Control System and Performance of DC Micro grid under Various Loads

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Abstract: DC microgrid is the high quality electric power system focused on the development of renewable energy resources. The dc distribution system is connected to AC grid, Photovoltaic system and synchronous generator. Moreover, the power is transmitted through dc distribution line and is converted to required AC or DC voltages by load side converters. Those converters do not require transformers by choosing proper DC distribution voltage. The DC power line is 400V. This distributed design of load side converters also contributes to provide supplying high quality power. In this research, the configuration of DC microgrid system, control methods of distributed generation will be presented. Moreover, stand-alone system and grid connected system of DC microgrid will also be expressed. The model of DC microgrid system will be constructed with MATLAB/SIMULINK. Simulation results will be described.

Keywords: DC Microgrid, Distributed Generation, High Quality Power, Converters.

INTRODUCTION:

Myanmar has abundant renewable energy resources. Among these resources, hydropower is being developed and utilized on a commercial scale. The other renewable energy resources remain under research and in development. Electricity generation has lagged behind demand for several years now.

The development in renewable energy system of Myanmar has still weakness compared with other foreign countries. Utilization of renewable energy resources such as photovoltaic cells, wind turbines, etc; should be promote throughout the country.

Distributed generation (DG) is becoming an increasingly attractive approach to reduce greenhouse gas emissions, to improve power system efficiency and reliability, and to relieve today's stress on power transmission and distribution infrastructure. In recent years, distributed generation systems based on renewable energy source or microsources such as fuel cells, photovoltaic (PV) cells, wind turbines, and microturbines are experiencing a rapid development, due to their high efficiencies and low emissions. The microsource based distributed generation also presents a challenge in terms of interaction to the grid, where the power electronic technology plays a vital role [1].

The development of distributed generation has lead to a more recent concept called microgrid, which is a systematic organization of distributed generation systems. Compared to a single distributed generation, a microgrid has more capacity and control flexibilities to fulfill system reliability and power quality requirements. Most microgrids adopt ac system as a main distribution. In this case, dc output type sources such as photovoltaic (PV) system, wind generation system, fuel cell and energy storages (secondary battery and super capacitor) need inverters. In addition, some gas engine cogenerations and wind turbines also need inverters because the output voltages and the frequencies are different from those of the utility grids. In this paper, the configurations of DC microgrid system and control methods of distributed generation are expressed. Moreover, stand-alone system and grid connected system of DC micrigrid are analyzed. Simulation to the proposed system is carried out by MATLAB/ SIMULINK.

CONFIGURATION OF DC MICROGRID:

DC microgrid is defined as a cluster of distributed loads, distributed storage devices and distributed generation sources that operate to improve the reliability and quality of the local power supply in a controlled manner. The main components of a micro grid are: (i) distributed generation sources such as photovoltaic panels, small wind turbines, fuel cells, diesel and gas micro turbines etc., (ii) distributed energy storage devices such as batteries, super capacitors, flywheels etc., and (iii) critical and non-critical loads. A typical DC microgrid configuration is shown in Figure 1. The dc grid line is connected to ac grid line or power system by using rectifier. At the source side, the distributed generations are connected to a dc distribution line through dc/dc converter. At the load side, dc distributed power is converted into required ac or dc voltage by each converter. These load side converters do not need transformers by choosing proper dc distribution voltage. For the high quality power supplying, the dc distribution voltage is quite important [2].

