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Distributed Cooperative Control of Hybrid AC/DC Microgrid

Rasel Mahmud[1], Arash Nejadpak[2]
[1]National Renewable Energy Laboratory
[2]University of North Dakota

INTRODUCTION

This paper presents a distributed cooperative control-based (DCC) power management algorithm for a hybrid AC/DC microgrid. The proposed algorithm for a hybrid microgrid system controls the power flow through the interface converter between the AC and DC microgrids. This algorithm allows power sharing between the distributed generators in the microgrid according to their power ratings. Moreover, it enables the fixed scheduled power delivery through the interface converters in both directions at different operating conditions while maintaining voltage regulation and improving the frequency profile.

HYBRID MICROGRID ARCHITECTURE

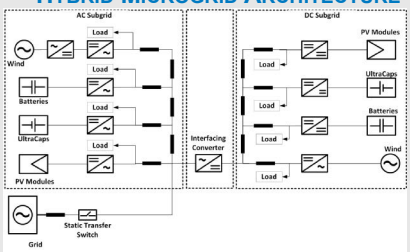

Fig. 1. Structure of the AC/DC hybrid microgrid

MODES OF OPERATION

A. Grid-Connected Mode of Operation for Hybrid Microgrid
B. Islanded Mode of Operation for Hybrid Microgrid
   1. Fixed Scheduled Power through Interface Converter
   2. Power Balance in the Subgrids through the Interface Converter
   3. Load Shedding

PROPOSED DCC FOR HYBRID AC/DC MICROGRID

The communications graph developed for the DCC of a hybrid AC/DC microgrid is presented in Fig 2.

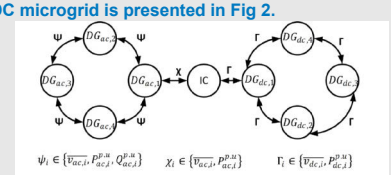

Fig. 2. Communication graph for DCC of hybrid AC/DC microgrid

When power is flowing to the DC subgrid, the reference output voltage of the interface converter is controlled by following equation:

$$v_{DC}^{IC*} = V_{rated} + \Delta v_1^{IC} + \Delta v_2^{IC}$$

Δv_1^{IC} → *regulates the DC-side voltage of the interface converter by estimating the average voltage of all nodes of the DC subgrid. The average voltage of the DC subgrid is estimated by the following equation:*

$$\overline{V_{IC}} = V_{IC} + \sum_{j \in N_{DC}} a_j \left(\overline{V_j} - \overline{V_{IC}}\right)$$

PROPOSED DCC FOR HYBRID AC/DC MICROGRID (CONT'D)

Δv_2^{IC} → is responsible for maintaining the scheduled power through the interface converter or maintaining the same per-unit power sharing by all distributed generation in the hybrid microgrid. The update protocol for the second correction factor is illustrated in the following figure:

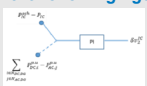

Fig. 3. Calculation of second correction factor

When the interfacing converter is injecting power from the DC subgrid to the AC subgrid, the reference frequency, ω, is updated according to the flowing equation:*

$$\omega^* = \omega_{rated} + \delta\omega_1^{IC} + \delta\omega_2^{IC}$$

SIMULATION RESULTS

Two case studies were considered to validate the proposed method:

- Case 1: Fixed scheduled power flow through the interfacing converter

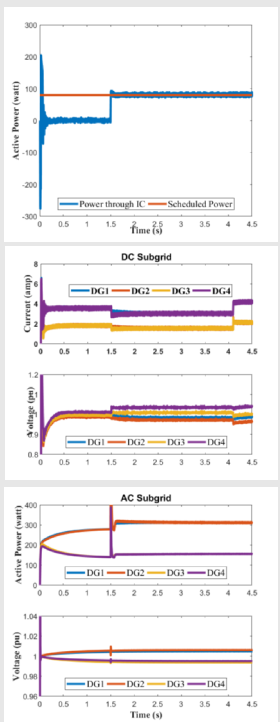

Fig. 4. Performance of the controller under the condition of fixed scheduled power through the interface converter: a) power flow through interface converter, b) power generation by distributed generation in the DC microgrid and their node voltages, C) power generation by distributed generation in the AC microgrid

SIMULATION RESULTS (CONT'D)

- Case 2: All the distributed generation units in the hybrid AC/DC microgrid sharing power according to their ratings

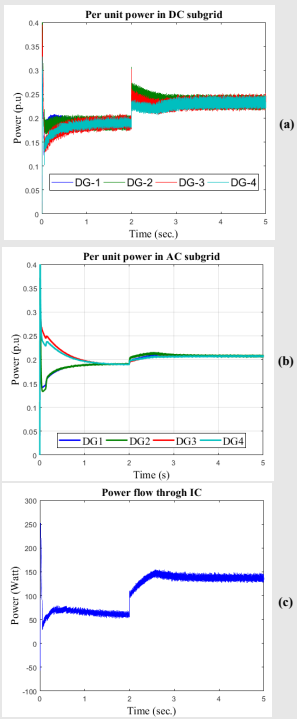

Fig. 5. Performance of the controller to share the load among the distributed generation units in a hybrid microgrid according to the power rating: a) per-unit power of the distributed generation in the DC subgrid, b) per-unit power of the distributed generation in the AC subgrid, and c) power flow through the interface converter.

CONCLUSION

A distributed cooperative control scheme for an AC/DC hybrid microgrid has been proposed. Key features of the proposed algorithm:

- *Controls the power flow through the interfacing converter between the AC and DC subgrids.*
- *The control algorithm uses limited information exchanged with some of the distributed generation in both the AC and DC subgrids to achieve the control objectives, i.e.,*
  - ❑ *Scheduled power flow through the interface converter or*
  - ❑ *Load sharing by the distributed generation units accruing to their ratings.*
- *The simulation results show that the proposed DCC enables control of the power flow through the interface converter in different modes of operation at different operating conditions while maintaining good voltage regulation in both subgrids.*

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