DESIGN OF ISLANDED DC MICROGRIDS FOR SYSTEM STABILITY ANALYSIS BY USING DROOP CONTROL TECHNIQUE

Bongoni Ajay Kumar[1], MA. Nadeem[2]

[1] *Student, Electrical and Electronics Engineering, Nigama Engineering College, Telangana, India*
[2] *Asst.Prof, Electrical and Electronics Engineering, Nigama Engineering College, Telangana, India*

ABSTRACT

This paper presents an islanded operation mode, droop control as basic method for bus voltage stabilization when there is no communication among the sources. In this work it is shown the consequences of droop implementation on the voltage stability of dc power systems with the DC-DC Boost converter for different loads, whose loads are active and nonlinear, e.g. constant power loads (CPLs). The set of parallel sources and their corresponding transmission lines are modeled by an ideal voltage source in series with an equivalent resistance and inductance. This approximate model allows performing a nonlinear stability analysis to predict the system qualitative behavior due to the reduced number of differential equations. Additionally, nonlinear analysis provides analytical stability conditions as a function of the model parameters and it leads to a design guideline to build reliable MGs based on safe operating regions. This paper compares the conventional two parallel DC-DC boost converters can be compared with the Proposed Three parallel DC-DC boost converters with the linear and non linear loads. MATLAB/SIMULINK software has used for simulation analysis of the proposed system.

Keyword: - *DC-DC Converter, soft switching, Microgrid, Droop control*

---

1. INTRODUCTION

Now a days, DC networks are embedded in several autonomous systems from ships to notebooks, and have been gaining ground energy distribution in the form of small dc microgrids (MGs). This resumption of dc power distribution is due to the ease of integration of renewable energy and the growing share of electronic loads in the system, which makes dc distribution an option to build more efficient systems. The main concern during the design of a dc MG is its stability, whose basic unit for stabilization and achieving the integration between loads and sources is the power converter, as illustrated. The power converters decouple loads and sources from disturbances and adjust the voltage levels required by each device in the network. In islanded dc MGs without communication, the system operates in a distributed control scheme where each unit has a controller whose decision is based on the available local variables. In such context, the stability is commonly obtained by sources in parallel controlling the bus voltage cooperatively. A common practice to accomplish this without overloading some sources is to include a virtual resistance on the output of the sources power converter, a technique known as droop control.

Droop control increases the output resistance of each source, which makes them farther away from an ideal source, and consequently there is greater interaction between sources and loads. Such interaction causes the stability of the bus voltage to be more dependent on the type of load coupled to the system. Additionally, dc MGs have nonlinear active loads with a constant power characteristic at their input terminals, which arise from tightly regulated point-of-load (POL) converters, commonly referred as constant power loads (CPLs). Most of the dc stability analysis are linear and based on the Middlebrook and Cuk criterion, due to the ease to obtain the system open loop gain knowing only the output impedance of the source Zs subsystem and the input impedance of the load subsystem ZL, as illustrated. Since dc MGs has a high insertion of nonlinear loads (CPLs), such loads must be linear zed in a voltage operating point to be able to use these methods. This linearization results in a model composed by a negative resistance in parallel with a current source that is suitable to local stability analysis, near to the voltage operating point. In such context, many researchers have successfully addressed the instability problem of constant power loads using linear stability analysis. However, a droop-controlled dc MG is allowed to work on voltage levels away from the linearization point making the linear negative resistance model unsuitable to stability analysis for the entire range of possible voltages. To overcome this problem, nonlinear stability analysis is used to predict the system's global qualitative behavior. Such approach models the POL converters with a constant power characteristic to any operation voltage using the ideal CPL model, which assumes that the input power of a POL converter is constant and equal to the power demanded by the load. A literature survey forms the basis on which a project can be built or developed. It forms the core to which ideas can be added and developed in to a comprehensive system, which will be able to cover the deficiencies of some of the existing system.

2. PROPOSED TECHNIQUE

2.1. INTODUCTION TO PROPOSED CONVERTER SYSTEM CONFIGURATION

The Below figure shows the conventional and Proposed system DC microgrid circuit diagram which contains DC-DC converter which is used to boost the input voltage to the output for different non linear and linear loads. DC-DC buck converter used to decrease the DC bus voltage to the respective loads as per the requirement. The proposed DC-DC converter can be controlled by using the Droop controller to increase the stability of a DC Microgrid system with the different renewable energy resources.

