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Procedia Engineering 15 (2011) 848 – 853

Procedia Engineering

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Advanced in Control Engineering and Information Science

Research on the control strategy of Bus Voltage of DC-Micro-grids utilizing bidirectional AC/DC converters

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Abstract

Design a small-family DC-Micro-grids system, analyzes its existence value and meaning. Regarding bus voltage of DC-Micro-grids, it has always been an important index of DC-Micro-grids, this paper puts forward a two-way AC/DC converter voltage current double closed loop control method. It is easier to control the voltage and current by using d-q shaft transformation decoupling. Build the system model with MATLAB/simulink software and simulate in the time domain cases in the Condition of Synchronization. The results prove that the method can very good control dc bus voltage stability, ensure system power safety.

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Selection and/or peer-review under responsibility of [CEIS 2011]

Keywords:DC-Micro-grids; DC bus voltage; bidirectional AC/DC converters; control strategy

1. Preface

With the development of technology of the wind, solar and other renewable energy efficient and cleaner fossil fuels new power generation technology，the distributed power generation system（DGS） is becoming a effective way to meet the growth of the load，reduce the pollution of the environment, improve the comprehensive utilization of energy efficiency and power supply reliability. DGS caused some negative effects to power system with using DGS in the great scope, such as single distributed generation access the high cost and control is more complex.

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doi:10.1016/j.proeng.2011.08.157

In addition, from the point of view of system, DGS is not controllable generating units. Therefore, the system is always trying to control the miniature generating system with the way of isolating and cutting machine. In order to impact of eliminate for larger system voltage and frequency. According to the literature, when power system is at fault, DGS must immediately stop operation, but it limits the operation mode of the distributed power generation and weaken its advantages and potential [1].

In order to integrate the advantage of distributed power generation of power grids, weaken the impact effect of the distributed power generation, give full play to the benefits and value of DGS, University of Wisconsin, Lassete etc, put forward the concept of micro nets [2].

Along with the application of the computer technology and the increase of electronic equipment, Modern buildings demand higher quality electricity. According to statistics, in the United States, only commercial buildings total power consumption of electricity is 35%. In these buildings, dc load (such as computer and network equipment, mobile phone charger, LED lighting equipment, even future car batteries) will occupy the important position. Based on distributed energy, the grid technology will be an effective way of power supply to solve modern architecture, such as photovoltaic building integrated is one of its application form. DC-Micro-grids [3] adopt form of dc power distribution. At the same time, it can transport directly dc power to dc load which demands for high quality electricity. Therefore, researching the DC-Micro-grids in a modern building is meaningful for whether dc power distribution could replace the traditional communication in future. Firstly, this paper describes the characteristics of DC-Micro-grids, then build a modern buildings can be used for the dc micro grid system (including distributed power, energy storage device and load), And control power and energy storage device with power electronics converter devices, finally in load change simulate and verify the feasibility of dc micro grid with MATLAB /Simulink.

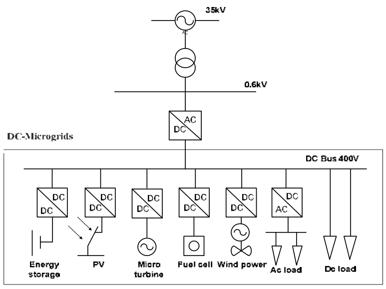

Fig.1 The structure of Dc micro grid

2. DC-Micro-grids

The emergence of DC-Micro-grids brought many convenient for distributed generation. If the distributed power is hardwired dc network, it will reduce the demand for control, it can also maximize distributed energy and save power electronics device. DC-Micro-grids has unique dc transmission lines, compared with the traditional communication system it won't produce large fault. No increase in costs, and avoids the exchange of AC-Micro-grids of reactive power and frequency, etc. The following description is a typical DC-Micro-grids structure, as shown in Fig.1 below

Compared with AC-Micro-grids, DC-Micro-grids have its unique advantages:

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(a)Dc micro power such as photovoltaic power generation and the fuel cell, can directly go into a dc power, not synchronous communication micro power can be connected through the AC/DC converter in DC micro power grid, and does not take into account frequency and voltage phase.

