DC MICROGRID THREE PHASE AC - DC CONVERTER CONTROL SCENARIO

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ABSTRACT Modern technology is changing rapidly it's completely occupying all the streams and it occupied electrical engineering Life too. It's our responsibility to build a reliable system to provide more efficient and effective. This basic idea makes us do DC microgrid three-phase AC to DC Converter control strategy. This paper aims to decrease the fluctuations and improve the system adaptability new voltage and current double loop control strategy is proposed to solve the DC microgrid bus voltage fluctuation caused by loads fluctuation, parameters perturbation and unbalanced three-phase power supply. Firstly, the dq axis mathematical model of three-phase AC-DC bidirectional converter in DC microgrid is analysed and established, and then the controllers are designed according to the dq axis mathematical model. The outer loop is a voltage loop based on variable gain linear extended state observer (VGLESO) and sliding mode theory. VGLESO can not only effectively overcome the problem of peak output of traditional high-gain LESO in the initial stage of operation, and ensure that the system has good start-up characteristics, but also quickly track and compensate the total disturbance of the system without additional current sensors. The inner loop is a current loop based on adaptive PI, which can eliminate the influence of system parameters perturbation on bus voltage and improve the system's adaptability. Under the action of the inner and outer loops, the system has good dynamic and static characteristics. Finally, the feasibility and correctness of the control strategy are verified by Simulink.

Keywords: DC microgrid, AC to DC Converter, Feedback loop, Bus voltage fluctuations

1. INTRODUCTION

With the promotion and popularization of distributed energy grid connection and the increasingly strict requirements of users on the power quality of terminal power supply, the traditional AC distribution network gradually shows its deficiencies in the ability to accept new energy and power quality.

The circuit topology of a typical DC microgrid is shown in fig.1 Compared with the AC distribution network, the use number and frequency of power electronic devices of the DC microgrid are much smaller than that of the AC distribution network, which reduces the energy conversion link of the distributed power grid connection and the cost of grid connection. In addition, the DC microgrid does not need to track reactive power and phase, which improves the controllability of the system, the reliability of power supply and the economy of operation [4], [5].

How to suppress the fluctuation of the bus voltage of the DC microgrid to ensure the stable operation of the system is one of the hot issues in the field of DC microgrid research. When the DC microgrid is connected to the AC power grid, the control of the bus voltage is often achieved by optimizing the control system of the DC microgrid three-phase AC-DC bidirectional converter. However, the loads carried by the three-phase AC-DC bidirectional converter of the DC microgrid are usually complicated and changeable, that is, the external interferences are time varying. Some parameters on the AC side of the converter, such as the equivalent resistance and inductance of the line, cannot be accurately measured. During use, these parameters often have different degrees of aging, and the parameters are perturbed. Therefore, in order to ensure that the converter tracks the reference signal quickly and accurately, the controller is required to have good dynamic and static characteristics and robustness to the time-varying loads and the perturbation of parameters.

At present, the control strategies of three-phase AC-DC converters in DC microgrids are mainly divided into linear and nonlinear control strategies. Among them, the linear control strategy is mainly based on linear PI, although PI control has been widely used in industry and achieved good control results. However, the PI controller based on the deviation control principle is difficult to overcome the control time lag caused by the capacitive element, which cannot meet the dynamic characteristics requirements of the power system [9], [10]. With the continuous development and improvement of the research on nonlinear control theory, nonlinear control strategies such as repetitive control, deadbeat control, fuzzy logic control, etc. have also been applied to different degrees in DC microgrids. Reference [11], [12] designed a repetitive controller for the three-phase AC-DC converter in DC microgrid, which improves the system's robustness to periodic disturbances. However, due to the inherent periodic delay of repetitive control, when the system is disturbed, at the moment, the control signal cannot act on the controlled object in time, which reduces the dynamic characteristics of the system. Reference [13][15] designed a fuzzy logic controller for power bidirectional AC-DC converter in DC microgrid, and applied it to the current inner loop in converter control system. This control strategy reduces the requirements for the mathematical model of the controlled object and improves the system's adaptability to the loads. But the realization of fuzzy logic control requires complex fuzzy operations, which increases the complexity of the system and construction costs.