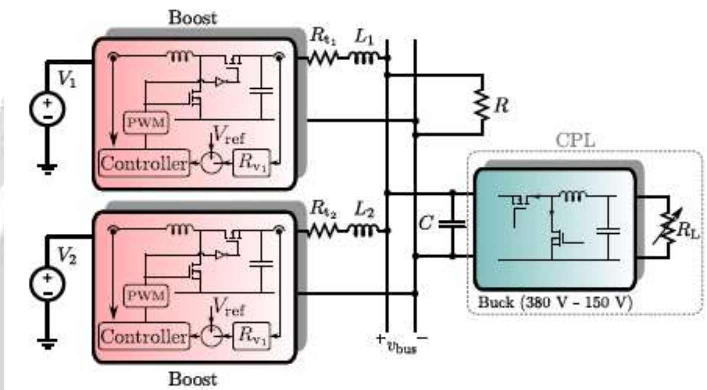

Fig.1: Conventional DC microgrid system

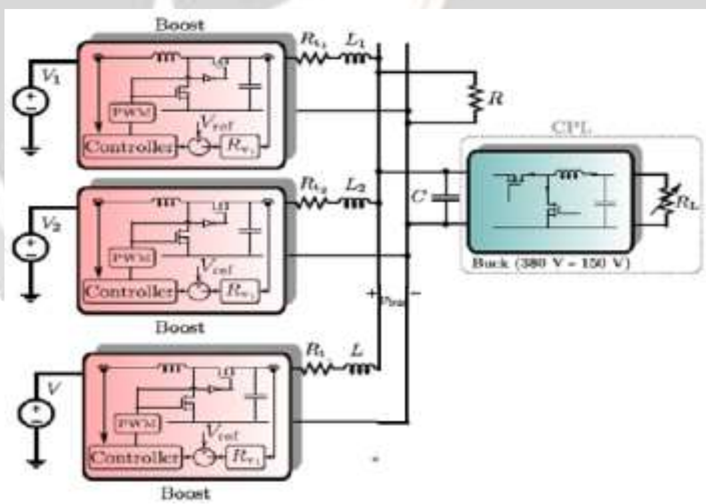

Fig 2: Proposed DC microgrid system

2.1.1. Operation of Boost converter

A boost converter (step-up converter) is a DC-DC power converter with an output voltage greater than its input voltage. It is a class of Switched mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in circuit diagram. When the switch is closed, electrons flow through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field.

Polarity of the left side of the inductor is positive and diode is open. When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

2.1.2. Operation of Buck converter

A Buck converter (step-down converter) is a DC-DC power converter with an output voltage lesser than its input voltage. It is a class of Switched mode power supply (SMPS) containing at least two semiconductors (2 transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. When the switch S1 is closed and S2 opened, electrons flow through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive. When the switch S1 is opened and S2 closed, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now).

3. ANALYSIS OF PROPOSED SYSTEM DROOP CONTROLLER

The sources in a distributed control scheme operate cooperatively to regulate the bus voltage, but a load sharing problem arises, where each source must provide power to the load proportional to its power capacity. In such a context, load sharing is critical to avoid that some sources become overloaded, loosing the reliability of distributed power systems (DPSs).

To understand the difference between power supplied from parallel sources, a simplified circuit with two sources providing power to a given load is analyzed. The static analysis of such simplified circuit is done by modeling power sources as a voltage source Vi in series with an output droop resistance Rdi, as illustrated in Fig.1. The difference in current supplied by each source in Fig.1 is

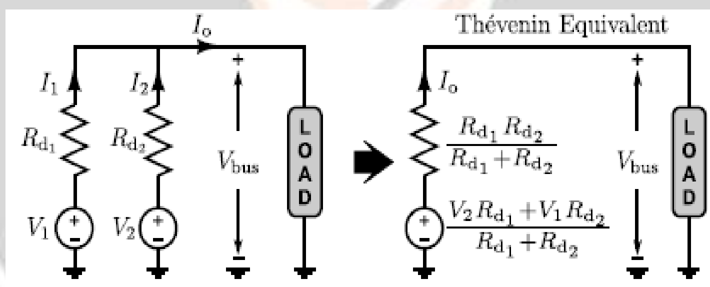

Fig. 3. Two sources in parallel feeding a common load and its Thevenin's equivalent circuit.

$$I_1 - I_2 = \frac{2(V_1 - V_2)}{R_{d_1} + R_{d_2}} + \frac{(R_{d_2} - R_{d_1})}{R_{d_1} + R_{d_2}} I_o. \quad (1)$$

It can be noted from (1) that the difference in the current provided by each source is inversely proportional to (Rd1 + Rd2). Therefore, as the output resistances Rdi grow, the denominator of (1) increases and consequently load sharing is improved.