(b)Dc micro grid reduced line loss caused by reactive power and overcame natural power restriction [4].

(c)Power grid can directly transport the power to converter device, and can save spare loss, caused in the traditional network by exchange converts dc.

The figure shows, DC micro nets connected 0.6 kV exchange bus-bar through a DC/AC inverter, and connected with 35kV grid connections through a transformer. In DC-Micro-grids, Energy storage unit, photovoltaic power generation, turbine, fuel cells, etc connected with 400V DC bus Through the DC/DC converter. And wind power connected with 400V bus-bar through an AC/DC rectifier. AC load obtain electricity, Through the DC/AC inverter from DC bus. DC load whose rated voltage is 400V can be directly meet in bus-bar.

3. Selection of operating voltage level

For a network the most important parameters in dc network is operating voltage level. The parameters on the whole system exists many implications, so the voltage level should also decided by many factors, the following three factors worth key consideration

3.1. Cross-section of Conductor

Obviously, wire must have enough cross-sectional area. In not more than allow pressure drop conditions, pledged to certain transmit power to greater distance. The minimum cross-section, S, of the conductor is calculated by

$$s = \frac{\rho(2l)P}{\Delta u U^2} \tag{1}$$

Where ρ(Ω mm2/m) is the specific resistance of the conductor, (2l) (m) is twice the distance between the source and the consumption, P (W) is the transmitted power, △u is the maximum allowed relative voltage drop, and U (V) is the voltage of the source. As can be seen from (1), the cross-section is a quadratic inverse function of voltage.

3.2. Electrical insulation and protection

If considering the security of system operation, obviously should choose low dc voltage, In addition, low voltage device demands less insulation, and without using electrical isolation in AC/DC or DC/DC converter. So it can reduce greatly the cost. The voltage bands represent in Table 1. The higher voltages allowed for DC might be an advantage of DC networks over AC networks.

Table 1 Voltage bands for DC and AC voltages

An example of a column heading	Band1	Band2
AC	0-50V	50-1000V
DC	0-120V	120-1500V

3.3. System costs and the difficulty of design

Because in this network, there are a lot converters, so cost of converter occupies quite share in total cost. In order to reduce the cost of converter, we should as far as possible only use a tube in arms (IGBT) in each bridge in various converters .In addition, only using a tube in each bridge arm can also greatly reduces difficulty of design converter. Due to the different converter topology is different, therefore, under the same dc voltage grade conditions the bridge legs pressure drop is different. Therefore, the dc voltage grade is not too high (should be less than 1000V) to meet the different needs of converter.

To sum up, considering the dc voltage level should be too much to avoid increasing cost of electrical insulation and reducing compatibility, also cannot be too low to avoid distribution range was too short. In addition, also considering the system and the compatibility of the existing distribution network, this voltage level should be between 1000V in 400V. In addition, dc micro power grid connected with 380V utility, considering the inverter export voltage cannot be too low to ensure dc bus near 380V, so the voltage level should be 600V.

4. Control strategy of bus-bar voltage in networking cases

4.1. Power grid connection control unit

Control structure of Power grid connections by voltage units of outer ring and current control loop composition Consists of Voltage controlling in outer ring and current controlling in loop. Fig. 3 shows. Output of PI of Voltage controlling ring decided the Reference values of current control loop:$I_{ac, ref}$. Make the actual value of dc bus voltage reference U_{dc} follows the $U_{dc, ref}$. Current controlling ring has adopted d axis and q shaft decoupling control. Output of PI controls PWM modulation of three-phase AC/DC converter. So the ac current can follow its references.

