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Modified Voltage Control Strategy for DC Network with Distributed Energy Storage using Fuzzy Logic Controller

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Abstract

Within a direct current (DC) distribution network, a revolutionary strategy for distributed energy storage (DES) is presented in this research. To what extent can the voltage stability and dependability of a DC network be improved via the use of a flexible voltage control strategy? Furthermore, under the shown virtual inertia and capacitances, the parameters of the AC and DC networks are briefly evaluated. The suggested control method for DES, which may be found in either an AC microgrid or at the network's terminal bus, is built on the interactive qualities that make it possible for the DES to react to both voltage and frequency changes in the utility's AC grid. To alleviate the stress of voltage degradation in a DC network, a cascading droop management approach with fuzzy is proposed for DES in a DC microgrid. Compared to other methods already in use, the simulation results showed that this approach worked well to increase voltage stability in a DC distributed network.

Keywords;Voltage stability, AC and DC networks, fuzzy logic, voltage regulation, and distributed energy storage. 1.

INTRODUCTION;Reaching Europe's lofty renewables goals requires intensive investigation, development, and implementation of efficient and cost-effective connectivity alternatives for offshore wind. Voltage Source Converter (VSC) High Voltage Direct Current (HVDC) transmission is becoming more popular in both academic and industrial applications of offshore wind integration [1]. When compared to the more conventional Line Commutated Converter (LCC), VSC-HVDC has certain clear benefits in terms of both control and layout. The traditional AC distribution network faces significant hurdles in plug-and-play performance and operational stability as the penetration of renewable resources and microgrids increases. Therefore, medium voltage DC (MVDC) distribution networks are gaining increasing interest in the future of smart grid design due to the need for power system operation and the success of DC technology in certain specialised applications, such as large-scale data centres and shipboard systems [2, 3]. The DC voltage is crucial to the reliable functioning of the system since it affects variables like reactive power and phase synchronisation. These days, there are two basic types of general voltage control strategies: master-slave control and voltage droop control. One voltage source converter (VSC) is designated as the slack terminal in the master-slave control method, and its job is to monitor the DC voltage and maintain a steady reference value regardless of fluctuations.

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With this control method, all power source converters are controlled in accordance with the system's state, allowing for precise functioning [4, 5]. However, high-speed and high-bandwidth communication are necessary to the master-slave control paradigm. Therefore, this control system necessitates a redundancy layout. However, the control frame has to be updated when new generation sources become available, making this technique unfriendly to their use. In order to adjust the output power of controlled converters, the droop control technique [6–10] leverages the voltage signal without requiring any additional connection. For multi-terminal DC (MTDC) systems, [11] proposes a coordinated droop control approach that allows for proportionate power dispatch between HVDC stations connected to the grid. An adaptive droop control approach [12] is studied for its potential to reduce the voltage drop and load current sharing discrepancy with the introduction of a figure of merit index, thus compensating for the voltage mismatch. In order to govern more involved aspects and reduce the impact of droop control, [13, 14] offer a hierarchical control method that assigns distinct control targets into many tiers.

Within a direct current (DC) distribution network, a revolutionary strategy for distributed energy storage (DES) is presented in this research. To what extent can the voltage stability and dependability of a DC network be improved via the use of a flexible voltage control strategy? Furthermore, under the shown virtual inertia and capacitances, the parameters of the AC and DC networks are briefly evaluated. Proposed is a control method for DES, which can be implemented either at the AC microgrid or the network terminal bus, and which takes into account the interactive characteristics of the two networks so that the DES can adapt to the simultaneous changes in voltage and frequency that occur in the utility AC grid and the DC network. To alleviate the stress of voltage degradation in a DC network, a cascading droop management approach with fuzzy is proposed for DES in a DC microgrid.

DIRECT CURRENT DISTRIBUTION NETWORK VOLTAGE CONTROL STRATEGY

In the same way as alternating current (AC) distribution networks are often divided into three distinct forms, direct current (DC) networks may be broken down into either a radial structure, a ring structure, or a dual or multi-terminal structure [26]. The standard two-terminal DC network is shown in Fig. 1 for this paper's purposes. Substations at the terminal are linked to a 4 kV DC network through isolation transformers and a voltage source converter (VSC), both of which have the capacity to electrically isolate their respective circuits and convert alternating current (AC) to direct current (DC). DC cables are used to connect the following three devices to the network.

