SIMULATION ANALYSIS OF POWER CONTROL USING DROOP CONTROLMEHTOD IN AC-DC MICROGRID

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Abstract: In this paper, data-driven control (DDC) structure for interlinking converters in interlinked ac and dc hybrid microgrids. One important reason that we try to use the data-driven MFAC method to design the controller of the IC is to take the most advantage of the process data, boost the efficiency, and cut the costs on the basis of achieving required control performance. The proposed control scheme employs a data-driven model-free adaptive voltage controller (DDMFAVC) for fast and robust voltage tracking and a dual-droop controller with a secondary controller for proportional coordinated power sharing between ac and dc microgrids and restoration of frequency and dc voltage. Considering the voltage controller, model-free adaptive control (MFAC) perhaps is the best solution. The introduced control scheme is analyzed and simulated using a MATLAB/Simulink and the results are presented.

Keywords: data-driven model-free adaptive voltage controller, model-free adaptive control, data-driven control.

I INTRODUCTION

Nowadays, because of high penetration levels of renewable energy resources, the paradigms of microgrids (MGs) and distribution generation (DG) are gaining vital role in power and distribution systems. MGs are categorized as ac MGs, dc MGs, and hybrid ac–dc MGs. Since a considerable portion of renewable energy resources, such as wind turbines, photovoltaic (PV), fuel cells and energy storage systems, and many modern loads such as communication technology facilities, data centers, and motor drives is dc-type, dynamics and controls of rectifiers and dc MGs are gaining high interest [1].

The promise of the smart grid (SG) is round the corner. However, research and society cannot wait for the approval of many standards and grid codes, particularly when these codes can restrict more the independence of the electricity users from the suppliers. In this sense, the demand side management can be satisfied by using local energy storage and generation systems, thus performing small grids or microgrids. Microgrids should be able to locally solve energy problems and hence increase flexibility. Power electronics plays an important role to achieve this revolutionary technology. We can imagine the future grid as a number of interconnected microgrids in which every user is responsible for the generation and storage part of the energy that is consumed and to share the energy with the neighbors [1].Hence, microgrids are key elements to integrate renewable and distributed energy resources as well as distributed energy storage systems. In this sense, new power electronic equipment will dominate the electrical grid in the next decades. The trend of this new grid is to become more and more distributed, and hence, the energy generation and consumption areas cannot be conceived separately. Nowadays, electrical and energy engineers have to face a new scenario in which small distributed power generators and dispersed energy storage devices have to be integrated together into the grid. The new electrical grid, also named SG, will deliver electricity from suppliers to consumers using digital technology to control appliances at consumer's homes to save energy, reducing cost and increasing reliability and transparency. In this sense, the expected whole energy system will be more interactive, intelligent, and distributed. The use of distributed generation (DG) makes no sense without using distributed storage (DS) systems to cope with the energy balances.

Recent innovations in small-scale distributed power generation systems combined with technological advancements in power electronic systems led to concepts of future network technologies such as microgrids. These small autonomous regions of power systems can offer increased reliability and efficiency and can help integrate renewable energy and other forms of distributed generation (DG) [1]. Many forms of distributed generation such as fuel-cells, photo-voltaic and micro-turbines are interfaced to the network through power electronic converters [2]–[5]. These interface devices make the sources more flexible in their operation and control compared to the conventional electrical machines. However, due to their negligible physical inertia they also make the system potentially susceptible to oscillation resulting from network disturbances.

A microgrid can be operated either in grid connected mode or in stand-alone mode. In grid connected mode, most of the system-level dynamics are dictated by the main grid due to the relatively small size of micro sources. In stand-alone mode, the system dynamics are dictated by micro sources themselves, their power regulation control and, to an unusual degree, by the network itself.

