# Design and Simulation of Dual-Buck-Boost AC/DC Converter for Dc Nanogrid Applications

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***Abstract*:-** *Now-a-days dc characterized loads are employed in domestic, commercial, and industrial applications. This new topology suggests a Dual-Boost-Buck ac/dc Converter and it is used to reduce the multiple conversion stages like ac/dc/ac or dc/ac/dc in a separate ac or dc grids. The Dc Nano-grid is best alternative method for ac- grid and it becomes more and more popular. Grounding should be maintained for safety consideration. This paper mainly disused about PV panel modelling and 3ϕ- BLDC motor. Both PV and BLDC are connected to the DC nano-grid, PV as a dc source and 3ϕ- BLDC as a dc load. The simulations are performed by using MATLAB/Simulink software.*

***Key word-*** Grounding, Dc-Nano grid, AC-DC converter, Buck-Boost, Permanent Magnet BLDC and PV system

## 1. INTRODUCTION

Resent days, Energy Storage Devices, RES and DC Electronic Loads have been utilized for residential loads. Consumers have also been frequently used in LED, electrical vehicles applications in manufacturing fields and consumer areas. It's easy to interface different electrical systems with DC distribution combined energy storage devices and RES systems. Higher distribution efficiency, larger power transformation can achieve in this systems because due to reducing power converting stages. In addition to that it can easily integrate electrical vehicles, DC loads, LED lightning for distribution systems compared by ac distribution systems [1, 2]. Therefore, for consumer houses, tale-communication towers and internet data centers are recently accessible. Its good method for reducing voltage raises and maintenance[3] of the conservative ac power system and can remove the conventional ac/dc converters for dc characterize loads, it helps for decreasing power drawbacks and saving materials [4]. The energy transformation efficiency in DC house applications is most grater then the ac home applications. The ac power appliances are modifies to dc power appliances. It reduces the No. Of energy stages in DC home applications it means dc distribution system will not require the condition like AC to DC conversion and power factor correction. So power consumption is reduced due to reduction of energy stages in AC to DC rectification, PFC and product cost [5]. Since, it indicates the price of installation and performance of dc Nano-gird

## 2. GROUNDING TECHNIQUES FOR RESIDENTIAL DC NANOGRID APPLICATIONS

Consider some safety precautions in the grid, because almost all the home equipments are necessary to connect with ground line, in a DC Nano-Grid , similar to a Low-voltage Ac grid, its major consideration to provide a ground line[8], [9]. Basically there are three types of groundings are there but out of those only one type is very advantageous and i.e., united grounding configuration.

### 2.1 United Grounding Configuration

In united grounding configuration, both DC Nano-Grid and the less-power ac system use the identical ground line. Fig 1 indicates a representative ac/dc connected circuit. The major reason for making united grounding technique is that installation of dc nano grids becomes more easily into the basic Low-Voltage AC power grid and it forms a Hybrid power system. In this configuration it has some demerits i.e. for low voltage equipments, most of the basic less-voltage AC power systems cannot try to be like this configuration [3], [6]. So, to overcome this dispute AC-DC Converter for the united grounding design base dc nano-grid systems was introduced.

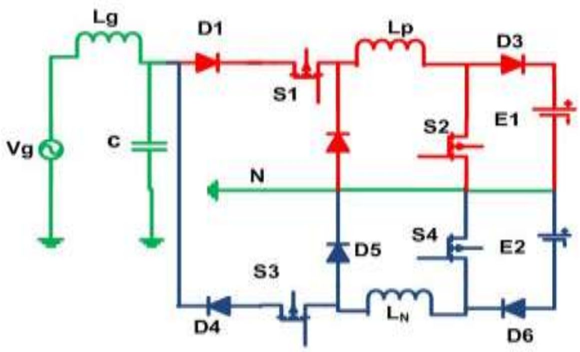


**Fig-1:** DC Nanogrid system with United- grounding Technique using ac-dc converter

According to the DC nano-grid, more effective and save the quantity of materials so more number of power conversion are not needed. Due to virtual isolated grounding the efficiency will be reduced because in between the dc systems and AC nano grids the link transformer with high frequency is used. At the same time as if using the uni-directional grounding this design is not flexible to the local load area because it will be limited to the dc nano-grids. So, comparing among three types of groundings the united -grounding design is highly efficient and low cost.