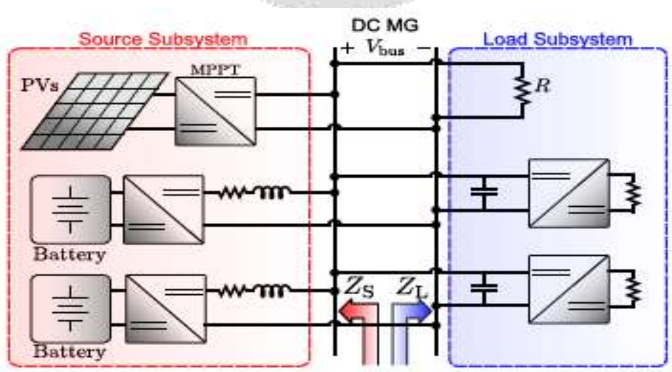

Fig. 4: Islanded dc microgrid with source and load subsystems highlighted

Thus, the main idea of droop control is to increase the output resistance to reduce the difference between the currents. The current sharing of two power sources as the output resistances are increased gradually by a factor of a. The power sources feed a 10A load with the same reference voltage (V1 = V2) and output resistances of Rd1 = (1 + a) and Rd2 = (9 + a). That the currents of each source get closer as the output resistances are increased. On the other hand, increasing the output resistances degrades the bus voltage regulation (Vbus) because the Thevenin resistance Rd is increased, as it becomes explicit by the equation obtained from the Thevenin equivalent circuit in Fig.4.1.

$$V_{bus} = \underbrace{\frac{V_1 R_{d_2} + V_2 R_{d_1}}{R_{d_1} + R_{d_2}}}_{V_{ref}} - \underbrace{\frac{R_{d_1} R_{d_2}}{R_{d_1} + R_{d_2}}}_{R_d} I_o. \quad (2)$$

Therefore, there is a trade-off between voltage regulation and load sharing. The bus voltage degradation as a function of a when two sources are feeding a constant current load (CCL). This analysis can be extended to several sources in parallel operating in droop control and connected to the bus by a transmission line, as described in the next topic.

4. DROOP CONTROL WITH MULTIPLE SOURCES

Based on analysis of the steps to get a stable DC MGs are summarized from the below figure:
1) Obtain the power capacities of each droop controlled source (Pci).
2) Set the desired tolerance range _ and the reference voltage Vref .
3) Set the maximum constant power and the resistive load allowed in the MG, PML and RML, respectively. As the resistance is reduced more power is required, so PML is the maximum value of P and RML is the minimum value of R.

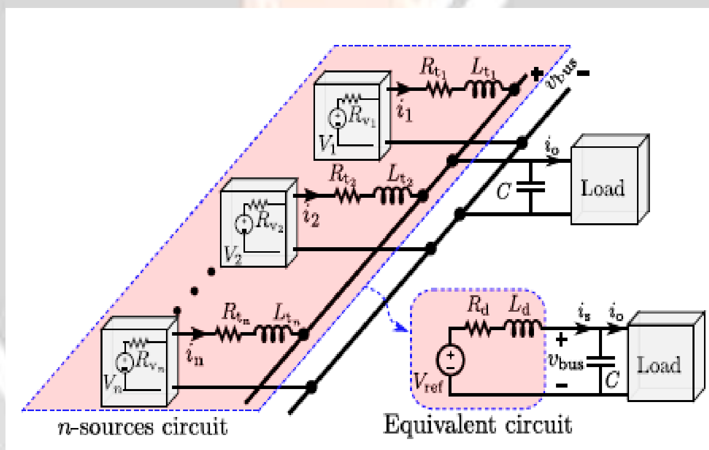

Fig 5: A dc MG composed by n sources in droop scheme (n-sources model) and the proposed equivalent circuit (equivalent model)

The sources in a distributed control scheme operate cooperatively to regulate the bus voltage, but a load sharing problem arises, where each source must provide power to the load proportional to its power capacity. In such a context, load sharing is critical to avoid that some sources become overloaded, loosing the reliability of distributed power systems (DPSs). To understand the difference between power supplied from parallel sources, a simplified circuit with two sources providing power to a given load is analyzed.

The difference in current supplied by each source in Fig is

$$I_1 - I_2 = \frac{2(V_1 - V_2)}{R_{d_1} + R_{d_2}} + \frac{(R_{d_2} - R_{d_1})}{R_{d_1} + R_{d_2}} I_o \quad (3)$$

The MG structure explored in this paper consists of multiple sources in parallel connected to a common load through transmission lines, Each source under droop control is modeled as an ideal voltage source Vi in series with a virtual droop resistance Rvi and each transmission line as a resistance Rti in series with an inductance Lti . The model obtained from the circuit with n sources in Fig. 4.4 is referred here in after as n-sources model.

$$\frac{di_s}{dt} \approx \left(\sum_{i=1}^{n} \frac{1}{L_{t_i}}\right)(V_{ref} - v_{bus}) - \frac{R_{d_i}}{L_{t_i}} i_s. \quad (4)$$