II SMART GRID

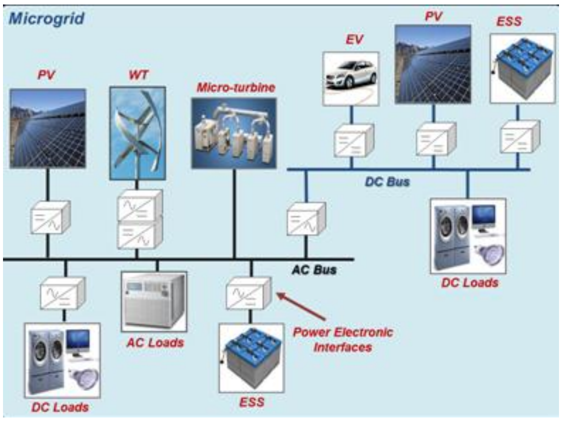

Fig.1: Configuration of a typical Microgrid

A microgrid (MG) is defined as a localized cluster of heterogeneous DGs and loads, placed in low voltage (LV) or/and medium voltage (MV) distribution networks, which is able to be either coupled to the main grid or operates autonomously in isolated mode. It is usually interfaced to the grid through a bypass switch at a single point, often referred to as the point of common coupling (PCC). Microgrid can ensure power quality independence from utility mains with its ability to perform hot-swap islanding in case of grid contingencies. Conversely, when connected to grid, it appears like a singular and flexible entity from the overhead power system perspective, which makes it a valuable building block in the future Smart Grid. In the grid-connected mode, the voltage of PCC is dominantly determined by the host grid; hence the main role of the MG is to accommodate the local load demand and the active/reactive power generated by the DGs. The MG can participate in reactive power support or regulating the voltage at the point of connection, if it is permitted by the host utility, by injecting reactive power. Moreover, it can help to improve the power quality in the utility grid. In the isolated mode, the MG operates as an independent entity and must provide voltage and frequency regulation as well as active/reactive power balance. Microgrids are divided into ac MGs and dc MGs, depending on whether DGs and loads are connected on the basis of ac or dc grid. However, hybrids dc-ac MGs are often implemented by means of power-electronic interfaces, being necessary to control the power flow between dc and ac parts. Fig.1 indicates typical configuration of a MG. A typical example of DC microgrid is as shown below:

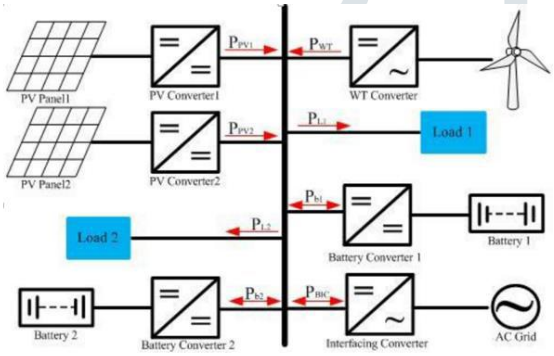

Fig.2: Structure of basic DC Microgrid

As seen, the PV panels are connected to the DC bus via DC/DC converters and the wind turbine is connected using an AC/DC rectifier. Also two battery units acting as power storage element are used to store excess power by help of DC/DC converters; this allows charging and discharging as and when required. As seen by making use of interfacing converters the load can be supplied to the AC grid. The operating modes of hybrid microgrid are based on the type of topology used and flow of power in the system. As seen in figure (a) and (b) the system is working as pure AC and pure DC microgrid respectively.

III MICROGRIDS CONTROL STRUCTURE

An interface is required when interconnecting dc power systems with an ac system. The design of the interface has great significance on the operation of the dc system and the impact on the ac system. A well-designed ac/dc interface shall provide a controllable dc-link voltage, high power quality and high transient performance during faults and disturbances. It must also have low losses and low cost. Moreover, bi-directional power-flow capability may be desired if generation is present in the dc system, in order to transfer power from the dc system to the ac system during low-load, high-generation conditions in the dc system. Finally, galvanic isolation is necessary to prevent having a current path between the ac system and the dc system in case of a fault.

Different designs of ac/dc converters and their control algorithms have been studied for many years. However, little research has been presented regarding converters which can be suitable to interconnect an ac system with an LV dc power system.