The use of distributed generation with the increasing number of renewable energy systems that directly deliver DC power such as PV systems, wind generation, or battery storage, combined with the advance in DC technology enables a direct, more efficient and sustainable use of the energy, eliminating losses associated with energy conversion. The growing use of DC distribution systems in data centres, residential buildings, lighting, transportation, and other applications, has prompted the need for definition and standardization of the supplied voltage and the power quality requirements to enable the reliable operation of equipment in DC networks, as well as in AC public distribution systems.

Low-voltage DC distribution networks (LVDCs) are regulated in the European Union by the Directive 2006/95/EC. This directive enables DC voltage to be used in electricity distribution systems up to 1500 V.

During recent years, a number of IEC international standards have been developed for LVDC systems, including electricity generation, transmission, distribution, storage and applications such as lighting, household appliances, and electric equipment for transportation, among others. The most comprehensive overview of the IEC related work in LVDC.

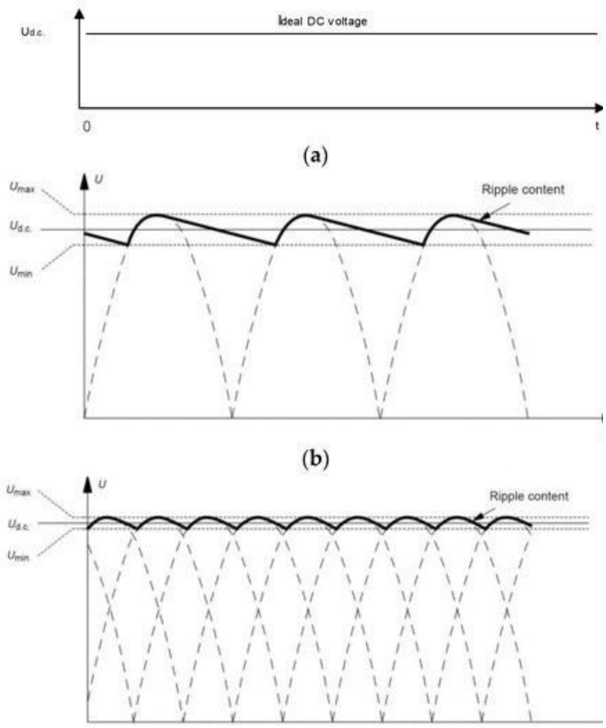
In spite of being power quality an important issue in the design of DC distribution networks, at present there is no standard norm for power quality in this type of distribution network.

Independent of the future development of LVDC systems, there is a need for definition and measurement of power quality indices in LVDC networks. In this sense, the international committees in charge of maintenance of European Standard EN 50160 “Voltage characteristics of electricity supplied by public electricity networks” and of the IEC 61000-4-30 “Power quality measurement methods” have started some preliminary studies in order to extend the scope of these two standards to low-voltage and medium-voltage DC public distribution networks in their future revisions.

At present, there are only a few proposals in the technical literature for definition and measurement of indices for relevant power quality disturbances in DC networks. Some of the first attempts in this subject have defined indices for harmonic/inter harmonic distortion and for ripple evaluation. Power quality indices in the time and frequency domains, such as average, median, and percentile variations of DC components, as well as peak-to-peak and r.m.s. variations, and low frequency distortion indices, have been defined for assessing power quality in DC microgrids. Finally, other important power quality concerns in DC networks, such as fault currents, inrush currents and grounding.

DC Voltage Characteristics

There are two main types of DC generation: DC sources that produce ideal or quasi-ideal DC voltage, such as PV, DC generators, and battery storage; or AC/DC conversion (single-phase or multi-phase rectifying) that produces DC voltage with a ripple content caused by feed-through from the AC input section to the DC output. **Figure 2** shows some examples of different voltage waveforms produced by different DC power sources.



(a)

(b)

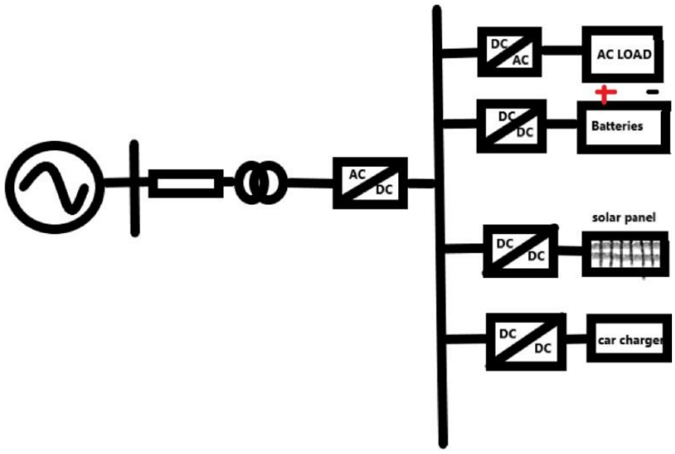
(c)

Figure 1. DC voltage shapes produced by DC power sources: (**a**) Ideal DC voltage, (**b**) single-phase AC/DC conversion, and (**c**) three-phase AC/DC conversion.