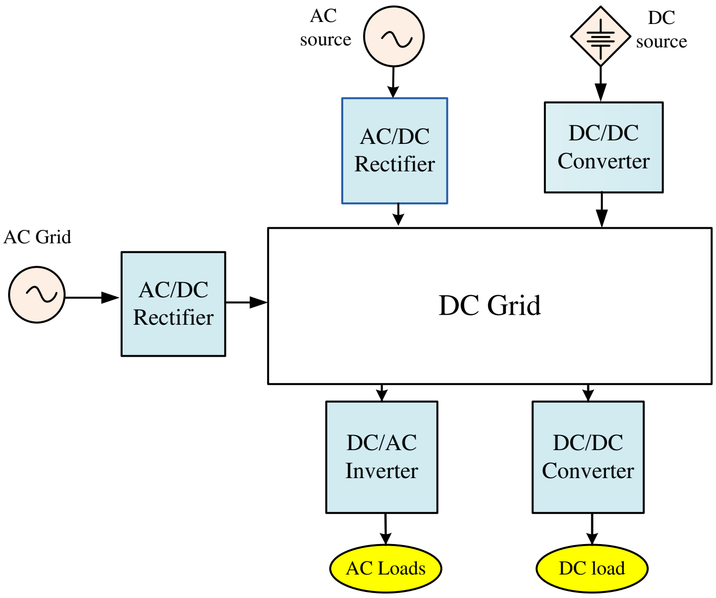


Figure 1 Configuration of DC Microgrid

The microgrid is operated in two modes: (1) stand-alone mode (off grid mode) and (2) grid-connected mode. In the islanded mode of operation, the control algorithm must control the local network voltage and frequency and provide the instantaneous real and reactive power of the loads. In the grid-connected mode of operation, distributed energy resources operate in a constant real and reactive-power control mode meaning that they exchange a pre-specified power with the distribution network, e.g., to minimize the power import or exports power from or to the main grid. Thus, appropriate voltage and frequency regulation schemes are necessary to enhance the network reliability and to preserve the system stability. Otherwise, microgrids with a high penetration of distributed energy resources can experience reactive and/or real-power oscillations. Unlike a large power system, the impedances between distributed energy resources in a microgrid are not significant. Therefore, small errors in voltage set points of distributed energy resources may cause large circulating currents that exceed the distributed energy resource ratings. The main benefits of microgrids are high energy efficiency, high quality and reliability of the delivered electric power, more flexible power network operation, and environmental and economical benefits [5].

CONTROL METHODS FOR DC MICROGRID :

Control of Distributed Generations

In this system, distributed generations are used PV and Simplified Synchronous Generator (SG). Photovoltaic system (PV) is connected to DC grid via DC-DC boost converter. And then, 88kW PV array uses Sun Power modules (SPR-305E-WHT-D). The array consists of 57 strings of 5 series connected modules connected in parallel. The control diagram is shown in Figure 2.The DC voltage is fixed 400V. The boost converter is controlled by Maximum Power Point Tracking (MPPT) to keep its efficiency high. MPPT technique is used to improve the efficiency of the solar panel. MPPT controller is based on the “incremental conductance” technique.

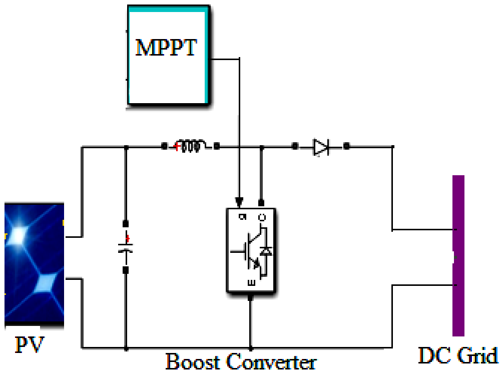


Figure 2 Control Diagram of PV

A 17kVA, 230V, 50Hz and two poles simplified synchronous machine is used and connected to dc distribution line through dc/dc converter. This converter is used with diode shown in Figure 3.

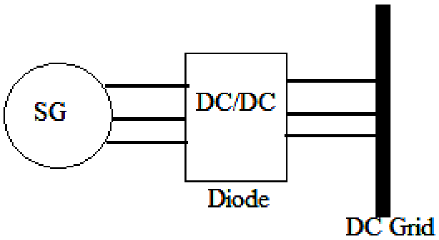


Figure 3 Control Diagram of Synchronous Generator

Load Side in DC Microgrid

DC microgrid distributes dc power and ac power that transmit various load side. Customer loads may be classified into three connections to the utility distribution system in DC microgrid. They are three phase load, single phase load and dc load. These loads are connected to the dc grid through power electronic interfaces such as inverters and buck converter and this diagram shows in Figure 4. The rating of the rectifiers and converters will be dependent on the requirements of the customers.

Three phase loads are transmitted to schools, hospitals, banks, etc. Single phase loads are applied for home system and stores. DC loads are widely spread in the houses such as PCs, portable electronic devices, LED lights, etc.

