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Improving the Stability of Islanded DC Microgrid with Constant Power Loads †

Sajid Ali Murtaza [1,*], Nazam Siddique [1], Javaid Aslam [1,*], Waqas Latif [2], Muhammad Wasif [1] and Iftikhar Hussain [1]

[1] Department of Electrical Engineering, University of Gujrat, Gujrat 50700, Pakistan; nazam.siddique@uog.edu.pk (N.S.); syed.wasif@uog.edu.pk (M.W.); Iftikhar.hussain@uog.edu.pk (I.H.)
[2] Saudi Electric Company, Riyadh 12271, Saudi Arabia; mianwaqaslatif@gmail.com
* Correspondence: sajid092@gmail.com (S.A.M.); Javaid.aslam@uog.edu.pk (J.A.)
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Abstract: The AC power system is leading due to its established standards. The depleting thread of fossil fuels, the significant increase in cost and the alarming environmental situation raises concerns. An Islanded DC microgrid, due to its novel characteristics of being able to withstand faulty conditions, has increased the reliability, accuracy, ease of integration, and efficiency of the power system. Renewable energy sources, characteristically DC, have wide usability in a distributive network and, accordingly, less circuitry and conversion stages are required, eliminating the need of reactive power compensation and frequency sync. Constant power loads (CPLs) are the reason for instability in the DC microgrid. Various centralized stability techniques have been proposed in the literature; however, the grid system collapses if there is a fault. To compensate, an efficient distributive control architecture, i.e., droop control method is proposed in this research. The significant advantage of using the droop control technique includes easy implementation, high reliability and flexibility, a reduced circulating current, a decentralized control with local measurements, the absence of a communication link and, thus, it is economic. Moreover, it offers local control for each individual power source in the microgrid. To investigate the stability of the islanded DC microgrid with constant power loads using the droop control technique, a small signal model of the islanded DC microgrid was developed in MATLAB/Simulink. Simulations were carried out to show the efficiency of the proposed controller and analyze the stability of the power system with constant power loads.

Keywords: DC microgrid; constant power loads; droop control; islanded DC

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1. Introduction

Global energy is going to "decentralize, decarbonize, and democratize" gradually. These 3D terms are determined to restrict energy prices, substitute aged infrastructure, increase ability to withstand and improve reliability, decrease CO_2 emissions, and deliver reliable energy to areas where the electrical infrastructure is absent or insufficient. A DC Microgrid has appeared as an alternative solution for installing distributive energy resources that can deal with the increasing demand of several societies ranging from NYC too far off places in Pakistan. Distributed generators are typically linked to the microgrid by converters, which increases the operational flexibility [1].

A power system is supposed to have many semiconductor devices; a novel variety of power system, an "intensive power electronics system", has been developed. Such novel infrastructures have distinctive features, behavior, and stability issues that are not realized because of the non-linear and time dependent behavior of power electronic converters and because of their constant power characteristic. This is the beginning of a new era of DC-based energy, which is yet to be researched, examined, and understood [2].

The constant power load (CPL) system is expected to be unbalanced when a conventional distributive control scheme is applied. The stability of the CPL systems with distributed control is still an open topic and new techniques need to be developed for its improvement. It is necessary to find a way and choose a topology that has maximum room to increase the efficiency and reduce the cost [3]. A microgrid is categorized into two types, i.e., AC and DC. In the modern era, DC microgrids have drawn increasing attention due to the many advantages they offer, including their reliability and efficiency, simple controls, robustness and an easy interface of renewable sources [4]. This will increase the DC microgrid efficiency and the absence of a transformer reduces its cost. In addition to this, the problems of harmonics due to PEC does not exist because of the DC nature of output energy and it increases the system's performance [5].

In addition, appropriate controllers are suggested to interlink the DC/DC power converter and battery branches so that stability is ensured. Since the PECs are implemented in DC microgrids, instability issues can be seen because of the regulation of the controllers [6]. An analysis of the stability of small signals of a low-voltage DC microgrid is given in. It is important to remember that any growth in cable resistance will also increase the distribution losses and, subsequently, the power losses [7].

In the traditional distribution strategies, the energy transferred and acquired through a communication line is used as an input variable of a proportional Integral (PI) controller to perform the voltage shift technique and droop gain difference method [8–12].

2. Methodology

A DC microgrid is a combination of solar PV modules, converters, storage devices and loads. A PV array is represented as an installation of solar cells in a controlled environment. It was found that MATLAB/Simulink is a suitable option to develop the component's models.