## 3. SYSTEM CONFIGURATION AND MODELLING

Generally dc Nano grids are connected in AC power systems with Bi-directional ac-dc converters, Due to additional Dc power the energy fed back into AC power lines. In a few places, distribution energy will not reach the local loads requirements because of high population density, so by connecting dc nano-grids across the AC power lines demand of energy will reduced and maintained power factor correction

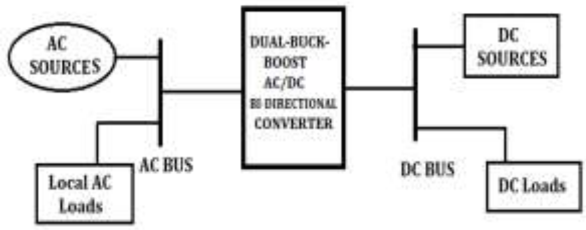


**Fig-2**: Block Diagram of the AC-DC Nano-grid System with Load

Fig 2 illustrates a circuit diagram of the ac-dc Nano-grid system configuration where a range of ac, dc sources and loads are associated to the equivalent dc & ac Networks. Fig 3 depicts ac-dc converter for united-grounding base dc Nano-grid applications. PV modules are associated to dc bus from beginning to end a dc/dc Boost converter. In this converter capacitor is presented it will helps to restrain the large ripple frequencies of output voltage across PV panel and also dc load is tied to the dc bus.

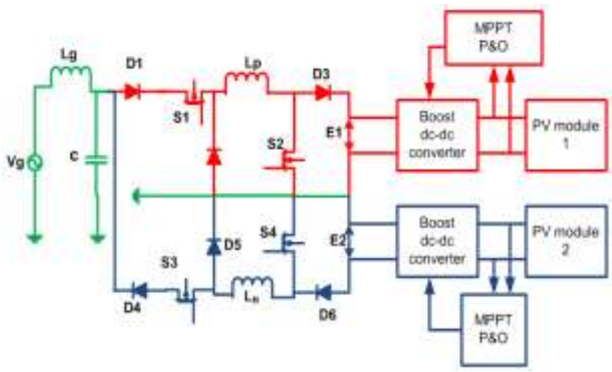


**Fig-3**: AC-DC Converter for United- Grounding technique base DC Nano-grid Applications

### A. Fundamental Topology

Figure 3 depicts the AC-DC converter is connecting in the middle of 3-level voltage dc Nano-grid and the Low voltage Ac power lines. This converter has a perpendicular symmetrical design. During the +ve interval of the ac voltage, the circuit devices in red are conduction at the same time the blue indicated circuit devices are OFF. During the –ve interval of the AC voltage, the devices in blue are conducting at the same time the red indicated circuit devices are OFF. Once this AC-DC converter is implemented, it's likely useful to connect the dc Nano-grids into the majority types of current Low-voltage AC power systems, for instance, the 1-Ø 110-V AC power grid, 220-V AC power grid, 3-Ø Four-line 380-V AC power grid by three of the similar converters. Voltage can varied at wide range in DC Nano-grids

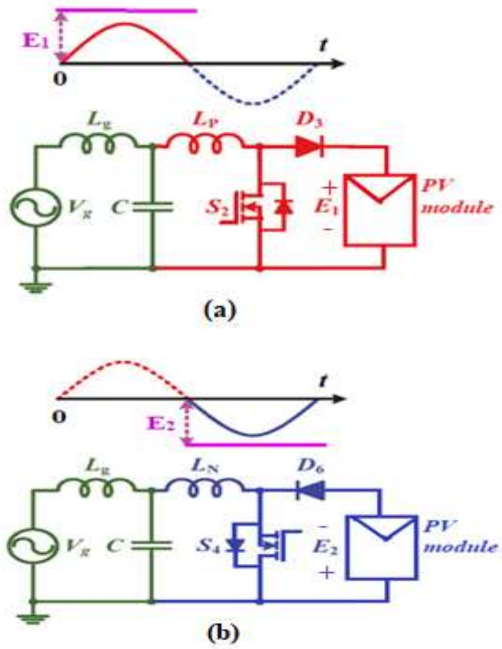


**Fig-4**: Equivalent diagram When$E_1$, $E_2$ is greater than the peak of the grid voltage and working in Boost Mode (a) for the period of +ve half cycle (b) for the period of –ve half cycle