From load side point of view, microgrids are beneficial for locally meeting their electrical/heat requirements. They can supply uninterruptible power and provide local voltage support. In addition, microgrids help to reduce the stress on transmission grid by sharing its loads. Microgrids can provide improved electric service reliability and better power quality to end customers.

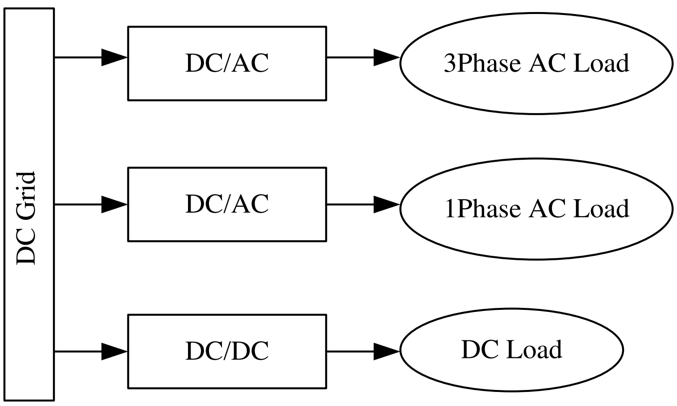


Figure 4 Load side of DC Microgrid

Most of the converter choose voltage source converter (VSC). The control structure of grid rectifier is depicted in Figure 5. It consists of output voltage and DC link voltage. PWM uses to control gate of the rectifier to output stable. It gives to reduce harmonics and to smooth the output of the rectifier. One of the methods to synchronize the reference current and voltage of the rectifier with the grid voltage and current is an algorithm called Phase Locked Loop (PLL). PLL determines a signal to track another so that the output signal is synchronized with the input one both in frequency and phase.

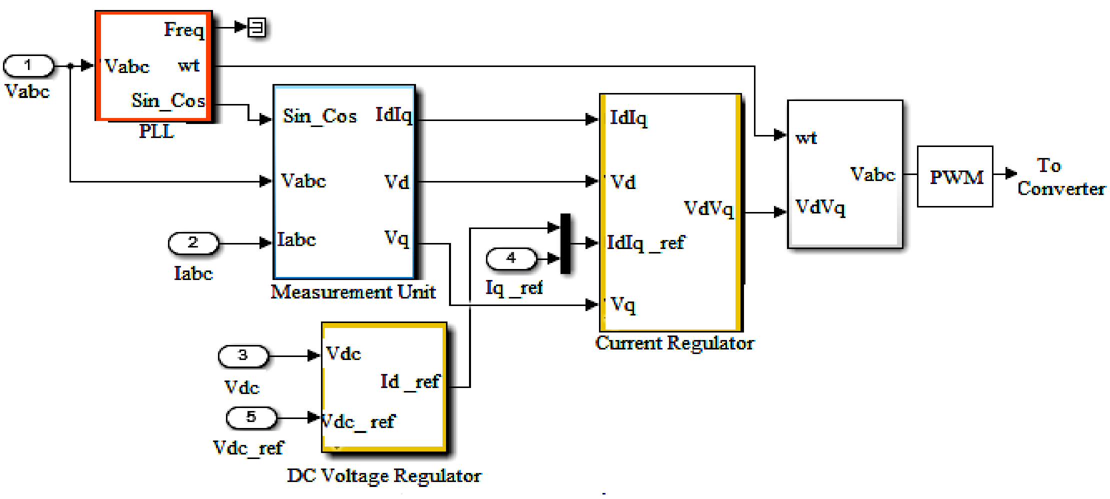
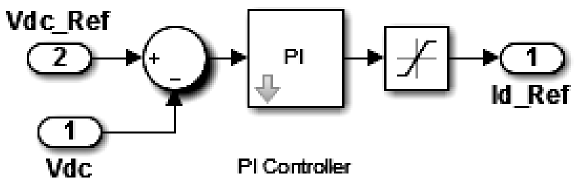
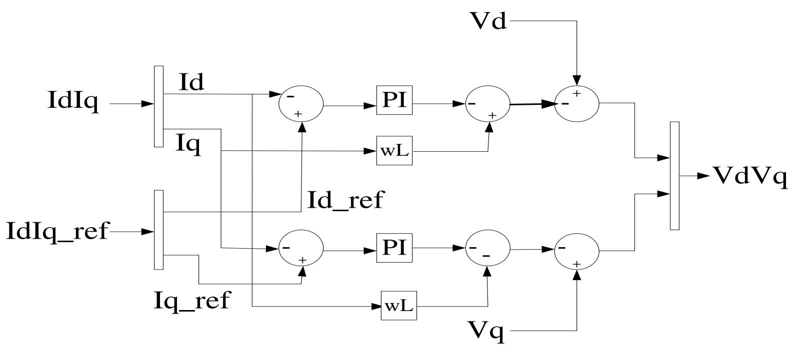