As can be seen in Figure 2, DC voltage shapes can be very different, requiring precise definitions of DC voltage characteristics as well as methods for their measurements, both under steady state and non-steady state conditions. It is necessary to clearly define the expected characteristics of the electricity supplied in DC distribution systems under normal operating conditions.

Implementation of Dc microgrid three phase ac to dc converter control strategy based on double loop Operation: by Boning wu This research paper by the author presents the implementation details of a dc mirogrid converter control strategy based on double loop that used to reduce fluctuation and to reduce power electronic devices in the circuit. So, the reliability of the system increases Flexibility and economic dispatching of AC/DC distribution networks by S. Gao This research paper presents the implementation of ac to dc distribution networks Implementing the voltage level sequence of future distribution operation: by J. Duan This research paper by the implementation of Dc distribution network of voltage level sequence.

2. BLOCK DIAGRAM



Block Diagram

Figure 2

Compared with the traditional double loop : in this paper, VGLESO and SMC are used to improve the voltage outer loop of three-phase AC-DC converter in DC microgrid. By seeing the block diagram we can understand that input is taken from an ac source and a transformer is used to convert voltage into requiring levels of voltage by stepping up or down and the converter is connected to the grid it converts ac to dc and further it is given to dc micro-grid, from dc micro-grid we connect different converts and given to the different loads as shown in fig 1

3. MATHEMATICAL MODEL OF DC MICROGRID AC-DC CONVERTER

The circuit topology of the three-phase AC-DC bidirectional converter of the DC microgrid is shown in _g. 2 In order to get a more concise mathematical expression of the AC-DC converter, combined with the actual power system, make the following assumptions:

a) The AC side power supply is an ideal three-phase power supply.

b) The AC system is a symmetrical three-phase system.

c) The power switch has no transition process, no power loss, and no dead zone.

In the picture: *ea*; *eb*; *ec* is the equivalent three-phase AC power supply; *ia*; *ib*; *ic* is the AC side line current; *R* is the line equivalent resistance; *L* is the line equivalent inductance; *C* is the DC side voltage stabilizing capacitor; *Udc* is the voltage across the DC side capacitor; *idc* is DC current at both ends of the side; *ic* is the current _owing through the ends of the capacitor; *iL* is the current _owing through both ends of the load; *RL* is the equivalent load of the DC microgrid; *Si* is the switch function.

According to the circuit topology of the three-phase AC-DC converter of the DC microgrid, the mathematical model of the three-phase AC-DC bidirectional converter in the three-phase static coordinate system can be obtained by Kirchhoff's law. The AC side model is equation (1).

$$\begin{cases} L\dfrac{di_a}{dt} = e_a - Ri_a - (U_{dc}S_a - \dfrac{U_{dc}}{3}\sum\limits_{i=a,b,c} S_i) \\ L\dfrac{di_b}{dt} = e_b - Ri_b - (U_{dc}S_b - \dfrac{U_{dc}}{3}\sum\limits_{i=a,b,c} S_i) \\ L\dfrac{di_c}{dt} = e_c - Ri_c - (U_{dc}S_c - \dfrac{U_{dc}}{3}\sum\limits_{i=a,b,c} S_i) \end{cases}$$

The DC side model is equation (2).

$$C\frac{dU_{dc}}{dt} = i_aS_a + i_bS_b + i_cS_c - i_L$$

In the above equation:

$$S_i = \begin{cases} 1, & i \text{ phase upper swith is on} \\ 0, & i \text{ phase bottom swith is on} \end{cases} \qquad i = a, b, c$$

The current on the AC side is nonlinear and strongly coupled, it is not conducive to the design of the controller.

Therefore, in order to simplify the controller design, it is necessary to use coordinate transformation to change the three-phase stationary coordinate system into a two-phase rotating coordinate system.