DC/AC microgrid

This component often includes distributed generators (DGs), energy storage (ES) systems, and local loads, the power of which is regularly adjusted to account for changes in environmental conditions like wind speed or solar irradiance. The microgrid modifies the amount of electricity used from the DC network to compensate for fluctuations in demand. Microgrids have the potential to regulate distribution network voltage in certain cases.

Dual-voltage (AC/DC) loads:

The aggregate loads have a one-way flow of power, hence they are seldom taken into account while regulating voltage. The loads may be shed passively to relieve the strain on the network, barring any unforeseen emergencies.

Unified ES functioning on its own:

This auxiliary DC voltage support system is plug-and-play and may be placed at any node. To account for voltage fluctuations, the controller of each ES unit takes node voltage signals as an input.

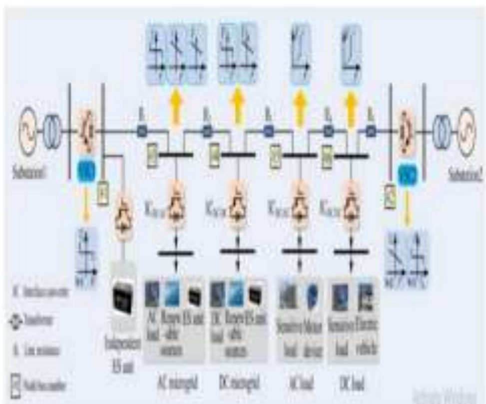


Fig.1 The schematic diagram of DC network with dual terminal.

CONTROL STRATEGY

Conventional Control Strategy for Network Bus Voltage:

According to the classification of network elements mentioned above, the nodes connected with different types of elements show different operating characteristics. Fig. 1 shows the control strategies of different types of nodes in the DC distribution network. More specifically, in this section, the voltage control of the nodes with different elements will be investigated. 1) Terminal nodes. At the terminal of DC network, the AC/DC converters are utilized to offer an access to AC grid for the network. These converters work under one of three control strategies, namely, the constant voltage control, the droop control (V-P) or the constant power control, as shown in in Fig. 2. No matter which topology the DC network adopts, at least one of the terminal converters should adopt the constant voltage control to ensure there is a slack terminal in the system.

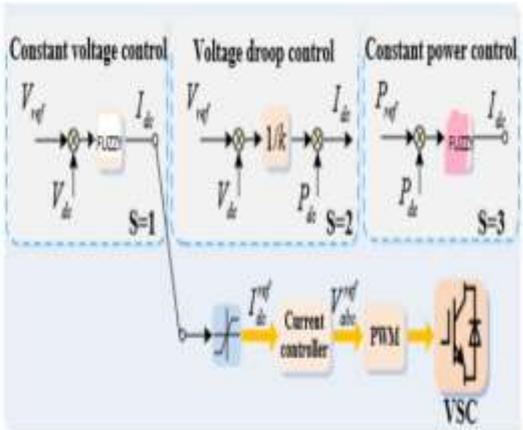


Fig.2 various control strategies for terminal converter.

2) The nodes connected with aggregating loads. These nodes work in a constant power consuming mode. In some emergency cases, some loads may increase the power demand within a narrow range. 3) The nodes connected with microgrids. The microgrids connecting to DC distribution network can output power if the distributed generators have more power that the local loads cannot be consumed, and the interface converters (ICs) are controlled in the similar way as the terminal VSC. When there is a lack of power demand in microgrid, its net power Pnet is defined as

$$P_{net} = \sum P_{load} - (\sum P_{DGs} + \sum P_{ESs})$$

The control strategy for ES unit of microgrid can be classified into two modes. In Mode I, ES unit will not beactivated during connection, all the net power demands will be satisfied by absorbing energy from distribution grid, and ES units should take part in power adjustment only when the microgrid is isolated from grid, or in the situation that power flow is beyond the capacity limitation, denoted as PN IC, of ICs. This mode can be described by

$$\begin{cases} P_{dc}^{ref} = \sum P_{load} - \sum P_{DGs} \text{ and } \sum \Delta P_{ESs} = 0, \text{ when } 0 \le P_{net} \le P_{IC}^{N} \\ P_{dc}^{ref} = P_{IC}^{N} \text{ and } \sum \Delta P_{ESs} = P_{net} - P_{IC}^{N}, \quad \text{when } P_{net} \ge P_{IC}^{N} \end{cases}$$

Flexible voltage control with DESS:

In this paper, the comprehensive demands of the operating characteristics and control aims for different interfaces are taken into account. As shown in Table I, the power flowing from microgrids or AC utility grid to the DC network is considered in the condition of charge, and thus the inverse power flow is in the discharge state. The inner traits describe the variation of the electrical characteristics of elements interfaced to the DC network, such as the frequency of AC grid and the voltage of DC grid. The control objectives of this paper are described in this Table, where the absolute frequency deviation |Δf | is limited within 1%, and the DC voltage variation is within 5%. ΔVdc and ΔVbus represent the voltage variation of DC microgrid and DC distribution network, respectively. It should be noted that when some severe power events occur and the power quality cannot be guaranteed, which means the above delta values are beyond their limits, the common emergency measures like load shedding or microgrid disconnection will be activated to keep the stability of the DC distribution system.