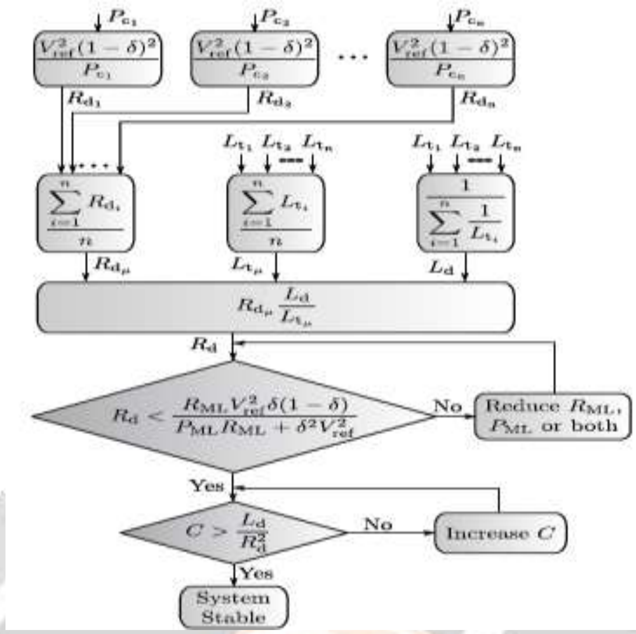

Fig 6: Flowchart to design a stable DC Microgrid.

5. SIMULATION RESULTS

In this section, simulation results are shown to validate the stability analysis under load variations. Two sources in parallel interfaced by dc-dc boost converters are connected through transmission lines to a bus with resistive and CPL loads. The below figures from Fig.7 to Fig.19 shows the conventional and proposed system configuration simulation results by using MATLAB/Simulink software for analysis.

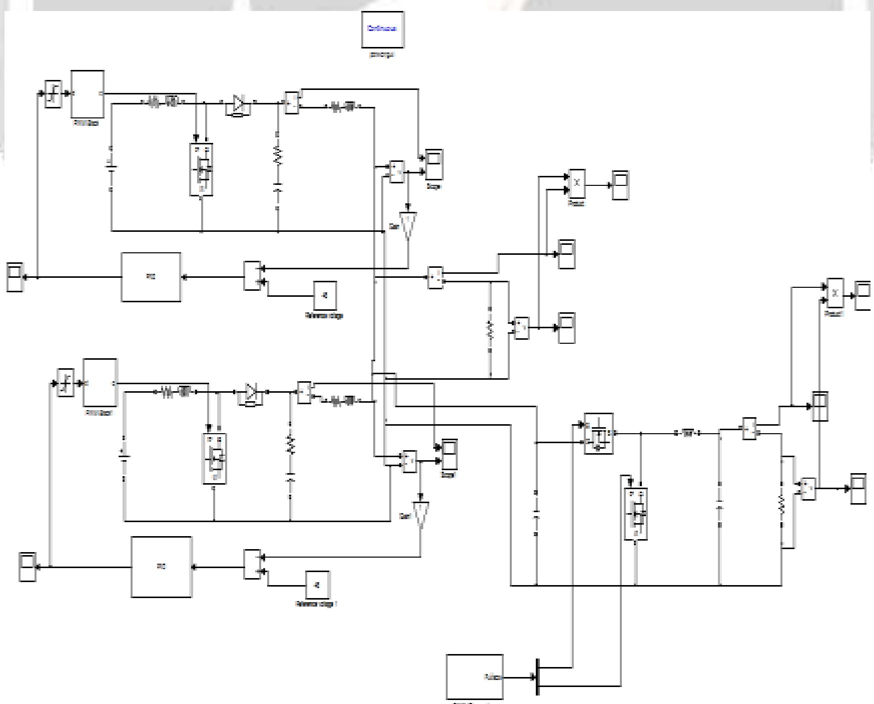

Fig 7: Conventional system simulation circuit diagram

Below waveforms as shown are the DC-bus linear load voltage, linear load current, linear load power, Buck converter voltage, current, power.