The transformation matrix from the three-phase stationary coordinate system to the two-phase stationary coordinate system is equation (4).

$$C_{3s/2s} = \frac{2}{3}\begin{bmatrix} 1 & -\dfrac{1}{2} & -\dfrac{1}{2} \\ 0 & \dfrac{\sqrt{3}}{2} & -\dfrac{\sqrt{3}}{2} \end{bmatrix}$$

The transformation matrix from the two-phase stationary coordinate system to the two-phase rotating coordinate system is equation (5).

$$C_{2s/2r} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$$

In the above equation: _ is the angle that the *d*-axis leads the *a*-axis.

The mathematical model of three-phase AC-DC converter in two-dimensional rotating coordinate system can be obtained by simultaneous equation (1-5).

$$\begin{cases} L\dfrac{di_d}{dt} = e_d - Ri_d - U_{dc}S_d + \omega Li_q \\ L\dfrac{di_q}{dt} = e_q - Ri_q - U_{dc}S_q - \omega Li_d \end{cases}$$

$$C\frac{dU_{dc}}{dt} = \frac{3}{2}(S_di_d + S_qi_q) - i_L$$

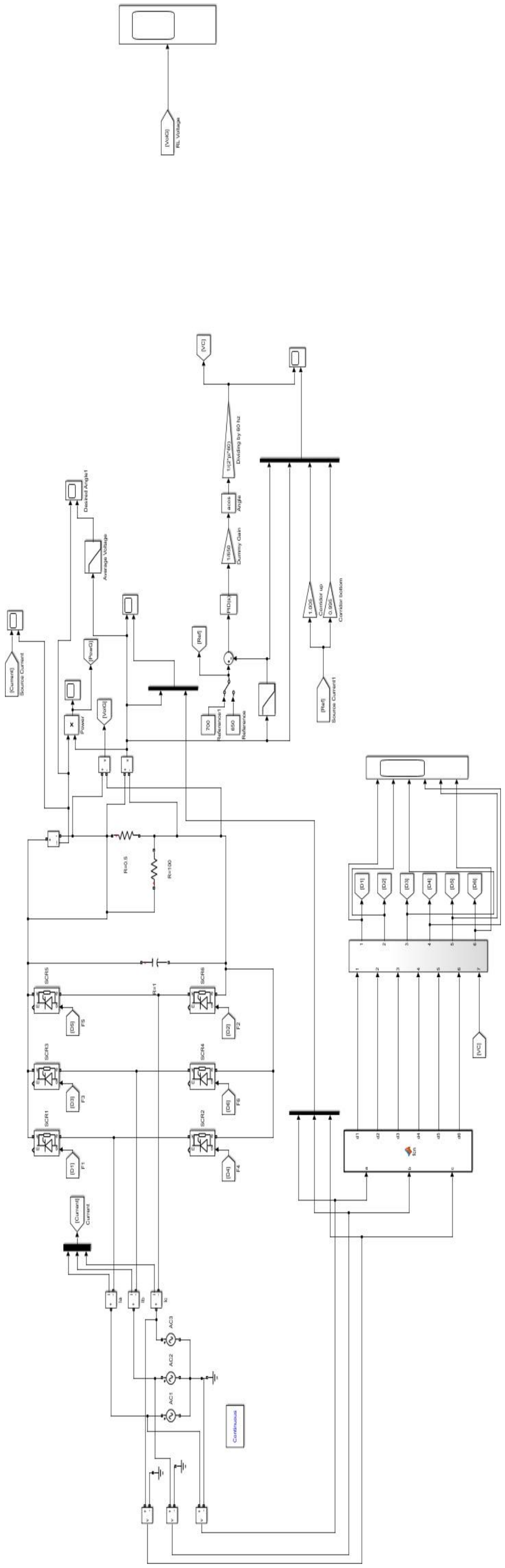
Both sides of equation (7) take derivatives of time at the same time, and then combine equation (6) to get equation (8).

$$\frac{d^2U_{dc}}{dt^2} = \frac{3}{2LC}\sum_{k=d,q}(S_ke_k - S_ki_kR) - \frac{3}{2LC}\sum_{k=d,q}(S_kU_k) + \frac{3\omega}{2C}S_di_q - \frac{1}{C}\dot{i}_L - \frac{3\omega}{2C}S_qi_d$$

In the above equation: *ed* ; *eq* are the components of the AC side voltage vector of the three-phase AC-DC converter on the axis of the rotating coordinate system; *id* ; *iq* are the components of the AC side current vector of the three-phase AC-DC converter on the axis of the rotating coordinate system; *Sd* ; *Sq* are the components of the AC side switching function of the three-phase AC-DC converter on the axis of the rotating coordinate system.