A PV array can be designed in multiple possible ways by using different characteristics of Simulink. For the simulation, the PV module block available in Simpower systems' library was used. In this method, we could model PV arrays as per our requirements.

A boost or step-up converter is type of converter that upgrades the lower voltage values and produces higher and stabilized output voltages, whereas a converter that converts the higher voltage into a stabilized lower voltage is called a buck or step-down converter. Both models are developed in Simulink. Converter parameters for the simulation purposes are mentioned in Table 1.

Table 1. Parameters of Buck and Boost Converters.

Parameters	Buck Converter	Boost Converter
Vin	100 V	100 V
Diode Resistance on	0.001	0.001
Period	1/25,000	1/25,000
Pulse Width	50%	75%
Inductance	1000	3.3×10^{-5}
Capacitance	4.3×10^{-4}	3.3×10^{-2}

The droop control technique allowed us to synchronize multiple sources connected parallel to a common DC bus in a DC grid. By adding an external resistance to an individual source, the circulating current can be suppressed. Though the principle of droop is discussed in the literature, the procedure for choosing a proper droop voltage range in DC systems is still not clear. Droop control enables the parallel operation of multiple sources without any communication. This distributed control method does not need a communication link for its procession. The significant benefits are improved reliability, lower cost and easy sizing. Due to the causes, the voltage droop method was applied. In

this control scheme, each source was designed with an output resistance Rd. Adding Rd in series with each source will cause the output voltage to drop proportionally with the increase in load current.

3. Results

The simulation results produced from the Simulink models are shown in Figure 1.

Several ripples were observed in the converter output, as we applied the droop resistances of 0.2 Ω and 0.8 Ω. The results shown in Figure 1b,c came out smooth as expected. However, it reduced the voltage output value.

The selection of the droop parameter has a direct impact on the balance of voltage accuracy and system stability; therefore, a careful selection must be made. During this project, it has been noted that if high droop values are selected, this results in a greater system voltage drop, causing imbalance. The voltage drop effect also depends on the topology of the islanded microgrid, the position of the installed load, as it changes the conduction line parameters, and droop constants. Adding an external resistance to power output drops the voltage level down. Therefore, the selection of droop resistance, Rd, needs vigilant consideration.