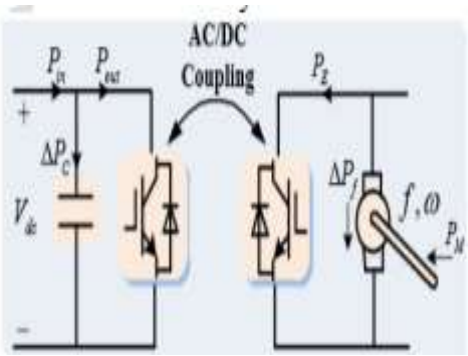


Fig.3 The power relationship between AC and DC.

ROUGH APPROACH

Since its introduction, fuzzy logic has seen a rise in both its quantity and range of uses. Cameras, camcorders, washers, and microwave ovens are just a few examples of consumer devices that use these systems, but there are also industrial process controls, medical instruments, decision-support tools, and investment portfolios. The term "fuzzy logic" itself requires clarification before one can grasp the reasons for its increasing popularity. You may use the term "fuzzy logic" in two separate contexts. With this definition in mind, we may say that fuzzy logic is a logical system that builds on multivalve logic. However, in a broader sense, the theory of fuzzy sets, which deals with classes of objects with fuzzy bounds and membership that is a question of degree, is virtually equivalent with fuzzy logic (FL). From this vantage point, fuzzy logic as commonly understood is a subset of fl. Fuzzy logic is conceptually and practically distinct from more conventional multi-gate logical systems, even in its narrower definition. Fuzzy logic, when used within the context of fuzzy Logic Toolbox, should be taken to mean FL, or fuzzy logic in its broadest definition. In Foundations of Fuzzy Logic, the core concepts of FL are laid forth in a way that is both accessible and illuminating. It may be added that the fundamental idea behind FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. Much of FL may be seen of as a means of doing computations not with numbers but with words. Words may lack the precision of figures, but they more closely reflect the way humans think. In addition, the cost of solving a problem may be reduced by taking use of the tolerance for imprecision in computing with words. The fuzzy if-then rule, or fuzzy rule, is another fundamental notion in FL that is crucial to the vast majority of its applications. Although rule-based systems have been used extensively in the field of Artificial Intelligence (AI), what is lacking in these systems is a method for dealing with fuzzy consequents and fuzzy antecedents. The fuzzy rule calculus provides this technique in fuzzy logic. A language that may be named Fuzzy Dependency and Command Language has its foundation in the calculus of fuzzy rules (FDCL).

