known as solar panel. In case these modules are connected in series, their voltages are added with the same current, and when they are connected in parallel, their currents are added while the voltage is same [49]. Its final equation is as below.

$$I = N_p I_{ph} - N_p I_o \left[\exp\left(\frac{V + I \frac{N_s}{N_p} R_s}{N_s a} \right) - 1 \right] - \left(\frac{V + I \frac{N_s}{N_p} R_s}{R_p} \right)$$

(1)

B. Droop Control

Droop control is a technique, which is use in power station to control generator output power according to load demand. It can also use for controlling VSI in distributed generator. The droop control is a technique which can control DGs individually. DGs are connected in parallel with microgrid to share load. When the output impedance is inductive, (P-F) and (Q-V) droop is used, and when output impedance is resistive (P-V) and (Q-F) droop is used [17]. If the line impedance is integrated resistive and inductive, so the active and reactive power will be effectively combined [30].

$$f_i^* = f_{rated} - mp * (P_i - P_{i,rated}) \quad (2)$$

$$V_i^* = V_{rated} - mq * (Q_i - Q_{i,rated}) \quad (3)$$

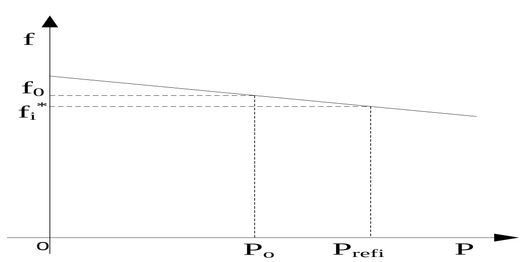

Fig. 2 P-F droop control

$$mp = \frac{f_i - f_{min}}{P_i - P_{i,max}} \quad (4)$$

$$mq = \frac{V_{i,max} - V_{i,min}}{Q_{i,min} - Q_{i,max}} \quad (5)$$

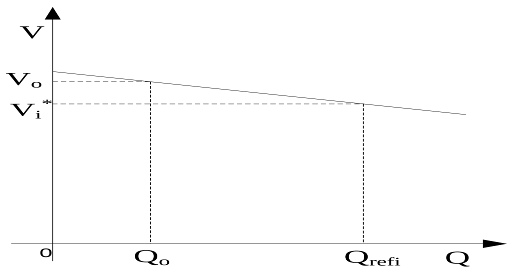

Fig. 3 Q-V droop control

III. MATLAB MODELING

The modelling of proposed technique is modelled in MATLAB/Simulink version R2017a. The solar photovoltaic array is selected from standard modules given in MATLAB/Simulink. Six switches are used to form three-phase VSI and at the output, line inductance and load are connected. With the help of measurement block three-phase voltage and current measurement are taken. In droop controller measured voltage and power are processed in the controller and action taken accordingly. As showed in fig. 4 MATLAB/Simulink model of proposed scheme. System is tested with R load. PV array is selected as DC supply source. Results are taken with variation of parameters such as irradiation, temperature and load.

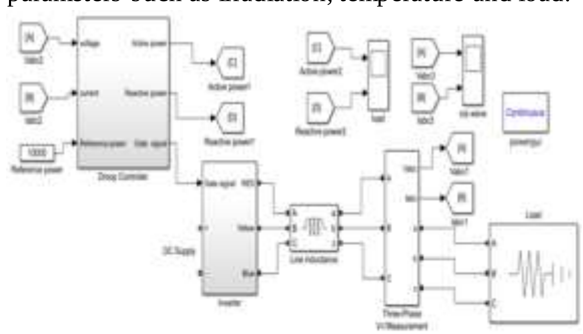

Fig. 4 MATLAB/Simulink model

IV. SIMULATION RESULTS

Results are taken by two methods, first without droop control and second with droop control. Without droop control means, inverter is direct control through PWM technique only, without any feedback. With droop control means, inverter is control through droop controller and PWM, and it takes feedback of voltage and power. Simulation is run for 0.2 seconds. The graphs are compared with same parameter configuration, but it is simulated without droop control and with droop control, therefore we can observe the effect of droop controller on system performance. For all simulation graph, waveform of blue phase is selected as sample from three phase output, therefore voltage and current waveform is started from negative cycle.