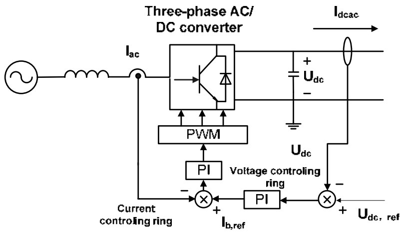


Fig. 3 Three-phase AC/DC converter

4.2. voltage current double closed loop control method

System three-phase voltages is symmetrical, shown below

$$e_a = E_m \cos(\omega t) \tag{2}$$

$$e_b = E_m \cos(\omega t - \frac{2}{3}\pi) \tag{3}$$

$$e_c = E_m \cos(\omega t + \frac{2}{3}\pi) \tag{4}$$

follows equation can be obtained by fig.4

$$e = Ri_m + Li_s + u_r \tag{5}$$

$$C\dot{u}_{dc} = i_{dc} - i_L \tag{6}$$

In the equation, $e = [e_a, e_b, e_c]^T$, $i = [i_{sa}, i_{sb}, i_{sc}]^T$, $u_r = [u_{ra}, u_{rb}, u_{rc}]^T$ .Through the Park transform, we can get the current equation under rotating coordinates

$$L\dot{i}_{sd} = -Ri_{sd} + \omega Li_{sq} + E_m - u_{rd} \tag{6}$$

$$L\dot{i}_{sq} = -\omega i_{sd} + Ri_{sq} - u_{rq} \tag{7}$$

We can get ac, dc power balance type by Ignoring loss

$$p = \frac{3}{2}(e_d i_{sd} + e_q i_{sq}) = \frac{3}{2}E_m i_{sd} = u_{dc} i_{dc} \tag{8}$$

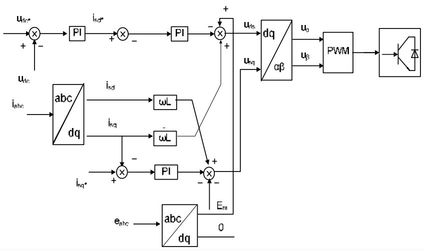
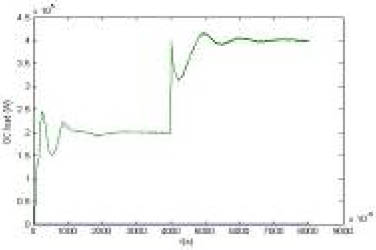
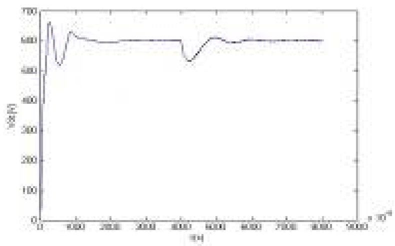


Fig.4 PWM rectifier control

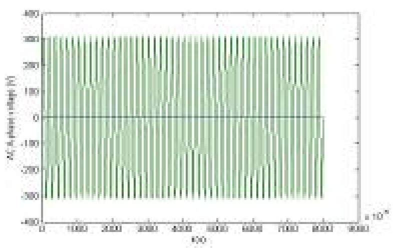
5. The simulation analysis



(a) Dc load increasing



(b) Dc bus voltage



(c)The change of A phase voltage of AC load

Fig.5. The changes of system voltage when dc load is increasing

Build the system model with MATLAB/simulink software and simulate in the time domain cases under the condition of the load increasing. By the following figure shows that the dc load increased to 40kW from the original 20kW in 0.4s (Fig .5(a)). In Fig. 5(b) and Fig.5(c), we can see the circumstances of change of DC bus voltage and A phase voltage of AC load. According to the simulation result, through the two-way AC/DC converter voltage current double closed loop control method, DC bus voltage can be controlled in the near 600V. At the same time the phase voltage of AC load is also controlled in the near 380V (RMS), the changes caused by the DC load don't make a major influence on the AC load.

6. Conclusion

According to the characteristics of DC-Micro-grids, the paper constructs a dc power supply micro system which used in modern architecture. The system contains photovoltaic power generation unit, battery energy storage unit, ac and dc load units, and the controller unit. The system can not only be run in parallel with the great power grid through the AC network connected unit, but also can run isolated through disconnecting the webmaster separation. Build the system model with MATLAB/simulink software and simulate in the time domain cases under the condition of the load increasing, proof that through a appropriate control strategy, all kinds of load in the modern buildings can get high quality power supply, and also can keep DC-Micro-grids operating steady. The above conclusion for the DC-Micro-grids will be used in modern architecture in the future, and better meet the future architectural power supply system in energy, environmental protection and power quality needs, provides a good theory and simulation basis.

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