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Decentralized current sharing in dc microgrids considering normal and disturbed operation modes

A. Kirakosyan[1], E. F. El-Saadany[2], M. Shawky El Moursi[3] and M. Salama.[4]

[1,4] ECE Department, University of Waterloo,Waterloo, ON, Canada
e-mail: akirakos@uwaterloo.ca, msalama@uwaterloo.ca
[2] Advanced Power and Energy Center, EECS Department, Khalifa University, Abu Dhabi, UAE
Adjunct Professor, ECE Department, University of Waterloo, Waterloo, ON, Canada
[3]EECS Department, Khalifa University, Abu Dhabi, UAE
e-mail: ehab.elsadaany@ku.ac.ae, mohamed.elmoursi@ku.ac.ae

Abstract. The accurate ratio-based current sharing, which is one of the desired features of the droop controlled dc microgrid, might be affected by the system impedance. Several strategies have been presented in the literature to achieve precise current sharing. This paper proposes a new controller reconfiguration algorithm that is capable to achieve enhanced operation during normal conditions and after system disturbances. For this purpose, the proposed algorithm allows the converter to follow the set-points determined by a higher-level controller when there is no disturbance in the system. After a system disturbance, when the necessity for the current sharing arises, the proposed controller enables accurate ratio based current mismatch sharing between the droop controlled converters. The time-domain simulation conducted in Matlab/ Simulink environment demonstrates the effectiveness of the proposed approach.

Key words. dc microgrid, droop control, common voltage based droop.

1. Introduction

Compared to ac microgrids, the dc microgrids enable a reduced number of conversion stages when a large number of dc loads are present in the system. In this aspect, dc microgrids are becoming increasingly appealing as dc loads such as consumer electronics, variable-frequency drives, LED lighting systems, data centers, and electric cars are becoming a significant portion of the energy-consuming loads [1]. Furthermore, dc microgrids can overcome challenges associated with ac microgrids such as reactive power flow, frequency regulation, transformer inrush current and power quality issues.

Fig. 1 depicts a general structure of an isolated dc microgrid, which is formed by parallel connection of the power sources and the loads with the help of the power electronic converters. The converters interfacing the loads are usually adapting some form of power control to deliver the required power to the consumer. On the other hand, droop control is adapted for the converters connecting the power sources to the dc grid.

Being decentralized in nature, droop control aims to regulate dc voltage simultaneously by several converters and to share the system power mismatch between power sources based on the preselected ratios. The load sharing accuracy is however affected by the line impedances of

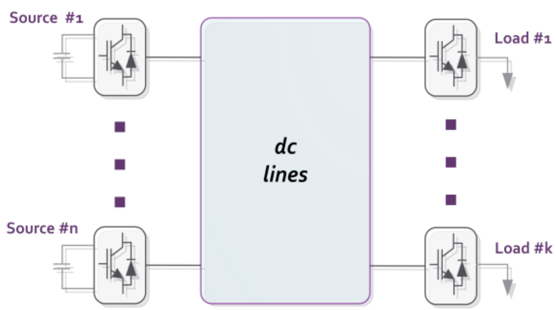

Fig. 1: The general structure of dc microgrid

the dc grid. Improper power-sharing can result in overloading of converters, which might, in turn, cause thermal stress on the switches [2].

The control approaches that have been presented in the literature to solve the aforementioned issue can be divided into three main groups: centralized, distributed and decentralized control strategies. The first two groups rely on a high-bandwidth communication infrastructure to exchange an information with the local controllers to adjust the reference signals [1], [3]–[13]. The cost and reliability related issues are the main drawbacks of the communication based approaches. Several decentralized strategies rely on the precise knowledge of the network topology and impedances during the whole operation period [14]–[16]. However, any change of this information such as system reconfiguration and load switching would result in sharing error with the latter strategies. The on-line estimation of this information is proposed in references [15], [16], which are however applicable to single bus dc microgrid only.

The last group of the papers relies on an intentional injection of ac signal into the dc grid [17]–[20]. References [17]– [19] superimpose a small ac signal in all droop controlled converters, after which the dc voltage is adjusted based on the small active [17] or reactive [18], [19] power flow resulted from the superimposed signal.

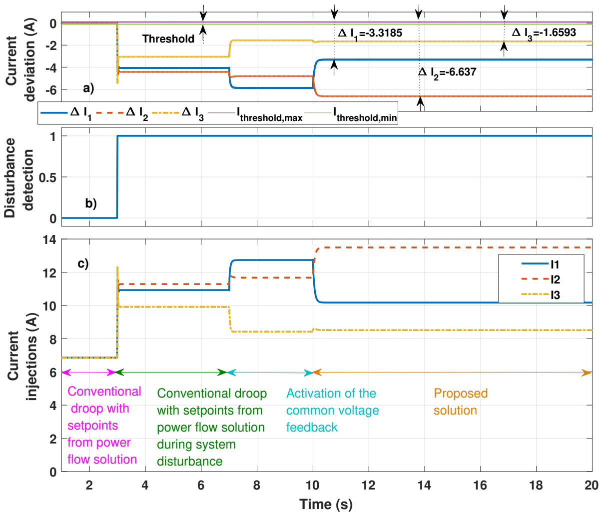

Fig. 9: The average currents of the droop controlled converters

9a, before the activation of the proposed controller the current mismatches are not sharing according to the predefined ratios. Once the controller of Fig. 5 is activated, the current deviations from the first to third converters become equal to 3.3185 A, 6.637 A and 1.6593 A, respectively. The achieved exact sharing verifies the validity of the proposed controller.

V. Conclusion

A controller reconfiguration strategy has been presented and analyzed in this paper. The proposed approach is capable of operating based on the predetermined set-points during normal conditions while ensuring an accurate ratio-based current sharing during the system disturbances. The performance of the proposed algorithm has been validated through time-domain simulations in Matlab/ Simulink environment.

VI. Appendix

The parameters of the considered DC system.

TABLE I: Microgrid parameters

$V_{DC,Grid}$	400 V	Line 1 and 6 Resistances	2 Ω
S_{base}	3 kW	Line 2 and 5 Resistances	1 Ω
Filter Inductance	0.2 mH	Line 3 and 4 Resistances	1.5 Ω
Filter capacitance	500 μF	Line 1 and 6 Inductances	15 mH
Filter Resistance	0.05 Ω	Line 3 and 4 Inductances	11.25 mH
Nom. Inj. Frequency	50 Hz	Line 2 and 5 Inductances	7.5 mH
$k_{p,DC}$	0.1 A/V	$k_{i,DC}$ (voltage reg.)	20 A/V
$k_{p,inner}$	0.02 pu/A	$k_{i,inner}$ (current reg.)	1 pu/A

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