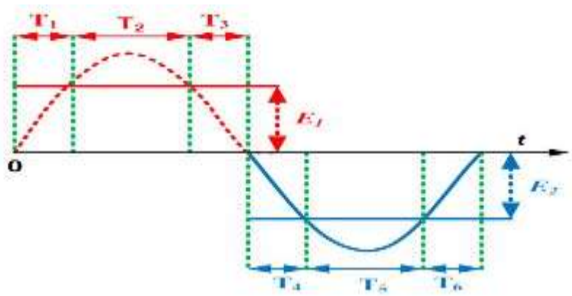


**Fig-5**: Working Succession When $E_1$ , $E_2$ are lesser than the peak of the Grid Voltage

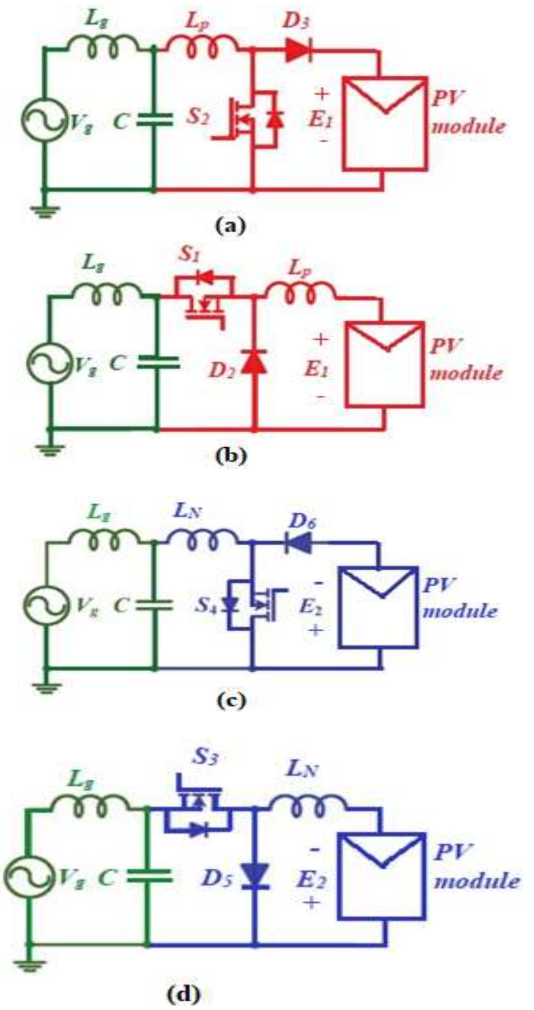


**Fig-6**: Corresponding block Diagrams for Buck–Boost Mode as depicted in Fig 5 (a) time duration at $T_1$ & $T_3$ (b) Time duration at $T_2$ (c) time duration at $T_4$ and $T_6$ (d) time duration at $T_5$

### B. Operating Modes

There are two modes of operation

**1)** $/E_1/$ or $/E_2/ \geq V_{gA}$

**2)** $/E_1/$ and $E_2/<V_{gA}$

**MODE-I:** $/E_1/$ or $/E_2/ \geq V_{gA}$ **:** When the input dc voltage ($E_1$,$E_2$) is greater than the amplitude value of voltage across grid, $V_{gA}$ the corresponding circuits are as depicted in Fig 4. $V_{DC}$ is injected into the $V_{AC}$. Here boost operation is required or boost the voltage in AC side. The inverter behaves like an original Boost PFC design.

**MODE-II:** $/E_1/$ and $E_2/ <V_{gA}$ **:** The controlling of this mode is little bit difficult only when $V_{gA}$ is more than the input $V_{DC}$ ($E_1$, $E_2$). Fig 5 shows the functioning order of the new ac-dc converter, when input $V_{DC}$ amplitude lesser then the AC grid voltage, and the working order can be bifurcated in 6 parts at a period of full line frequency

### C. Modeling of PV Panel

Generation of electricity from the conversion of Solar energy using semiconductors is called a solar cell. It's a unit to convey certain amount of electrical energy. The solar panel is a single part of a whole PV solar system. Fig. 7 shows the corresponding design of a PV panel through a load. Modeling of the output current across the PV panels by the following [10], [11]. All the designed values are shown in Table I:

Photo current ($I_{ph}$):

$$I_{ph} = \left[I_{sc} + K_i\left(T_{op} - T_{ref}\right)\right]\frac{G}{1000} \quad (1)$$

Reverse Saturation current ($I_{rs}$):

$$I_{rs} = \frac{I_{sc}}{\exp\left[\frac{q.V_{oc}}{n.C.K.T}\right] - 1} \quad (2)$$

Saturation current ($I_s$):

$$I_s = I_{rs}\cdot\left[\frac{T}{T_n}\right]^3 \exp\left[\frac{q.E_g\left(\frac{1}{T_{ref}} - \frac{1}{T_{op}}\right)}{n.K}\right] \quad (3)$$

Load current/PV current (I):

$$I = I_{ph} - I_s\left[\exp\left(\frac{q(V + IR_s)}{n.K.C.T}\right) - 1\right] - I_{sh} \quad (4)$$

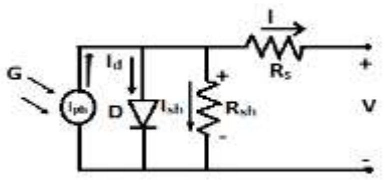


**Fig 7**: Equivalent Circuit of a Solar Cell

**TABLE-1** Parameters for PV Panel

| Parameter | Value |
|---|---|
| $V_{oc}$ | 45.30V |
| $R_s$ | 0.18 Ω |
| $R_p$ | 360.002 Ω |
| $I_{sc}$ | 8.81 A |

### D. BLDC Theory of Operation

The 3-Ø bridge inverter circuit is very useful to transfer dc to 3-Ø ac. In this 3-Ø bridge inverter consists of six MOSFET switches are used. Among them, two out of six switches are energized at once. Here the condition is "no two switches are conducted in the same arm". At this condition, just 2 switches are in conduction i.e., one from lower leg and one from upper leg. For that reason, only two phases are in operation. The direction of current flow to the motor by upper leg conducted switch and returns from lower leg conducted switch. The high conducting voltage range at output stage delivers the Drive voltages essential by gate controlled devices. So, the conduction of both upper and lower on arms of MOSFET the trapezoidal output is obtained across the 3-Ø inverter. Each turn off sequence will energized by positive power of the windings both second and third winding are in negative and non-energized condition. Magnetic field produced by the stator coils, permanent magnets and torque developed due to the interaction between these coils. Whenever the fields are at $90^0$ it leads move together and peak torque condition is possible in ideal condition. Windings shift their positions because of the magnetic field generated at motor running condition.

**TABLE-2** Specifications of 3- Ø BLDC motor

| Parameters | Values |
|---|---|
| $R_{s(phase)}$ | 11.648Ω |
| $L_{s(phase)}$ | 28.71Mh |
| Voltage constant ($P_{eak}$, L-L) | 180V |
| Motor feedback | Hall effect sensors |
| Speed | ~ 1800 rpm |
| Mode of operation | Velocity mode(closed loop control) |
| Operating temp./Humidity | 0 - 55°C/ 95 |

## 4. SIMULATIONS AND DISCUSSIONS

Simulations of a Dual Buck- boost AC-DC converters with Dc Nano-grid applications and motor load are performed by using MATLAB software. This AC-DC converter is carry out in the Ac Grid condition of 110V/50Hz. The required parameters are shown in Table III

**Table-3** Designed Parameters

| Description | Values |
|---|---|
| $L_g$ | 200µH |
| C | 2µF |
| $f_s$ | 60KHz |
| $V_{g-A}$ | 155.5V |
| $F$ | 50Hz |
| $R_s$ | 11.648Ω |
| $L_s$ | 28.71Mh |
| $L_P$ & $L_N$ | 400µH |
| $V_{mpp}$ | 37.5V |
| $I_{mpp}$ | 8.8A |

Where both the ratings of the $E_1$ & $E_2$ are taken as 90V it is variable voltage and the rating of the ac grid voltage is 110V and its amplitude is 155.5V ($110*\sqrt{2}$)V it is considered as fixed voltage