Figure 5 Control Structure of Grid Rectifier

In this system, voltage source converter (VSC) control uses two control loops. They are outer control loop and inner control loop. The outer control loop (DC voltage regulator) which regulates V_{dc} and $V_{dc\text{-}ref}$ and the inner control loop (current regulator) which regulates I_d and I_q. Direct axis current component is used to control the DC link voltage and quadrature axis current component is used to regulate the reactive power. I_d current reference is the output of the DC voltage external controller. I_q current reference is set to zero. Voltage output converted from V_d and V_q in the current control loop are supplied to the Pulse Width Modulation (PWM) generator.. The current control loop diagram of the DC micogrid is shown in Figure 6.



(a)



(b)

Figure 6 (a) Voltage Control Loop (b) Current Control Loop

SIMULINK MODEL AND RESULTS OF DC MICROGRID:

In order to confirm the control system DC Microgrid under various loads, computer simulations were carried out by using MATLAB/SIMULIMK. The main parameters of this system show in Table 1 and the simulation circuit is shown in Figure 7. DC microgrid is classified into two types. They are stand-alone system and grid connected system. In this research, photovoltaic source and synchronous generator are demonstrated at the source side and AC loads (both single phase and three phase load) and DC load are connected at the load side. In simulation results of DC microgrid, the DC microgrid is connected to AC grid and it is disconnected from AC grid are considered. In stand-alone system, both with energy storage device and without energy storage device are also analyzed.

TABLE I

Main Parameters of the Simulated System

PV	87kW, 273.5V, 50Hz
	Duty Cycle=0.3163
Synchronous Generator	17kVA, 230V, 3000rpm H=0.6s, L=1.98mH
Switching frequency	5kHz
DC Voltage	400V
AC Grid	20MVA, 11kV
Step Down Transformer	11kV/230V, 100kW
	R_m=500pu, L_m=500pu
Rectifier (IGBT)	R_s=1.66 Ω, C_s=6.072e^{-6}F
Inverter (IGBT)	R_s=2.7 Ω, C_s=3.6e^{-6}F
Diode	R_s=9.8 Ω, C_s=1.02e^{-6}F
Boost Converter	L=1mH, R_{on}=1e^{-4} Ω
Loads	
Three Phase load	230V
Single Phase Load	200V, 0.5Ω
DC Load	100V, 1Ω