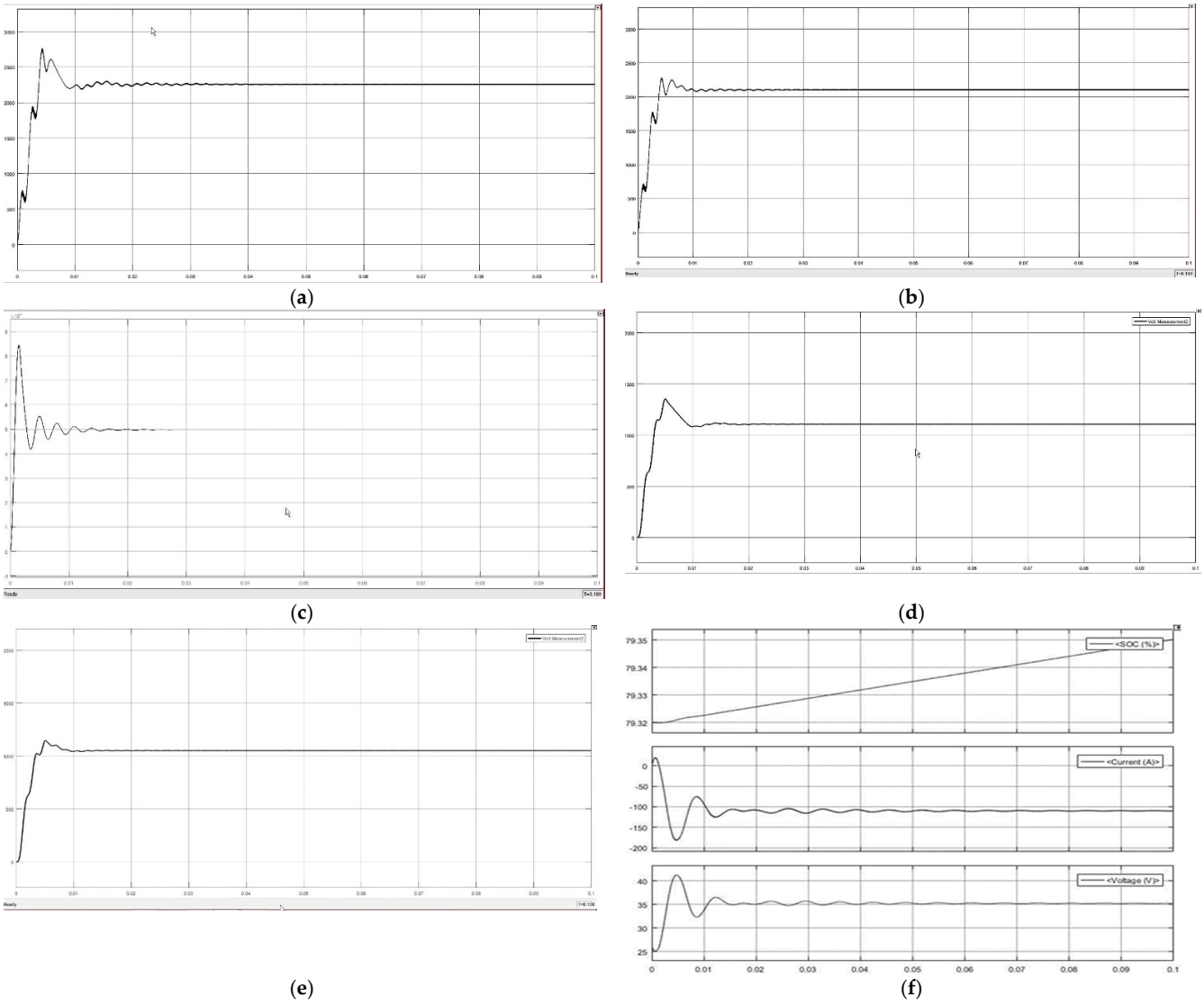
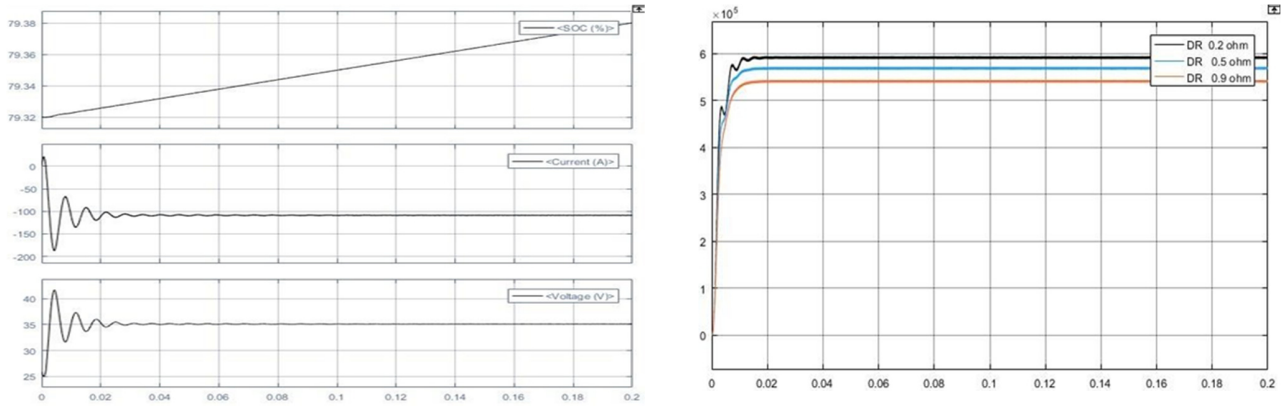


Figure 1. *Cont.*



(**g**) (**h**)

Figure 1. This figure shows simulation results; scope waveforms of boost converter without and with stability: (**a**) with droop resistance of 0.2 Ω (**b**) with droop resistance of 0.8 Ω. Scope waveform of buck converter without and with stability, (**c**) without stability technique, (**d**) after applying 0.2 Ω droop resistance and (**e**) after applying 0.8 Ω droop resistance. Results of battery model without and with stability, (**f**) scope waveform of battery attached with proposed circuit without stability, (**g**) Scope waveform of battery attached with proposed circuit after stability technique is applied, (**h**) Scope waveform of Impact of different droop resistances on Voltage output.

4. Conclusions

This paper presented a detailed survey on the current status of the literature on improving the stability of a DC microgrid with CPL and IEEE standards. The impact of negative incremental resistance caused by CPL was deliberated in detail and it was found that the voltage stability of the Islanded DC microgrid is still a major issue. The results obtained from the simulation were achieved as expected. The droop control technique was chosen because it is independent, autonomous and has no communication link, which makes much easier and economical to control.

Conflicts of Interest: The authors declare no conflict of interest.

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