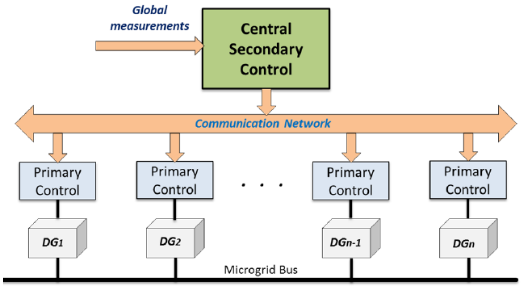

Fig.3: Centralized secondary control structure

The centralized approach requires point-to-point communication, which adds complexity to the system and compromises its reliability due to a single point of failure issue. Alternatively, distributed control methods have attracted a lot of interests in MG research community recently, due to their attractive features as they accommodate more reliable and sparse communication networks.

Distributed secondary control (DSC) is an alternative which avoids a single centralized controller and therefore improves reliability of the MG. The idea is to merge primary and secondary control together into one local controller. However, for proper operation, these local controllers need to talk with their companions, as shown in Fig.3 and Fig.4. Their conversation is typically processed through neighboring communication, resulting in a control system that is in literature generally referred to as distributed control.

The basic working principle of DSC is to exchange the information through the neighboring communication, by utilizing a distributed protocol and achieving a consensus, e.g. the average value of measured information. As opposed to frequency, voltages are local variables, implying that their restoration can be done either in selected critical buses, or on the total average level. In the latter case, DSC can be exploited to generate a common signal which is compared with a reference and passed through a local PI controller, which produces appropriate control signal to be sent to the primary level for removing associated steady state errors. It should be noted that the type of protocol, which is essential for making the secondary control distributed, influences the feasibility and performance of DSC.

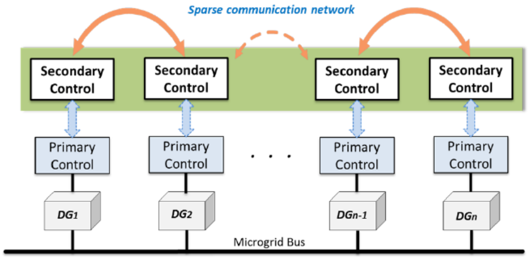

Fig.4: Distributed secondary control structure

The main functions of secondary control are to simultaneously shift the droop characteristics of associated DGs in order to perform restorations of voltage and frequency levels to nominal values while keeping active and reactive power shared between the units. Moreover, secondary control can encompass synchronization loop, as well as power quality regulation capability, optionally. The synchronization control loop can be considered in this level of control to seamlessly connect/disconnect the MG to/from the distribution ac networks. This loop is designed to synchronize the voltage, frequency and phase of MG with the main grid. In addition, global objectives regarding voltage control and power quality of the MG, such as voltage unbalance and harmonic compensation can be also considered as a function for secondary control.

IV DISTRIBUTED GENERATION

Large amount of electricity is harnessed from PV modules connected in an array configuration. PV systems are very dependable as it produces constant DC voltage. The PV configuration consist of power electronics devices to interface with the grid, the inverter circuit changes the DC to required AC voltage (50 Hz). But the power generation varies with changes in weather conditions and thus it is necessary to control the output to achieve maximum efficiency possible. Therefore, maximum power point tracking (MPPT) technique is used to extract maximum power produced by various PV modules under various weather conditions [2].

PV cells are semiconductor devices having the ability to absorb solar energy and convert it into usable electrical power. The basic construction consists of P-N junction diodes that convert the light incident on its surface into electrical energy. As the energy generated in PV cells is directly proportional to incident radiation. As seen the PV module consist of number of PV cells, enclosed within back sheet and front panel. The number of PV modules depends on the manufacturer but mostly a module consists of either 36 or 72 PV cells.

The wind system makes use of the gushing wind flowing across the globe due to the effect of earth's motion. It converts the kinetic energy of winds into mechanical energy which is used to generate electricity. But this mechanical rotation of blades is affected by the flow of wind, the electrical power is generated by a generator or induction motor using power electronic devices so as to connect to the microgrid. A wind system capable of generating power in the range of 10 W to 2.5 MW.

