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

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Abstract

Important new methods for using distributed energy storage (DES) in direct current (DC) distribution networks are presented in this research. Which is the most adaptable voltage control approach for enhancing DC network voltage stability and reliability under a wide range of disturbances? In addition, the shown virtual inertia and capacitances are evaluated briefly, together with the AC and DC network parameters. The suggested control method for DES, which may be found in either the AC microgrid or the network's terminal bus, is built around the interactive qualities that make it possible for DES to react to both the voltage fluctuation of the DC network and the frequency shift of the utility AC grid. To ease the burden of DC network voltage decline, a cascading droop control approach using fuzzy logic is proposed for DES in 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.

INTRODUCTION

Key to meeting Europe's lofty renewables goals is the exploration, development, and deployment of effective, cost-efficient connectivity options for offshore wind. High voltage direct current (HVDC) transmission using voltage source converters (VSCs) is a popular topic in offshore wind integration research and practice at present [1]. When compared to the more conventional Line Commutated Converter (LCC), VSC-HVDC has some noteworthy benefits in the areas of control and design. 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 direct current (MVDC) distribution networks are gaining popularity in the design of future smart grids due to the need of power system operation and the success of DC technology in certain specialized applications, such as massive data centers and shipboard systems [2, 3]. The DC voltage is crucial to the reliability of the system's functioning since it has nothing to do with other variables, such as reactive power or phase synchronization. Master-slave control and voltage droop control are two of the most common types of general voltage control systems used today. If you're using a master-slave control technique, one of your voltage source converters (VSCs) will be designated as the slack terminal and tasked with monitoring DC voltage fluctuations and maintaining a constant reference value

When all power source converters are controlled in accordance with the system's current state, as is the case with this control method, precise functioning is possible [4, 5]. However, high-speed and high-bandwidth communication is necessary to the master-slave control paradigm. Therefore, this control system necessitates a redundancy layout. In addition, the control frame needs to be updated when new generation sources become available, making this approach unfriendly to their use. The droop control strategy [6, 10] regulates the output power of controlled converters without requiring any form of communication. To facilitate proportional power dispatch among grid-side HVDC stations, a coordinated droop control strategy is proposed for MTDC systems in [11]. An adaptive droop control method [12] is studied for its potential to reduce the voltage drop and load current sharing difference via the introduction of a figure of merit index, thus compensating for the voltage mismatch. In order to regulate more involved elements and reduce the impact of droop control, [13, 14] propose a hierarchical control strategy in which different control goals are assigned to several levels.

Important new methods for using distributed energy storage (DES) in direct current (DC) distribution networks are presented in this research. Which is the most adaptable voltage control approach for enhancing DC network voltage stability and reliability under a wide range of disturbances? In addition, the shown virtual inertia and capacitances are evaluated briefly, together with the AC and DC network parameters. 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 ease the burden of DC network voltage decline, a cascading droop control approach using fuzzy logic is proposed for DES in DC microgrid.

VOLTAGE CONTROL STRATEGY OF DC DISTRI-BUTION NETWORK

DC networks, like AC ones, may be broken down into three distinct categories: There are three types of networks: 1) the radial network, 2) the ring network, and 3) the dual or multi-terminal network [26]. The standard dual-terminal DC network is shown in Fig. 1 for this paper's purposes. Substations at the terminal are linked to the 4 kV DC network by means of isolation transformers and the voltage source converter (VSC), both of which have the ability to electrically isolate their respective circuits and convert alternating current (AC) to direct current (DC). Using direct current (DC) wires, the network is interfaced with the following three devices. A combined alternating current and direct current microgrid: The power of these components, which typically include distributed generators (DGs), ESs, and local loads, is periodically adjusted to account for changes in environmental factors like wind speed and photovoltaic irradiance. Microgrids may regulate the amount of electricity drawn from the DC network to meet fluctuating demand. Microgrids are increasingly being utilized to regulate distribution network voltage. Conventional alternating current and direct current loads: The aggregate loads have a unidirectional power flow and are thus not very relevant to voltage regulation. Loads may be shed passively to relieve network strain, barring exceptional circumstances. any node can host a standalone ES unit, which provides DC voltage redundancy or auxiliary support. In order for the controller of an ES unit to account for voltage fluctuations, it must receive the node voltage signal as an input.

