MODELLING DYNAMICS OF ELECTRIC AND ELECTRONIC COMPONENTS IN DC DISTRIBUTION GRIDS

Mai Tuan Dat and Johan Driesen

Department of Electrical and Electronics Engineering, KU Leuven

E-mail: tuandat.mai@esat.kuleuven.be

Abstract. DC power has recently become a potential option to contribute in future power systems. While the steady state analysis of DC distribution networks is becoming mature, dynamic analysis of DC grids is under-investigated. On the other hand, transient of DC network is different from AC networks due to a greater participation of electronics converters at generator sides and consumption sides. This paper describes modelling of components to carry out the general formulation of a DC distribution network..

Keywords: DC power system, DC grids, distribution networks, Renewable Energy Sources (RESs), converters, dynamic analysis.

INTRODUCTION

The continuously power demand at distribution grids dives distribution systems to operate more efficient. Nevertheless, quick development of Distributed Energy Resources (DERs) introduces a technical stress on the existing AC power networks because of unpredictable production of Renewable Energy Sources(RESs) particularly low-power top-roof PVs and wind turbines.

In order to overcome these issues, DC grid is proposed as a alternative solution at distribution power networks to integrate completely RESs, electronically loads and electric vehicles into DC power. DC technology in several applications such as telecommunication systems, data centres and digital entertainment devices currently has technical-economic advantages over traditional AC power. One of distinguishing features of DC grids is the requirement of electronic converters at both generator sides and load sides to regulate power as well as voltage in the networks.

While the analysis of DC distribution networks is becoming mature in steady states, the dynamic analysis is under-investigated to assess the reliability during transient [1]. Firstly, independent controllers of each converter should be taken into account of the analysis. Secondly, non-linearity of constant power loads causes incorrect results if the model linearization does not coordinate to all of sub-models of the system. Thirdly, grouping different sub-models which yields an overall system need to be defined for stability analysis and this task is not straightforward.

This paper propose a general methodology to build a whole formulation which consists of generators models, line models load models for DC grids. Different kinds of controlled converters situated at generator side and loads side are taken into account. Large signal analysis and result of a test case is to validate the transient of model in MATLAB.

MODEL OF COMPONENTS

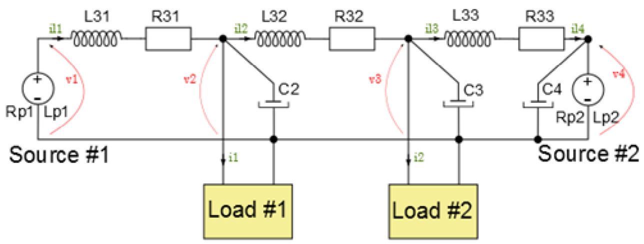

Figure 1. This is the figure caption for centred figure.

Model of generators is divided into 3 groups depending on the hardware topology. They are three phase AC-DC rectifier, single phase AC-DC rectifier and DC-DC converter. Controllers are integrated at each converter to regulate either voltage or current at bus. Due to the page limit in abstract, only the model of single phase DC converter is described as a demonstration in this abstract. The alternative representative model of DC-DC converter is briefly introduced which slightly different from [2] and suitable with the PV model in [3].

The generators operate at one of two functions which are either a slack bus or no-slack bus according to the architecture of a multi-terminal DC grid [4]. General dynamic equations of distributed generators and lines are described in Eq. 1 and Eq.2 respectively.

(1) $$\frac{d}{dt}x_{gen} = A_c \cdot x_{gen} + B_c \cdot i + S_c \cdot e_{source};\quad i_{gen} = C_c \cdot x_{gen}; v_{gen} = E_c \cdot x_{gen};$$

(2) $$\frac{d}{dt}x_{line} = A_n \cdot x_{line} + B_n \cdot u_v + G_n \cdot u_c + L_n \cdot u_{load};\quad i_{line} = C_n \cdot x_{line};\quad v_{conv_i} = E_n \cdot x_{line};\quad v_{bus} = H_n \cdot x_{line}$$

R-L Load: (3) $$\frac{d}{dt}x_{load} = A_l \cdot x_{load} + B_l \cdot u_l;\quad x_{load} = C_l \cdot x_{load}$$

Constant power Load (CPL):

A CPL is interfaced through a power electronic stage which is either DC-DC or DC-AC converter [5]. A feedback loop is required to control load demand described in [6]. A formula in [7] expresses a strict relation of consumption demand and converter component values as the following:

(4) $$P_L < V_l^2\left(\frac{C}{L_l}R_l + \frac{1}{R_0}\right)$$

where V_l : steady voltage across load;
$C;R_0$: capacitor and resistor in parallel with CPL respectively;
$L_l;R_l$: inductor and resistor connecting in series with the converter stage.

Battery energy storage source (BESS) is modelled as a bi-direction single DC-DC converter which is similar to a single phase DC generator in discharging mode. Conversely, the BESS is modelled as a current constant load in charging mode.

VALIDATION

In this abstract, a simple DC distribution system including 2 generators and 2 loads and 3 distribution lines are introduced. This simple model shown in Fig.1 is suitable to emphasis the idea. A more general model will also be presented in the full paper. A global model is obtained by linearizing sub-models and coupling them. The dynamic behaviour of each component is plotted and evaluated if there is any transient occurring at a specific bus. For instance, electric values of Source#1 are simulated and plotted in Fig. 2 when the load demand suddenly changes at the time of 2s.

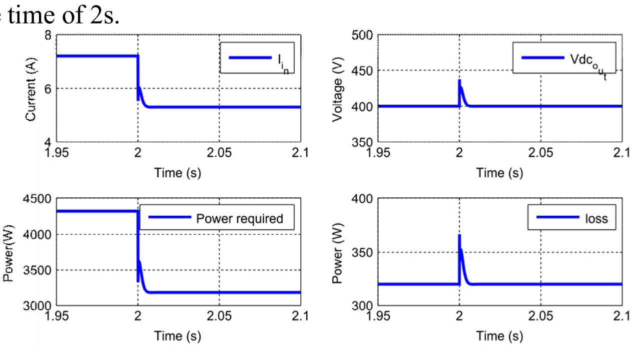

Figure 2. This is the figure caption for centred figure.

The proposed dynamic model is applied not only for transient analysis such as voltage, power, current but also for evaluating total losses of system caused by converters in DC grids. Because control parameters of converters mainly affect to the overall system, the dynamic model is also an alternative assessment tool to tune the parameters of converters.

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