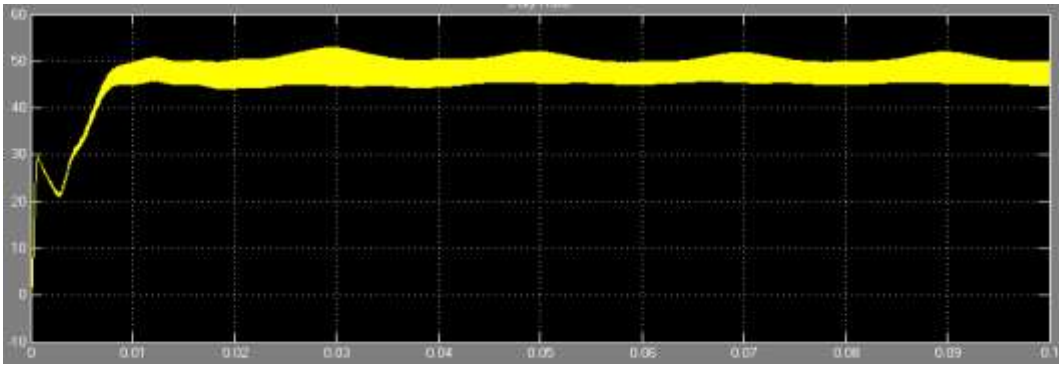

Fig 8: DC bus Linear load voltage

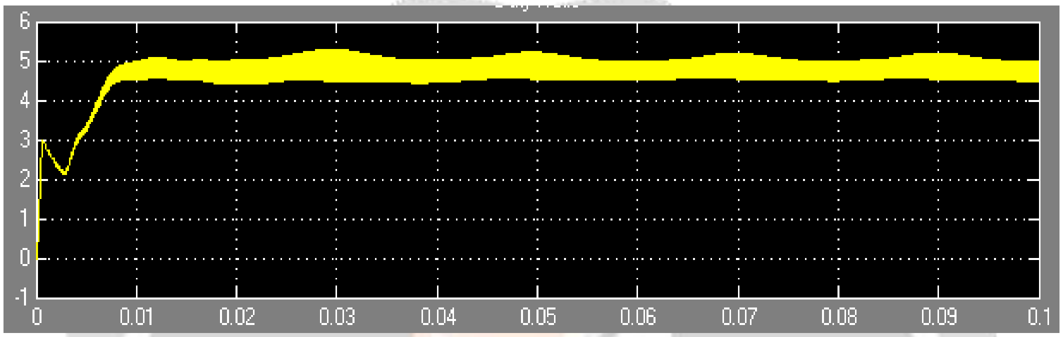

Fig 9: DC bus linear Load current

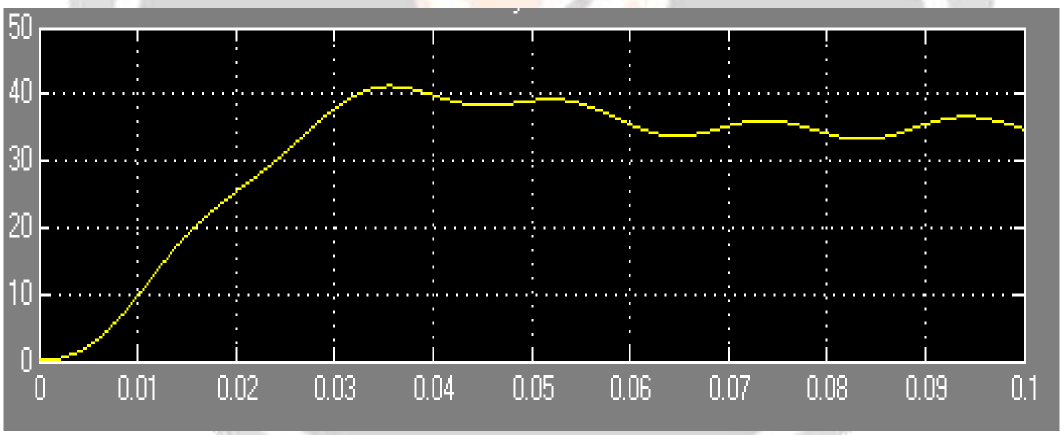

Fig 10: Buck converter Output Voltage

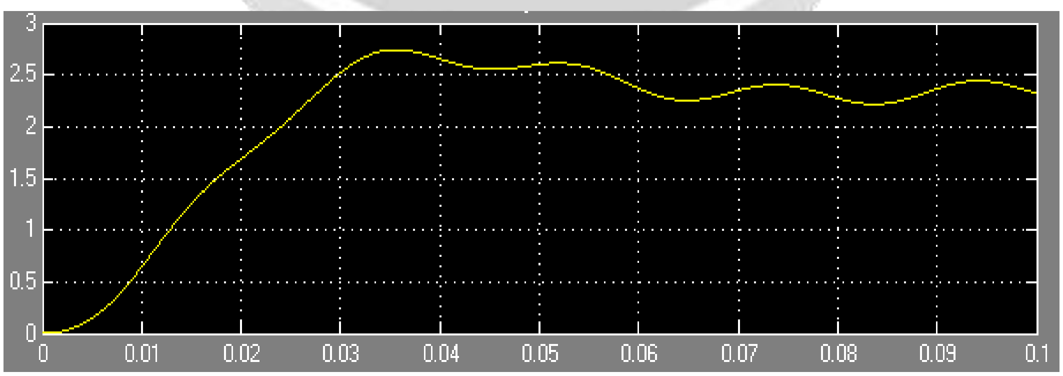

Fig 11: Buck converter Output current

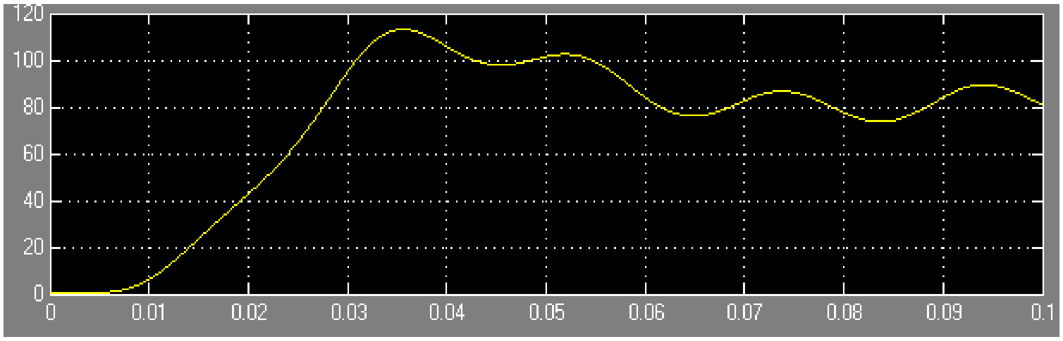

Fig 12: Buck converter Output Power

The below figures shows the simulation circuit diagram of the proposed converter with the three DC-DC converter parallel DC- bus system. And the Proposed converter waveforms as shown in the below ie., DC-bus linear load voltage, linear load current, linear load power, Buck converter voltage, current, power.