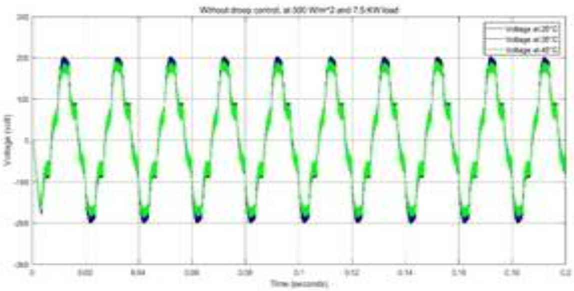

Fig. 5 Voltage without droop control, at 500 W/m^2 and 7.5 KW load.

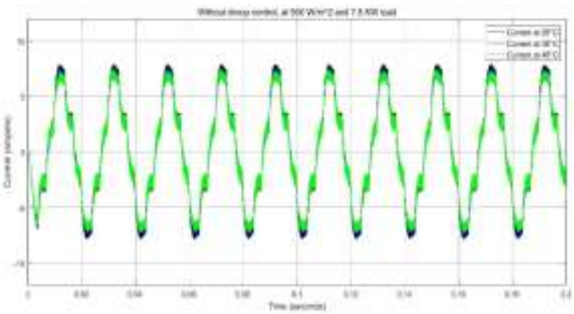

Fig. 6 Current without droop control, at 500 W/m^2 and 7.5 KW load.

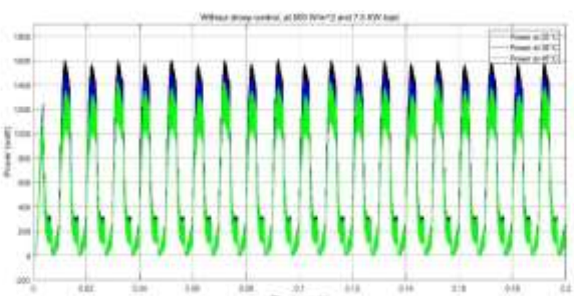

Fig. 7 Power without droop control, at 500 W/m^2 and 7.5 KW load.

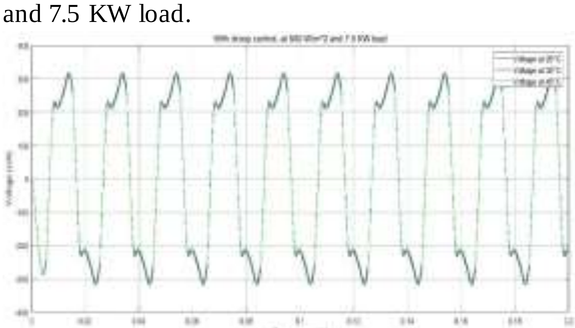

Fig. 8 Voltage with droop control, at 500 W/m^2 and 7.5 KW load.

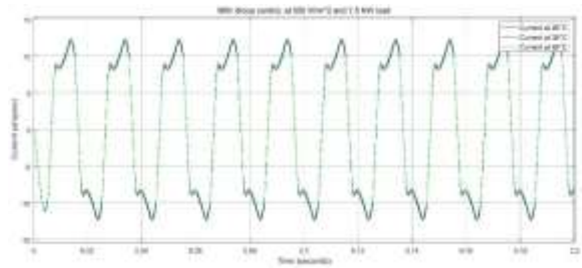

Fig. 9 Current with droop control, at 500 W/m^2 and 7.5 KW load.

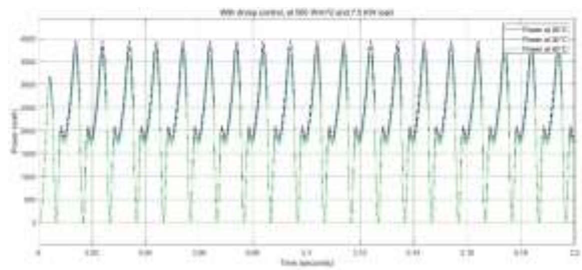

Fig. 10 Power with droop control, at 500 W/m^2 and 7.5 KW load.