From equation (8), we can see that the AC-DC bidirectional converter in the DC microgrid can be regarded as a second order system. For a measurable second-order system, the state variable and total disturbance of the system can be observed by designing an appropriate linear expansion state observer.

4. CIRCUIT DIAGRAM



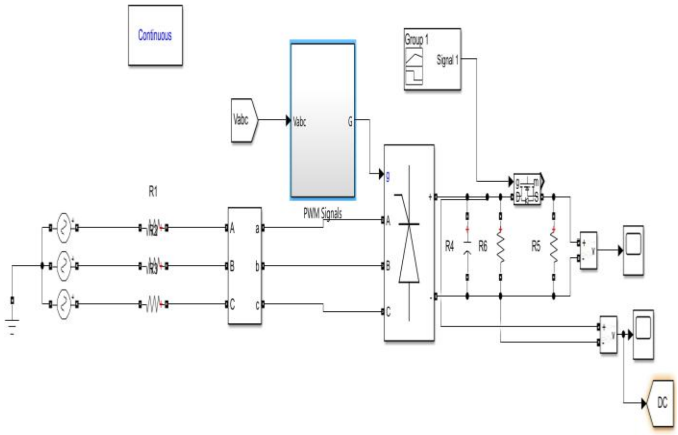
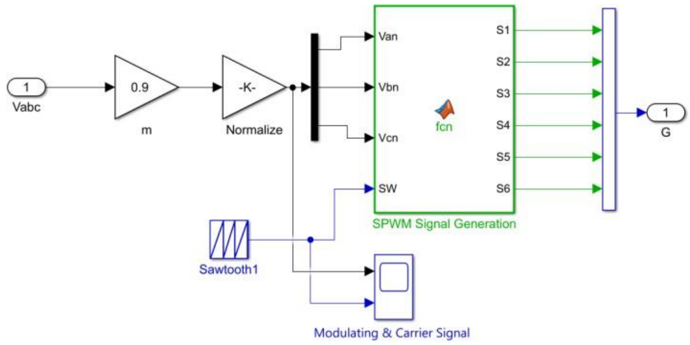


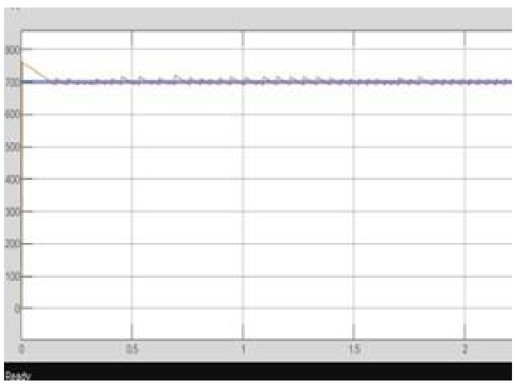
Fig 3: Simulation Design of Proposed System



STEADY ON SYSTEM STARTUP CHARACTERISTICS

It can be seen from the figure that, on the one hand, the rise time of the system under the control of the two controllers is the same, but the overshoot of the two controllers is quite different.

Among them, the overshoot of the system under the control of VGLESO and SMC is almost zero, while the overshoot of the system under the control of LESO and SMC is 7%.



On the other hand, when the bus voltage reaches the rated voltage 700V, the system under the control of VGLESO and SMC is basically maintained near the rated voltage, almost no transient process, while the system under the control of LESO and SMC needs a series of transition processes to maintain near the rated voltage.

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5. SIMULATION RESULT OF DC MICROGRID

Technical Description

A. VGLESO Inhibitory Effect on LESO Initial Peak

Figure shows the tracking curves of VGLESO and traditional high gain LESO to the system state variable U_{dc}. It can be seen from the figure that under the premise of ensuring the same tracking accuracy, VGLESO effectively weakens the initial peak of high gain LESO.

It is not conducive to measure the value of the state variable U_{dc}. Because the U_{dc} has no clear physical meaning. Thus, the state variable U_{dc} is converted into a current i_c flowing through the two ends of the capacitor. According to equation (46), we know that the value size of *ic* reflects the change of U_{dc}.