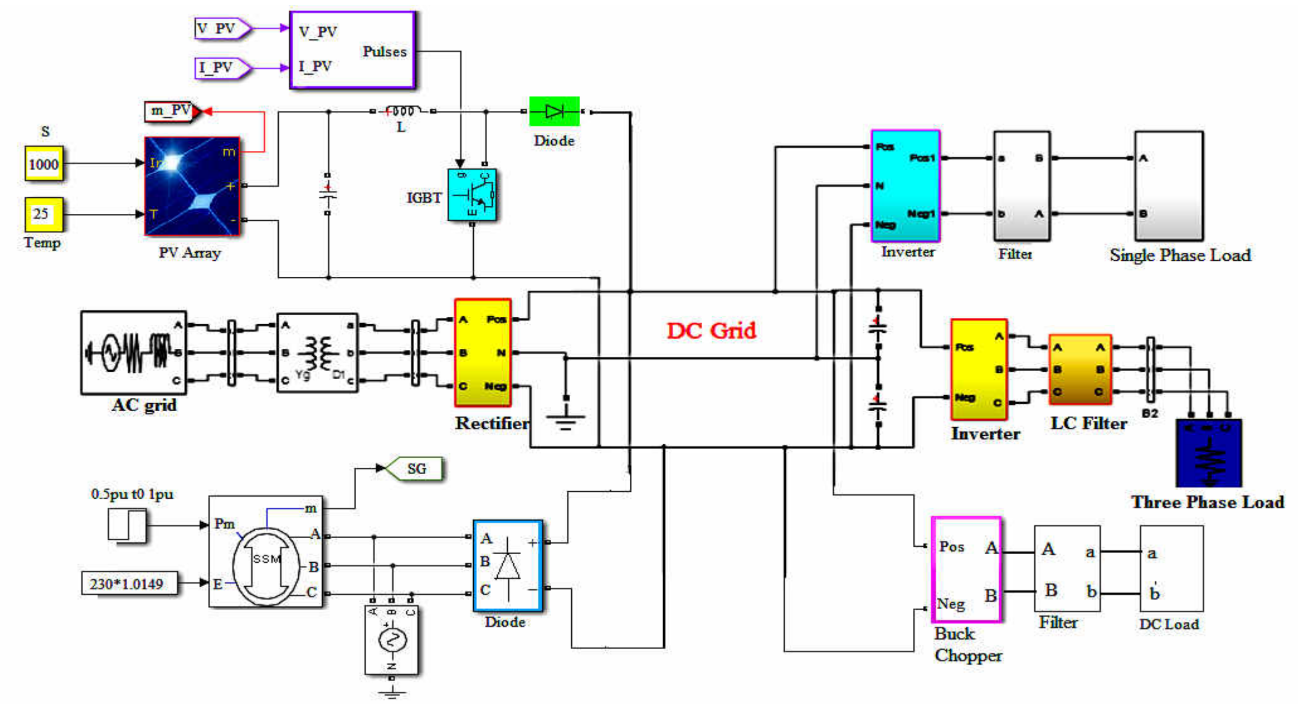
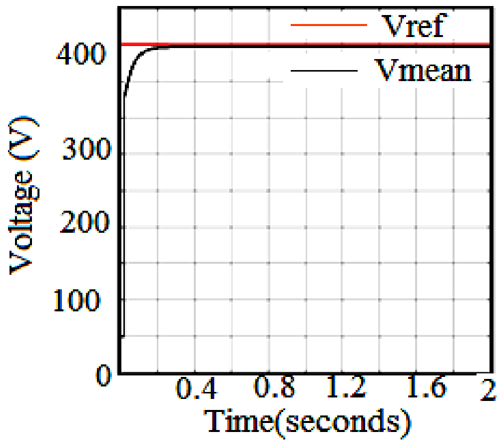


Figure 7 Simulation Diagram of DC Microgrid

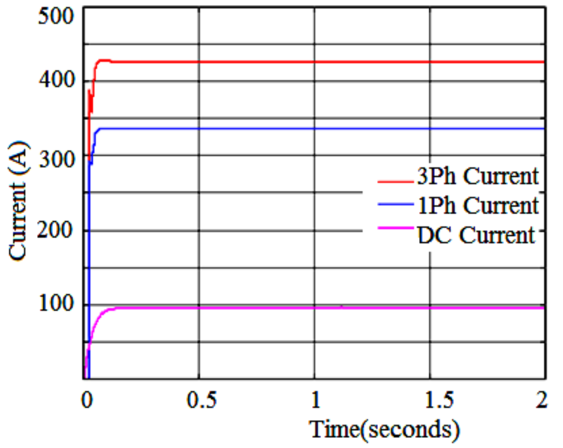
RESULTS:

Grid Connected System of DC Microgrid

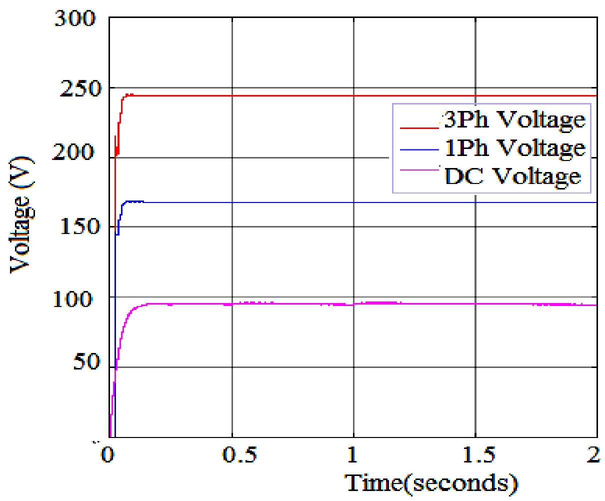
The simulation results of the DC voltage of grid connected system are shown in Figure 8 (a). DC bus voltage is around 397.4V because of line impedance voltage drops. In Figure 8 (b), (c) and (d) show that the three phase voltage, three phase current, single phase voltage, single phase current, DC load voltage and DC load current.



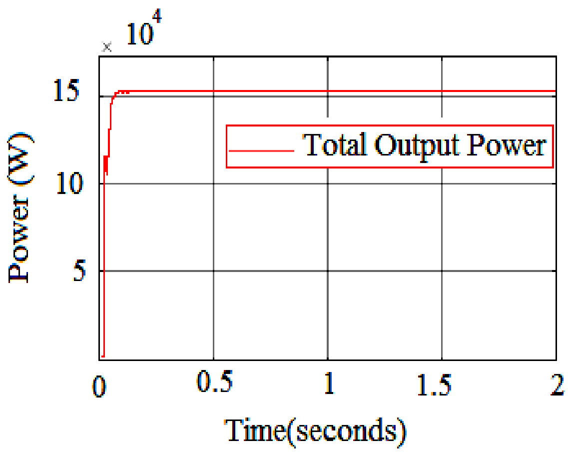
(a)



(c)



(b)



(d)

Figure 8 Simulation results of Figure 8

(a) Reference DC Voltage and Mean DC Voltage of Grid connected System in DC System
(b) three phase voltage, single phase voltage and dc voltage.
(c) three phase current, single phase current and dc current.
(d) total output power of DC microgrid.

Stand-alone System of DC Microgrid

The simulation results of reference and mean voltage are shown in Figure 9. In this diagram, the reference voltage is 400V and the mean voltage is the same reference voltage. In addition, Figure 10 (a) and Figure 10 (b) show the demonstration of energy storage device effectiveness of the DC microgrid. The energy storage device is used Lead acid battery that is 100kAh Capacity. When energy storage is not considere, the total output power decreases about 90kW. Moreover, the total output power increases till 170kW when energy storage device is used in DC microgrid.