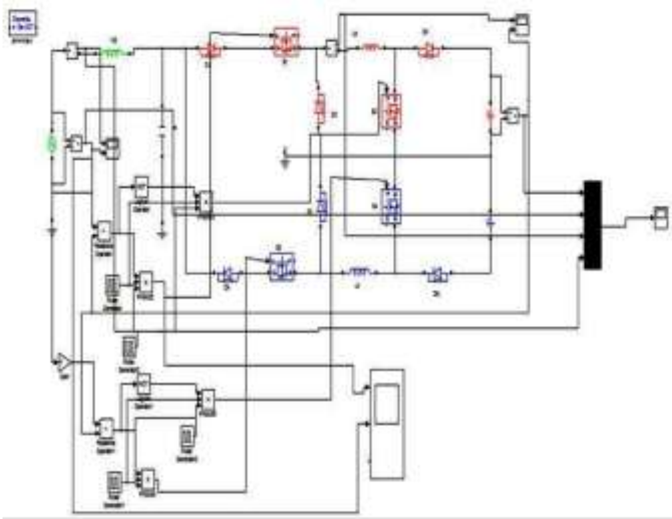

**Fig 8**: MATLAB/Simulink diagram of dual-buck-boost AC/DC converter

For example consider both $E_1$, $E_2$ are 90V and amplitude of the ac grid voltage is $(110\times\sqrt{2})$V. This is one case for this topology the below figure represents ($E_1$, $E_2$) < $V_{g-A}$