Energy storage System (EMS) is used to help the distribution systems at peak load as the consumption of electricity is high by the customers. Thus energy storage units are used in order to supply the required balanced power between the load and generation units. There by providing energy to the grid and other micro units having insufficient energy to manage the load. This problem arises as the demand increases in certain area and that excess requirement is difficult to meet by the distributed resources present in that area. In order to meet these additional requirements, the Energy storage system can be used to boost the system requirement in given period of time and avoid power outage. Energy storage system stores the excess power generated during off-peak time and during peak demand, when there is heavy utilization of power, the stored energy in EMS is used to feed the demand. Various technologies are implemented to store this energy in battery system but most commonly flywheels and electrochemical capacitor. Few other technologies used in this sector are compressed air energy storage (CAES) and superconducting magnetic energy storage system (SMES)Fuel cell makes use of chemical reaction to generate electricity. It is possible to generate electricity with minimum pollution by making use of Fuel cell as it makes use of hydrogen and oxygen to ultimately generate electricity and a harmless byproduct, water. Fuel cells provide efficient and clean energy using this energy conversion and thus regarded as renewable energy resources. In general, chemical reaction takes place inside the fuel cell and it makes use of two electrodes, an anode and cathode respectively and an electrolyte between them for the reaction to take place. Hydrogen is the basic fuel for the reaction to take place but it also makes use of oxygen and a catalyst to speed up the reaction [6].
As fuel cells are static in nature because of their quiet operation without noise or vibration and its simple modular construction makes them highly efficient. Thus fuel cell provides a cleaner, much efficient and flexible source of energy. A fuel cell consists of following components: Anode, cathode and an electrolyte between them. The Fig.4.5 shows the process of fuel cell operation:

Fuel cell and batteries work on same working principle and consist of electrochemical cells i.e. electrolyte between two electrodes. In order to generate electrical energy, both system use oxidation reduction methods to convert the stored chemical energy. But the type of material and its composition significantly differs for both of them. In a battery metal rods are immersed in acidic solutions. The fuel cell consists of 2 electrodes and an electrolyte for conduction and transportation of electrons. In a battery, the energy stored in electrodes is utilized by electrochemical reactions at certain potential difference. Thus, a battery has limited life time and can be used till complete depletion of electrode material doesn't take place.

V SIMULATION RESULTS

This Section presents detailed simulation results of the proposed control system. The simulated system is shown in Fig. 5.

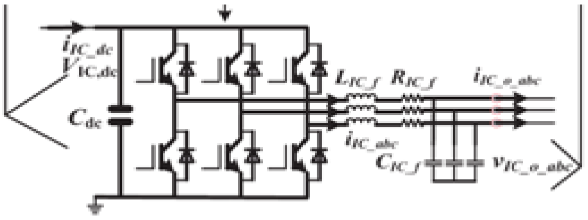

Fig.5: Schematic diagram of tested system

To validate the performance of the proposed control scheme for the interlinked ac/dc microgrids, the interlinked system, depicted in Fig.5 has been simulated in MATLAB/Simulink environment.

Case I:

In this case, both the ac and dc microgrids are initially experiencing a load demand of 2 kW each; this means that the microgrids are initially operating in light load condition. The interlinking converter operates in mode-3. Fig.6 shows the power responses and the per unit values of the dc side voltage and the ac side frequency. The operation mode is changed from mode-3 to mode-1. Upon reaching steady-state, the ac and dc source generations are noted to be the same at about 6 kW each.