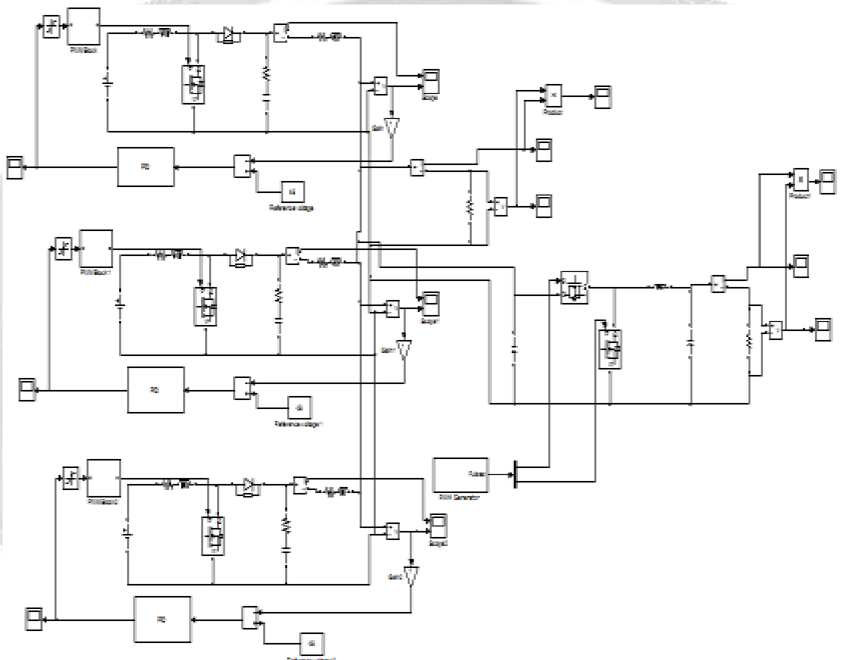

Fig 13: Proposed system Simulation circuit diagram

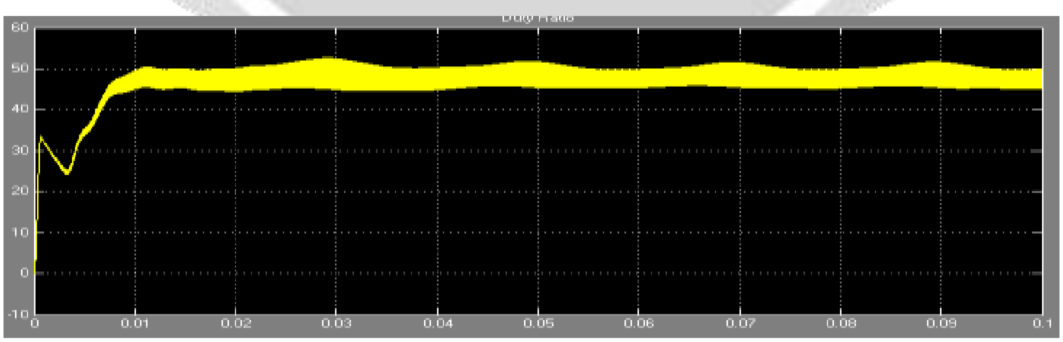

Fig 14: DC bus Linear load output voltage

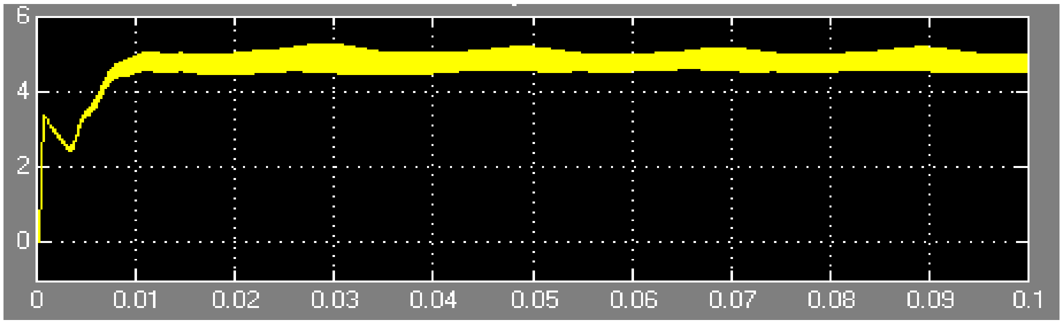

Fig 15: DC bus Linear Load Output Current

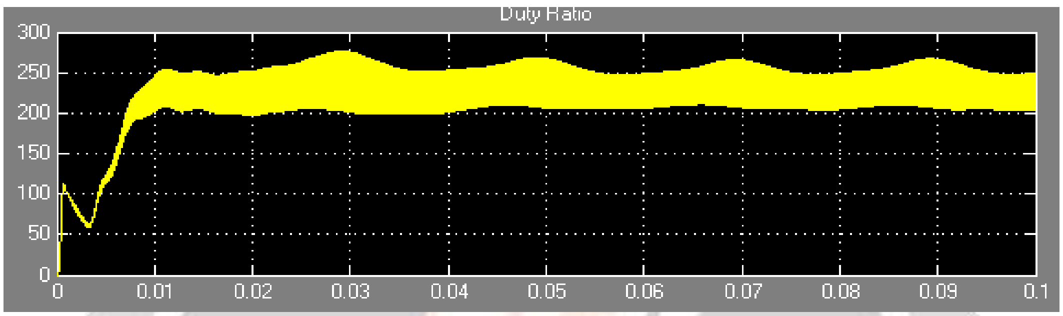

Fig 16: DC bus Linear load Output Power

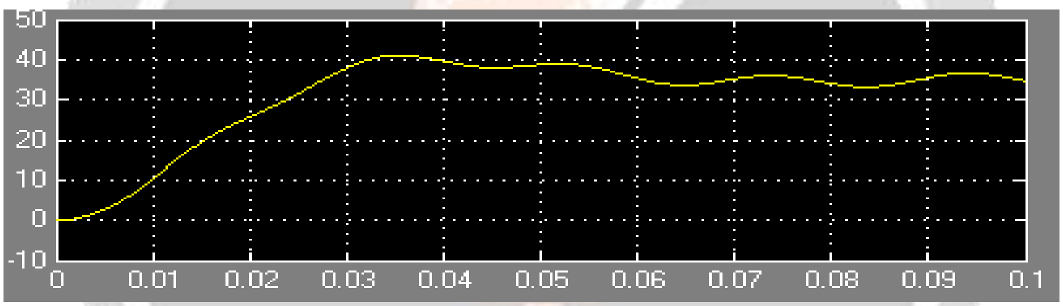

Fig 17: Buck converter Output Voltage

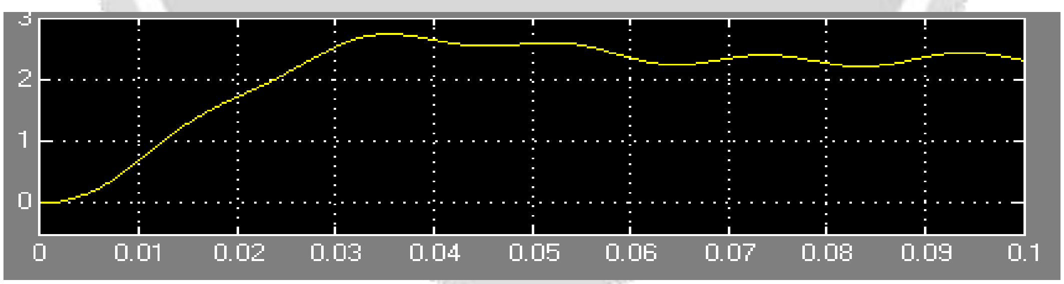

Fig 18: Buck converter Output current

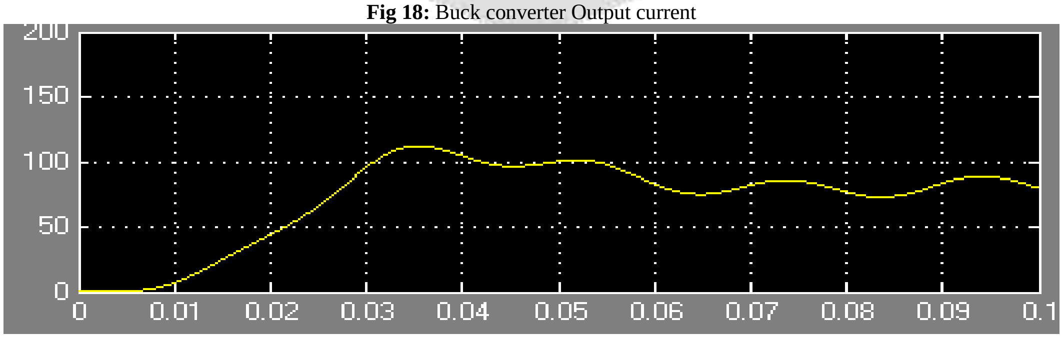

Fig 19: Buck converter Output Power

4. CONCLUSIONS

In this paper a system has proposed with the three parallel DC-DC Boost converters are compared with the conventional converter for a DC microgrid system. DC MGs are emerging as distributed generation solutions to some applications that need efficiency and reliability. Under this perspective, this paper has addressed a simplified model to reduce the complexity of the nonlinear stability analysis for small dc microgrids under droop control without communication. The proposed equivalent model keeps the qualitative behavior of the system while reducing the complexity of the stability analysis. The nonlinear analysis based on bifurcation theory give us some relations among the MG parameters, which allow us to determine the qualitative behavior of the system. In this sense, bifurcation diagrams presented along this paper offers a design guideline to build reliable MGs based on safe operation regions. The simulation analysis has done by using the MATLAB/Simulink.