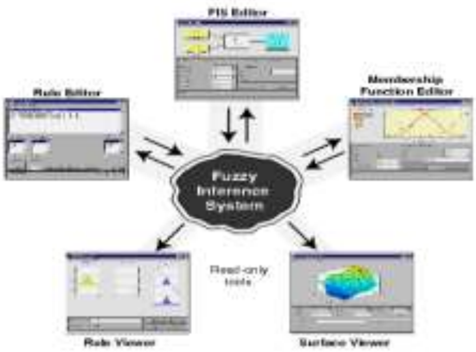
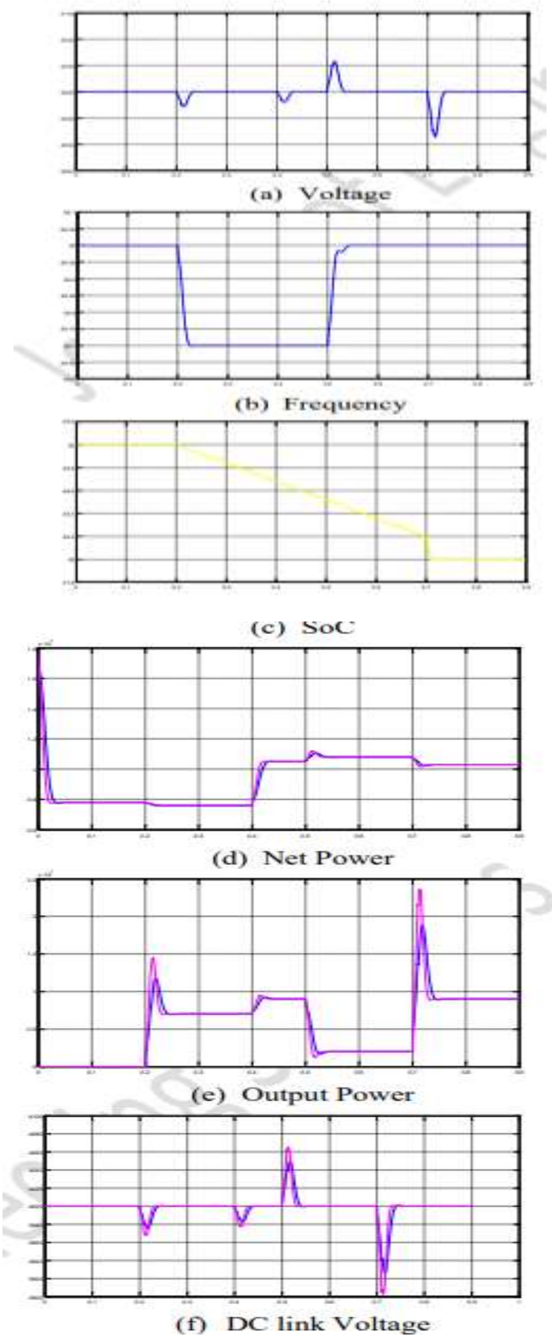
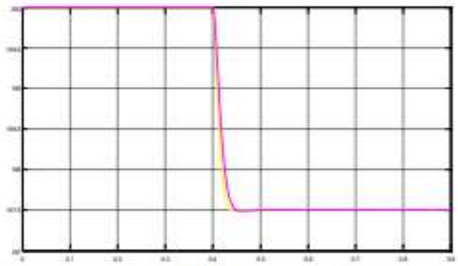


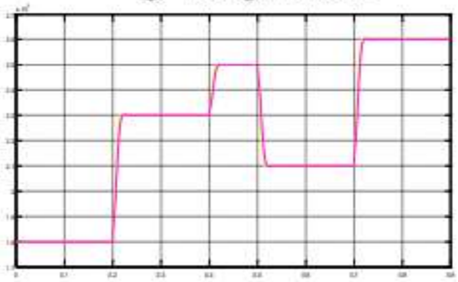
Fig.4 The Primary GUI Tools of the Fuzzy Logic Toolbox

SIMULATION OUTCOMES



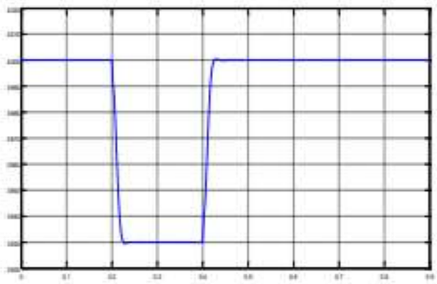


(g) Voltage variation

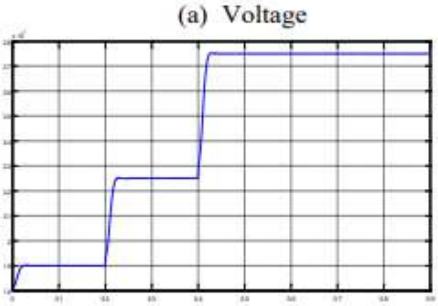


(h) VSC active power

Fig.5 Simulation results of the DC microgrid for case 1with fuzzy



(a) Voltage



(b) Power

Fig.6 Simulation results of DC bus #1 for case 2 with fuzzy

CONCLUSION

The research herein suggests a way of flexible voltage regulation that improves the controllability of DES units in a DC distributed network. When applied to different networks, the suggested method always provided optimal performance. Additionally, under the shown virtual inertia and capacitances, the parameters of the AC and DC networks are briefly evaluated. An AC microgrid or network terminal bus is where the suggested DES control strategy would be implemented. This would allow the DES to react to changes in both the DC network's voltage and the utility AC grid's frequency. To alleviate the stress of voltage degradation in a DC network, a cascade droop control approach with fuzzy is proposed for use with DES in a DC microgrid. When compared to other methods already in use, the simulation results showed that this approach was the most effective for enhancing voltage stability in a DC distributed network.

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