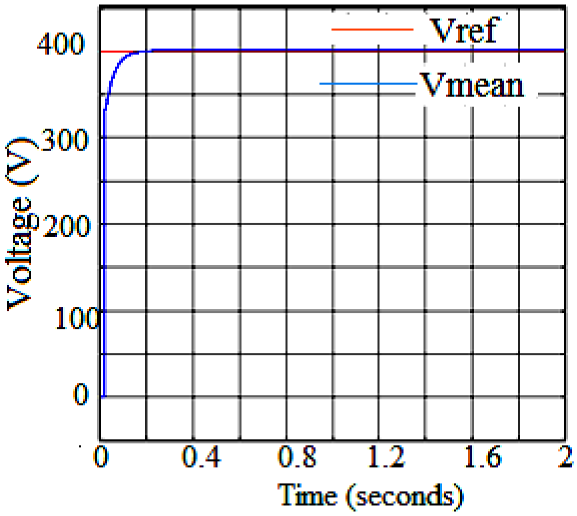
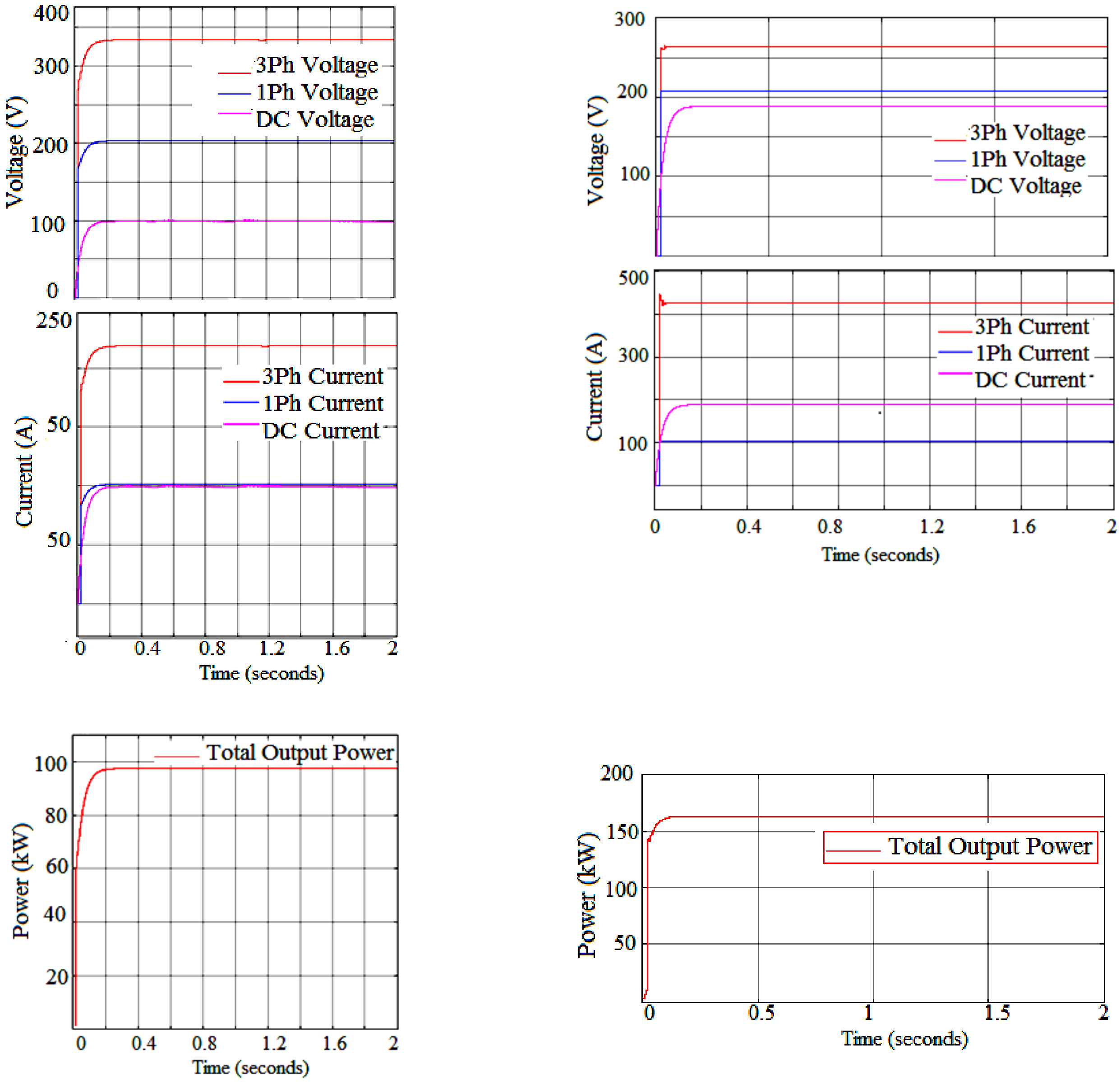


Figure 9 Mean Voltage and Reference Voltage of stand-alone system



(a) (b)

Figure 10 Simulation Results of the operation (a) without energy storage device (b) with energy storage device

CONCLUSION:

In this paper, "Control System and Configuration of DC Microgrid under Various Loads" is proposed. This paper is implemented the concept of DC microgrid, control methods for distributed generations, power converters and load side in DC microgrid. It is analyzed for system stability and reliability. Simulation results demonstrated that the DC microgrid is connected to AC grid and it is disconnected from AC grid. Moreover, it is considered both with energy storage device and without energy storage device in stand-alone system. The demonstration of DC microgrid for high quality distribution system is carried out with MATLAB/ SIMULINK Software.

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BIOGRAPHY:

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