5. REFERENCES

[1] D. Boroyevich, I. Cvetkovic, D. Dong, R. Burgos, F. Wang, and F. Lee, "Future electronic power distribution systems a contemplative view," in Optimization of Electrical and Electronic Equipment (OPTIM), 12th International Conference on, May 2010, pp. 1369–1380

[2] G. Spiazzi, P. Mattavelli, and A. Costabeber, "High step-up ratio flyback converter with active clamp and voltage multiplier," *IEEE Trans. Power Electron.*, vol. 26, no. 11, pp. 3205–3214, Nov. 2011.

[3] W. Li, L. Fan, Y. Zhao, X. He, D. Xu, and B.Wu, "High step-up and high efficiency fuel cell power generation system with active clamp flyback forward converter," *IEEE Trans. Ind. Electron.*, vol. 59, no. 1, pp. 599–610, Jan. 2012.

[4] Y. Zhao, X. Xiang, W. Li, X. He, and C. Xia, "Advanced symmetrical voltage quadruple rectifiers for high step-up and high output-voltage converters," *IEEE Trans. Power Electron.*, vol. 28, no. 4, pp. 1622–1631, 2013.

[5] W. Li and X. He, "Review of non-isolated high step-up DC/DC converters in photovoltaic grid-connected applications," *IEEE Trans. Ind. Electron.*, vol. 58, no. 4, pp. 1239–1250, 2011.

[6] H.Wu and X. He, "Single phase three-level power factor correction circuit with passive lossless snubber," *IEEE Trans. Power Electron.*, vol. 17, no. 6, pp. 946–953, Nov. 2002.

[7] L. huber and M. M. Jovanovic, "A design approach for server power supplies for networking," in *Proc. IEEE INTELEC'00*, 2000, pp. 1163–1169.

[8] M. Prudente, L. L. Pfitscher, G. Emmendoerfer, E. F. Romaneli, and R. Gules, "Voltage multiplier cells applied to non-isolated DC–DC converters," *IEEE Trans. Power Electron.*, vol. 23, no. 2, pp. 871–887, Mar. 2008.