B. Study on System Start-Up Characteristics

Figure shows the waveform of bus voltage when bidirectional AC-DC converter is started with different control strategies. It can be seen from the _gure that, on the one hand, the rise time of the system under the control of the two controllers is the same, but the overshoot of the two controllers is quite different. Among them, the overshoot of the system under the control of VGLESO and SMC is almost zero, while the overshoot of the system under the control of LESO and SMC is 7%. On the other hand, when the bus voltage reaches the rated voltage 700V, the system under the control of VGLESO and SMC is basically maintained near the rated voltage, almost no transient process, while the system under the control of LESO and SMC needs a series of transition processes to maintain near the rated voltage. In conclusion, the start-up performance based on VGLESO and SMC controller is better than that based on LESO and SMC controller.

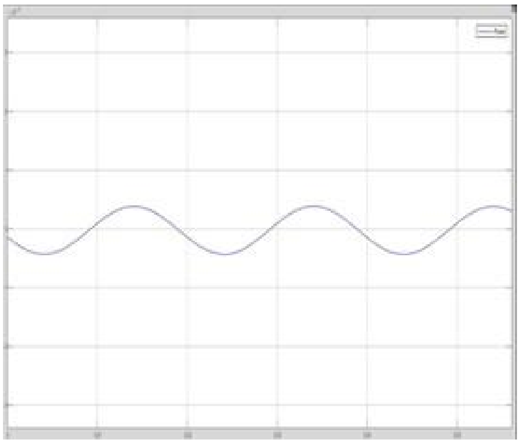
C. Study on The Influence of The Voltage Fluctuation of The Bus When the Load on The Dc Side Suddenly Reduces by Half

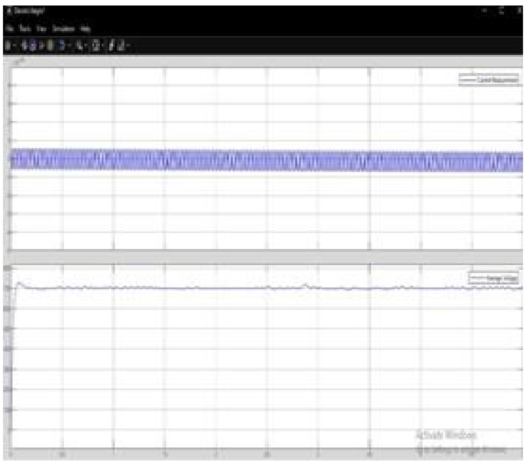
In order to study the influence of sudden load halving on bus voltage, the simulation experiments under two conditions are carried out.

a) Condition 1: The system operates stably before 0.5s. At 0.5s, the resistive load is suddenly halved, and the bus voltage fluctuation diagram is shown in fig.13.

b) Condition 2: The system operates stably before 0.9s. At 0.9s, the constant power load is suddenly halved, and the bus voltage fluctuation diagram is shown in fig.14.

When the load current suddenly decreases, since the voltage across the capacitor cannot be abrupt, the change of the current *idc* on the DC side lags behind the change of the load current *iL*. So, the current *ic* flowing across the capacitor should be reduced. According to equation (48), the bus voltage will drop.





7. CONCLUSION

Aiming at the mathematical model of AC-DC converter in DC microgrid, considering the initial peak value of high gain LESO, a VGLESO is designed to track and estimate the state variables and total disturbances of the system. And the convergence of the VGLESO is proved. On this basis, the variable gain active disturbance rejection sliding mode control strategy is designed by combining the sliding mode theory with VGLESO. In addition, aiming at the problem that the traditional PI controller is too sensitive to the system parameter perturbation, the adaptive PI control law based on the *fal* function is designed.

The simulation results show that, compared with the high gain LESO, the VGLESO designed in this paper cannot effectively weaken the initial peak phenomenon, but also maintain the high observation accuracy of the high gain LESO. The control strategy based on VGLESO and sliding mode theory can realize the feedforward control without additional current sensors, which improves the dynamic quality of the control system. At the same time, compared with the traditional linear PI controller, the adaptive PI controller can overcome the influence of parameter perturbation on the bus voltage. Finally, because the design of the two controllers
does not depend on the structure and parameters of the system, they have strong robustness and portability, especially for the nonlinear system which is difficult to establish accurate mathematical model.

Although VGLESO weakens the output peak of LESO at the initial moment and enhances its engineering practicability, its parameter designs are based on the working experience of researchers. It is not conducive for the large-scale industrial promotion of this technology. Therefore, the next work is to give the parameter setting criteria of VGLESO.

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