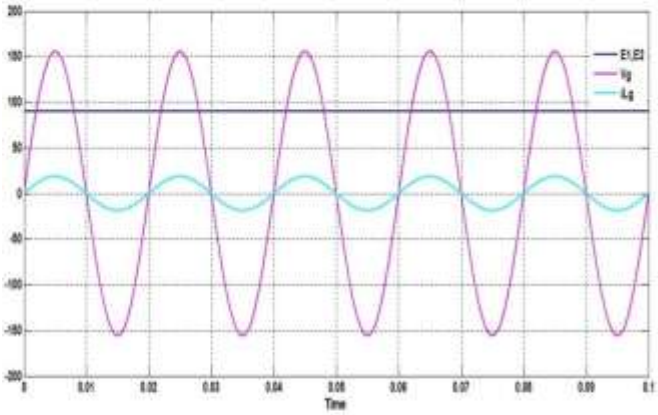


**Fig 9**: Simulation waveforms when $E_1$ and $E_2$ are lower than the amplitude of the grid voltage

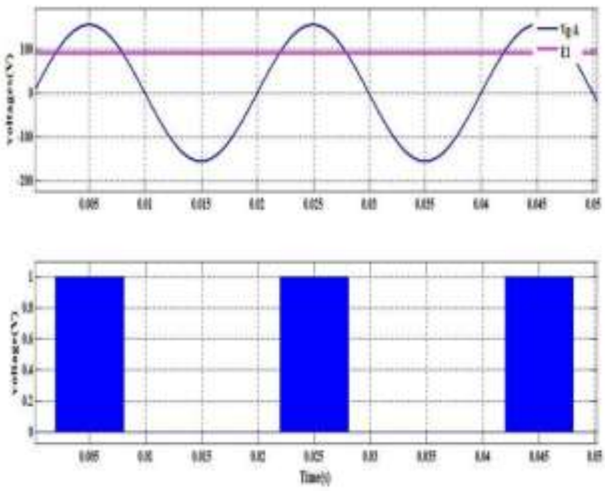

**Fig 10**: Gating Pulses of MOSFET

## A. SIMULTAION DIAGRAM OF PV FED DUAL-BUCK-BOOST AC/DC CONVERTER

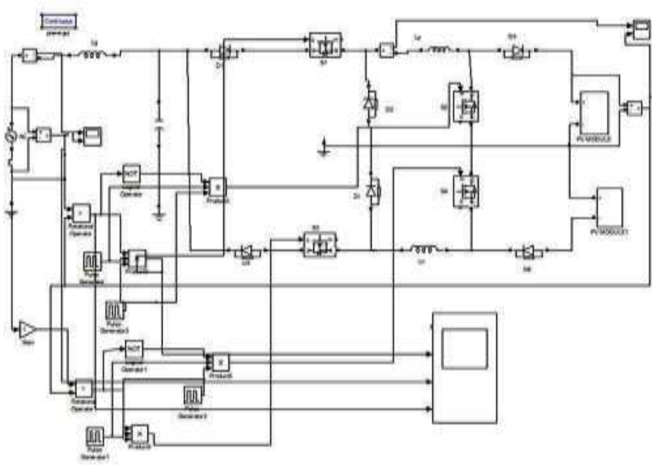

**Fig 11:** MATLAB/Simulink diagram of solar fed dual-buck-boost converter

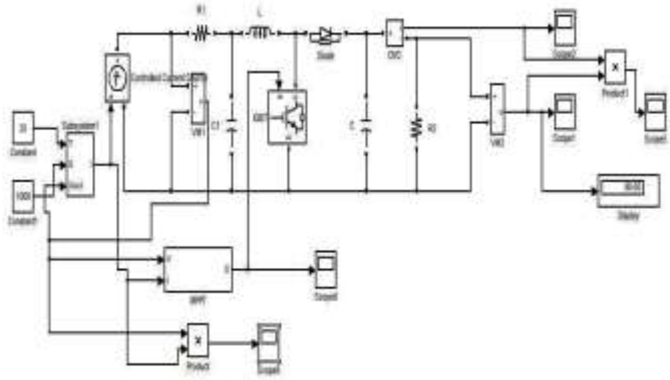

**Fig 12:** Sub-circuit of PV panel

Fig 13 depicts, each PV module generates a maximum voltage of 37.05.

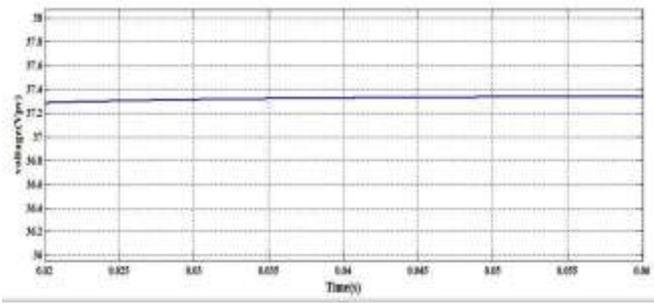

**Fig 13**: Output Voltage of PV Module

The characteristics of PV modules are obtained at irradiance and temperature of $1000 w/m^2$ & $25^oC$.

Fig 14(a) and 14(b) shows the PV & IV characteristics Of Module.

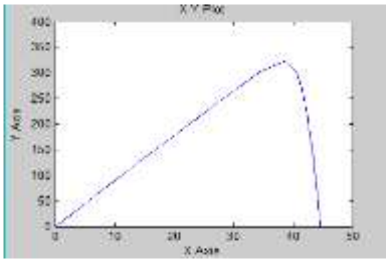


**Fig 14(a):** P-V characteristics of PV panel

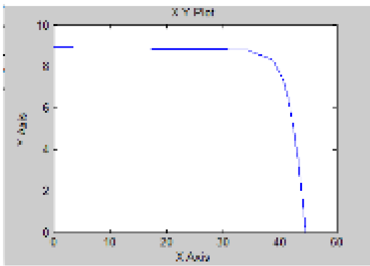


**Fig 14(b):** I-V characteristics of PV panel

The output of the PV panel is given to the input to MPPT and the output of the MPPT i.e., duty cycle of the MPPT is given to the boost converter and boosted to 90V as shown in Fig 15.

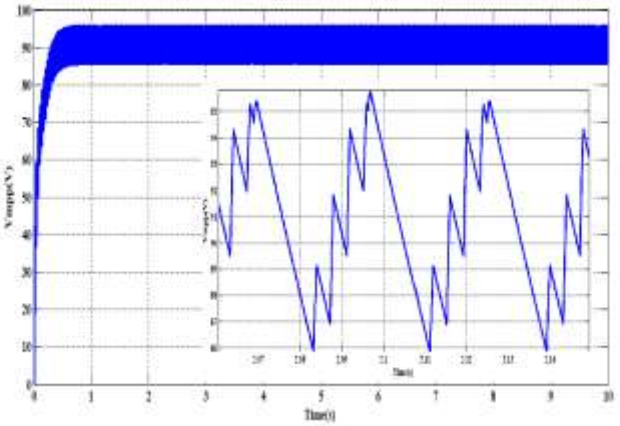


**Fig 15**: Boosted PV panel module voltage fed as input to the dual-buck-boost Converter

## B. APPLICATIONS OF DUAL-BUCK-BOOST AC/DC CONVERTER FED 3-Ø BLDC MOTOR

Fig 16 shows the BLDC motor is connected to the dc nanogrid as a dc load. The input voltage of the BLDC is 180V dc and it is converter DC-AC by using inverter and later observes the performance of 3-Ø BLDC motor is analysed in terms of stator current, speed, back EMF and electromagnetic torque.