[9] F. Zhang, L. Du, F. Z. Peng, and Z. Qian, "A new design method for high-power high-efficiency switched-capacitorDC–DC converters," *IEEE Trans. Power Electron.*, vol. 23, no. 2, pp. 832–840, Mar. 2008.

[10] B. Axelrod, Y. Berkovich, and A. Ioinovici, "Switchedcapacitor/ switched-inductor structures for getting transformerless hybrid DC–DC PWM converters," *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 55, no. 2, pp. 687–696, Mar. 2008.

[11] E. H. Ismail, M. A. Al-Saffar, A. J. Sabzali, and A. A. Fardoun, "A family of single-switch PWM converters with high step-up conversion ratio,"*IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 55, no. 4, pp. 1159–1171, May 2008.

[12] K. B. Park, G. W.Moon, andM. J. Youn, "Nonisolated high step-up boost converter integrated with sepic converter," *IEEE Trans. Power Electron.*, vol. 25, no. 9, pp. 2266–2275, Sep. 2010.

[13] K. C. Tseng and T. J. Liang, "Novel high-efficiency step-up converter," in *Proc. IEE-Elect. Power Appl.*, vol. 151, no. 2, Mar. 2004, pp. 182–190.

[14] Y. Zhao,W. Li, and X. He, "Single-phase improved active clamp coupled inductor- based converter with extended voltage doubler cell," *IEEE Trans. Power Electron.*, vol. 27, no. 6, pp. 2869–2878, Jun. 2012.

[15] L. S. Yang, T. J. Liang, H. C. Lee, and J. F. Chen, "Novel high step-up DC–DC converter with coupled-inductor and voltage-doubler circuits," *IEEE Trans. Ind. Electron.*, vol. 58, no. 9, pp. 4196–4206, Sep. 2011.