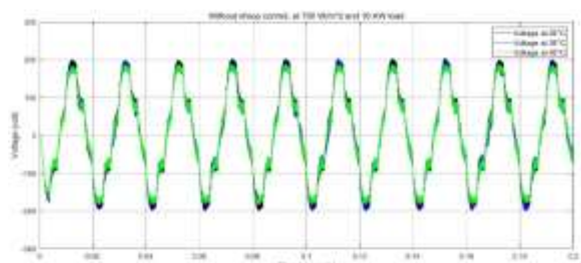

Fig. 11 Voltage without droop control, at 700 W/m^2 and 10 KW load

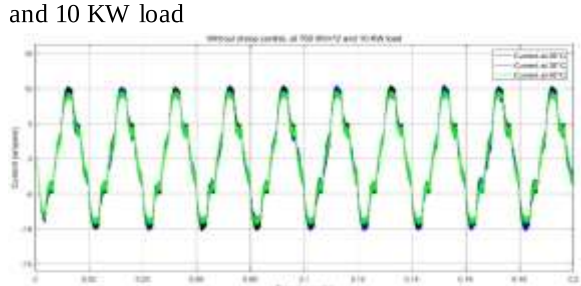

Fig. 12 Current without droop control, at 700 W/m^2 and 10 KW load

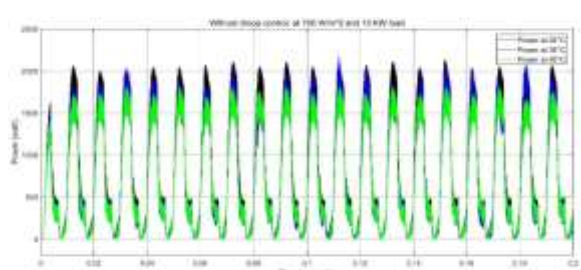

Fig. 13 Power without droop control, at 700 W/m^2 and 10 KW load

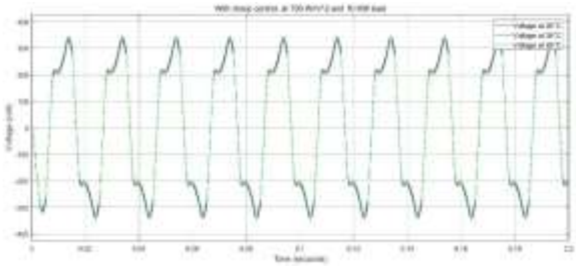

Fig. 14 Voltage with droop control, at 700 W/m^2 and 10 KW load

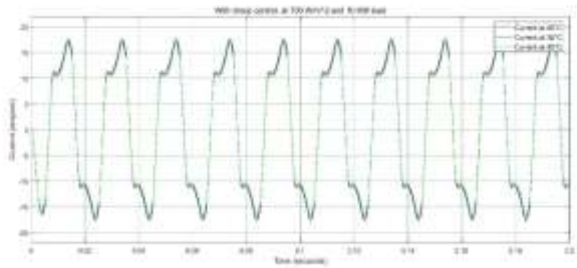

Fig. 15 Current with droop control, at 700 W/m^2 and 10 KW load

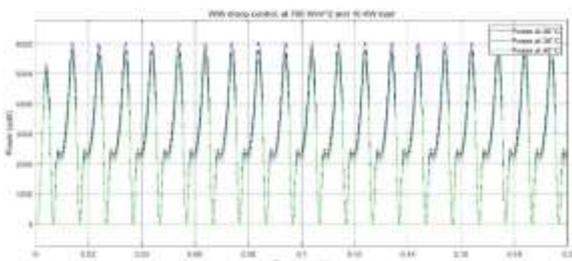

Fig. 16 Power with droop control, at 700 W/m^2 and 10 KW load

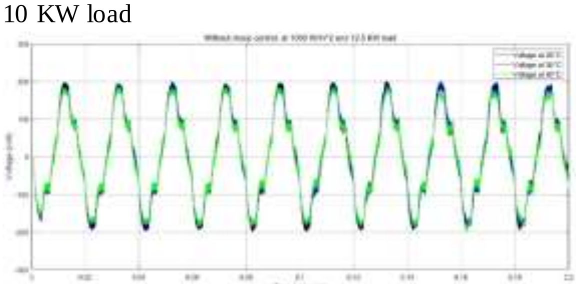

Fig. 17 Voltage without droop control, at 1000 W/m^2 and 12.5 KW load

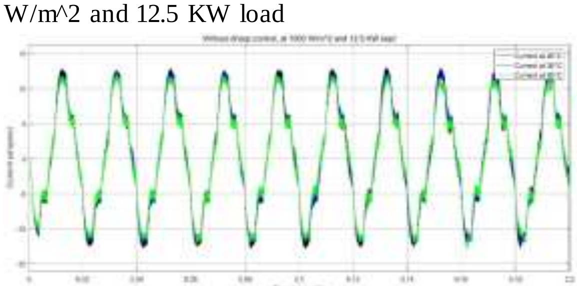

Fig. 18 Current without droop control, at 1000 W/m^2 and 12.5 KW load

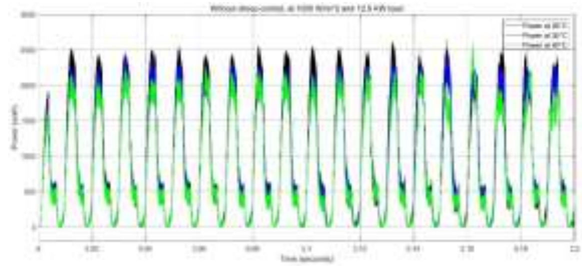

Fig. 19 Power without droop control, at 1000 W/m^2 and 12.5 KW load

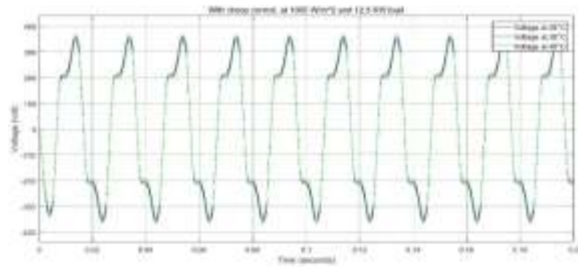

Fig. 20 Voltage with droop control, at 1000 W/m^2 and 12.5 KW load

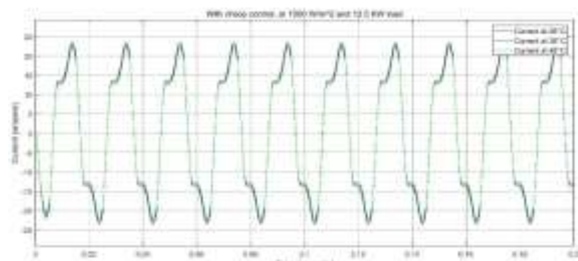

Fig. 21 Current with droop control, at 1000 W/m^2 and 12.5 KW load

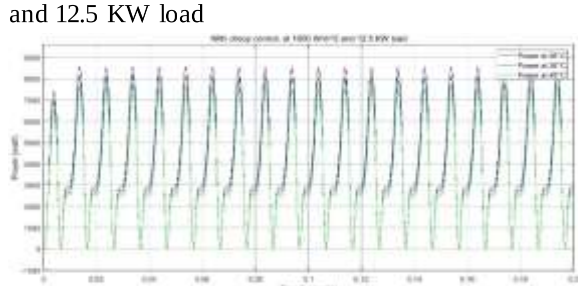

Fig. 22 Power with droop control, at 1000 W/m^2 and 12.5 KW load

V. CONCLUSION AND FUTURE WORK

A. Conclusion

The performance of the presented system is examined through MATLAB/Simulink for various parameter conditions of atmosphere and load. A comparative study is also performed in order to evaluate the performance analysis of PV solar based VSI with droop control technique. The theoretical explanation and the simulation results attained from MATLAB/Simulink lead us to the following conclusions.

1. The presented PV solar distributed generation system can successfully connect with VSI using droop controller in islanded microgrid.
2. Using droop control, the performance of VSI is improved in islanded microgrid.
3. Droop controller gets output power near to maximum power point and also reduce the fluctuation at output.
4. Droop controller uses feedback signals from VSI output, therefore it does not require feedback from communication center.
5. In simulation the results are obtained from various atmosphere and load condition, which can occur throughout year, therefore we can say that the droop control technique can give same performance according to variation of the parameter.

B. Future work

The presented PV solar based distributed generation can test in parallel condition. MPPT can also implement with droop control technique, therefore system can get better performance. This system can also test with RL load and RLC load. System for multi-level VSI with Droop control technique can also analyze.

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