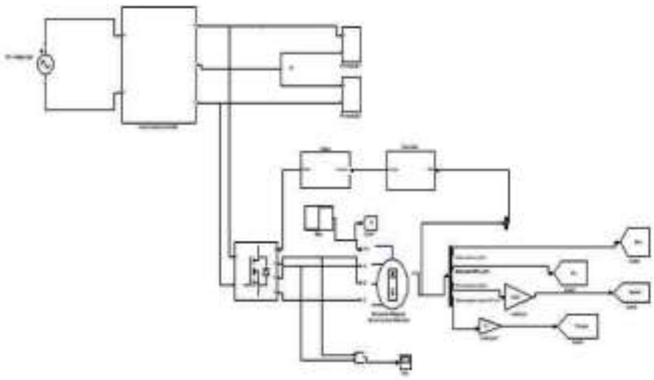

**Fig 16**: MATLAB/Simulink model of BLDC is connected to the DC nano-grid

Fig 17 shows the simulation waveforms of the back EMF of the motor. In BLDC motor the waveforms are in trapezoidal shape and it is fed back to the source when the motor is in freewheeling mode.

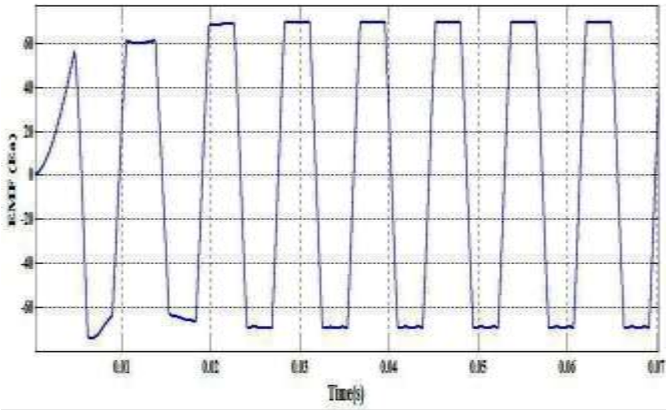


**Fig 17**: Back EMF of BLDC Motor

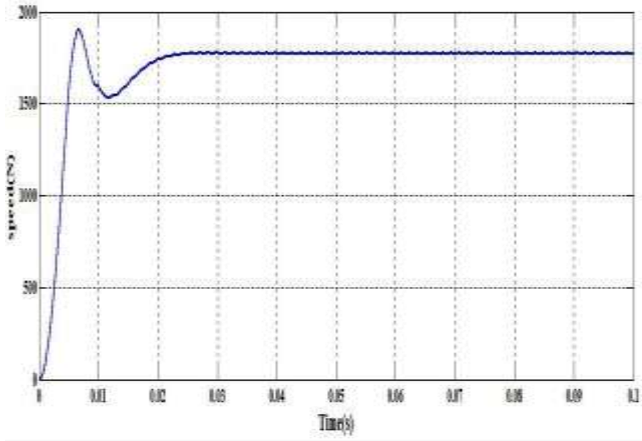


**Fig 18**: Speed Response of BLDC Motor

Fig 19(a) shows it is the reference torque and it is a step input and Fig 19(b) shows the actual torque response to the BLDC motor. Generally BLDC motor runs at high starting torque, at 0.01sec the load will be applied and it reaches to 10N-m but the actual performance is when the load will be applied it has some fluctuations and at some point of time it will settled with the reference value.