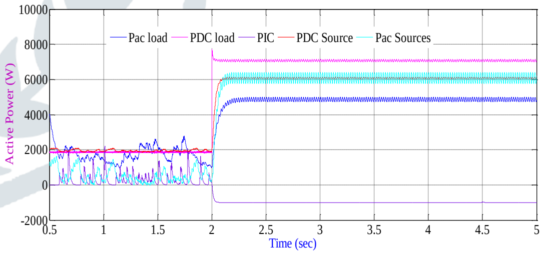

Fig.6: Power responses under case-I

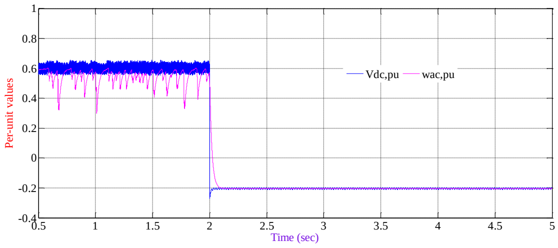

Fig.7: Per unit values under case-I

Case II:

Similar to case I, in this case, the initial load conditions are set to 5 kW for the ac microgrid and 7 kW for the dc microgrid. At t=3 s, the load demands of the ac and dc microgrids are changed to 8 kW and 6 kW, respectively. Then normalized values of the ac side frequency and dc side voltage are changed to -0.6 p. u and -0.2 p. u, respectively. The operation mode of the interlinking converter is changed from mode-1 to mode-2 now. Fig.8 shows the power responses and the normalized values of the ac side frequency and the dc side voltage. The ac and dc microgrids have the same normalized value of -0.4 p. u. as shown in Fig.9.

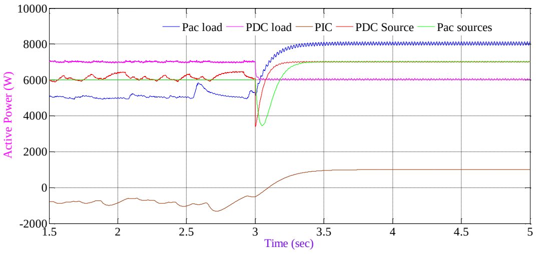

Fig.8: Power responses under case-II

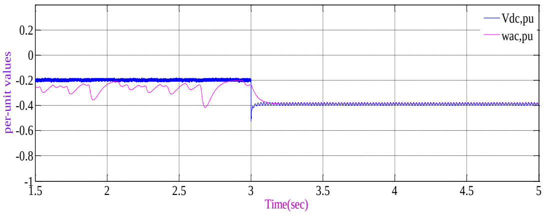

Fig.9: Per unit values under case-II

Case III:

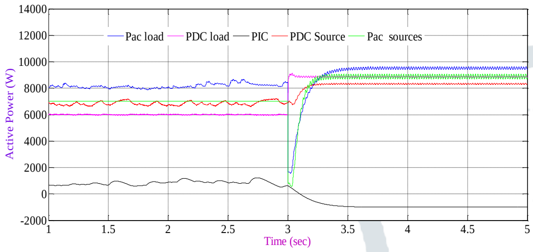

Fig.10: Power responses under case-III

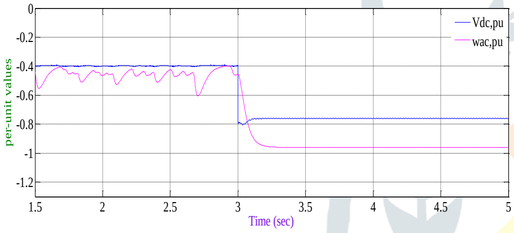

Fig.11: Per unit values under case-III

The over load condition of both the ac and dc microgrids is considered in this case. The initial conditions are set to 8 kW for the ac microgrid and 6 kW for the dc microgrid, respectively. That means the ac microgrid is initially operating in over load condition while the dc microgrid is operating in normal load condition. At t=3 s, the ac and dc microgrids are changed to 9.5 kW and 9 kW, respectively, which makes both the ac and dc microgrids over loaded. Fig.10 and Fig.11 shows the power and the normalized values of the ac side frequency and the dc side voltage.

VI CONCLUSIONS

In this paper the concept of DC microgrid, AC microgrid and hybrid ac/dc microgrid is analyzed and presented. The principles of primary control and secondary control methodology is explained and presented. The different types of distributed generation sources are presented. The simulation results are analyzed by simulating the proposed model in the environment of MATLAB/SIMULINK.

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