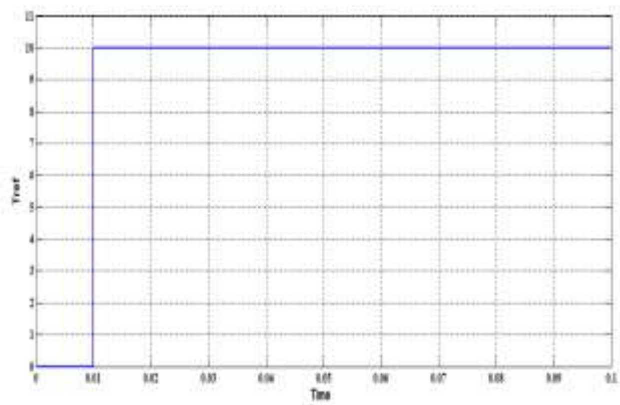


**Fig 19(a):** Reference Torque Response of BLDC Motor

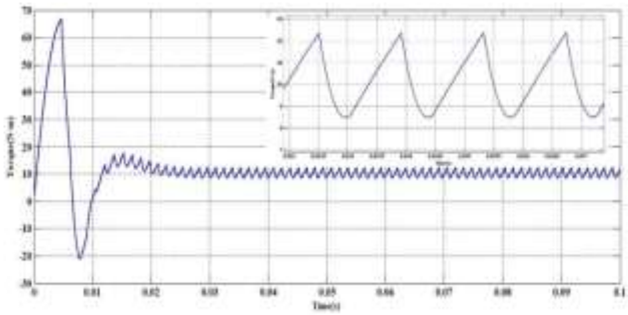

**Fig 19(b):** Actual Torque Response of BLDC Motor

## 5. CONCLUSION

In dc Nano-grid applications, safety is main consideration for residential loads. The united grounding is preferable for Flexible maintenance and high efficiency. Equivalent circuit will shows the working of new AC-DC converter modes and its operation. Both PV&IV characteristics are presented in the PV module. The inputs for the Dual-Buck-Boost AC-DC converter are taken from the output of the PV module which is boosted at 90volts. Sudden load at 0.01 sec the torque changes from 0 to 10N-m and the performance of 3ph BLDC motor is simulated by using MATLAB software.

## REFERENCES

[1] D. J. Hammerstrom, “AC versus DC Distribution Systems-Did We Get it Right,” in *proc. 2007 PES*, pp. 1-5.

[2] X. Yu, X. She, X. Zhou, and A. Q. Huang, “Power management for DC Microgrid Enabled by Solid-State Transformer,” *IEEE Trans. Smart Grid*., vol. 5, no. 2, pp. 954-965, Mar. 2014.

[3] H. Kakigano, Y. Miura, and T. Ise, “Low-voltage bipolar-type DC microgrid for super high quality distribution,”*IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 3066–3075, Dec. 2010.

[4] X. Liu, P. Wang, and P. C. Loh, “A hybrid AC/DC microgrid and its coordination control,” *IEEE Trans. Smart Grid*, vol. 2, no. 2, pp. 278 286, Jun. 2011.

[5] M. Ryu, H. Kim, J. Baek, H. Kim, and J. Jung, “Effective test bed of 380- V DC distribution system using isolated power converters,” *IEEE Trans. Ind. Electron.*, vol. 62, no. 7, pp. 4525–4536, Jul. 2015.

[6] R. Sebastian,B.Wu, S.Kouro,V.Yaramasu, and J.Wang, “Electric vehicle charging station using a neutral point clamped converter with bipolar DC bus,” *IEEE Trans. Ind. Electron.*, vol. 62, no. 4, pp. 1999–2009, Apr. 2015.

[7] T.-F. Wu, C. Chang, L.-C. Lin, G. Yu, and Y.-R. Chang, “DC-bus voltage control with a three-phase bidirectional inverter for DC distribution systems,” *IEEE Trans. Power Electron.*, vol. 28, no. 4, pp. 1890–1899, Apr. 2013.

[8] D. Salomonsson, L. Soder, and A. Sannino, “Protection of low-voltage DC microgrids,” *IEEE Trans. Power Del.*, vol. 24, no. 3, pp. 1045–1053, Jul. 2009.

[9] J.-D. Park and J. Candelaria, “Fault detection and isolation in low-voltage DC-bus microgrid system,” *IEEE Trans. Power Del.* vol. 38, no. 3, pp. 779–787, Apr. 2013.

[10] M. E. Ropp and S. Gonzalez, “Development of a MATLAB/Simulink model of a single-phase grid-connected photovoltaic system,” *IEEE Trans. Energy Conv.*, vol. 24, no. 1, pp. 195–202, Mar. 2009.

[11] K. H. Chao, C. J. Li, and S. H. Ho, “Modeling and fault simulation of photovoltaic generation systems using circuit-based model,” in *Proc.IEEE Int. Conf. Sustainable Energy Technol.*, Nov. 2008, pp. 290–294