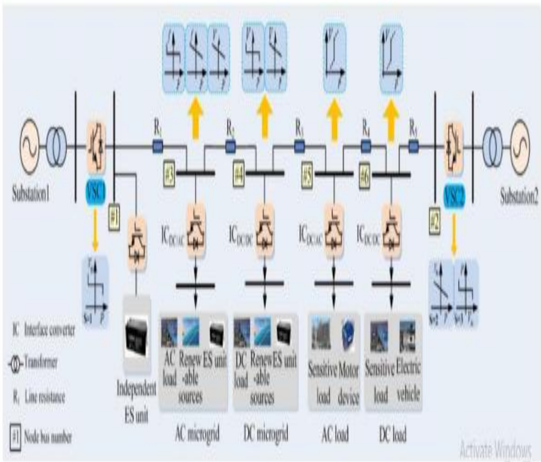

Fig.1 The schematic diagram of DC network with dual terminal.

CONTROL STRATEGY

Traditional Method of Network Bus Voltage Regulation 3.1: Nodes that are linked to various types of network elements exhibit varying behaviors, as described by the aforementioned classification. Different types of DC distribution network nodes' control strategies are illustrated in Fig. 1. Here, we'll focus on exploring voltage regulation at the nodes using a variety of components. Foremost, the apex of a network. At the DC network's endpoint, AC/DC converters provide connection to the alternating current (AC) grid. As can be seen in Fig. 2, these converters can operate in one of three different control modes: constant voltage control, droop control (V-P), or constant power control. To guarantee a slack terminal exists in the system, at least one of the

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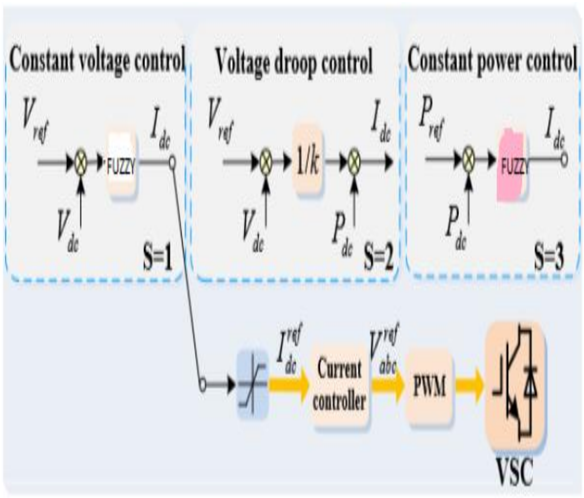
terminal converters must use constant voltage control, regardless of the DC network's topology.



Several terminal converter control schemes are shown in Fig. 2. Load aggregating nodes, n. 2. These nodes are always drawing electricity. Some loads may increase the power consumption within a small range in the event of an emergency. 3. The microgrid nodes that are interconnected. If the distributed generators produce more energy than the local loads can use, the microgrids connected to the DC distribution network can send the excess power to the grid. The interface converters (ICs) are managed in the same way as the terminal VSC. Microgrid's net power Pent is defined as when there is excess supply over demand.

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

In a microgrid, the ES unit's control strategy falls into one of two camps. In Mode I, the ES unit is not activated during connection, and the microgrid's net power needs are met through energy absorption from the distribution grid. The ES unit should participate in power adjustment only when the microgrid is disconnected from the grid, or when power flow exceeds the capacity limitation, or PN IC, of the ICs. For a definition of this mode, see:

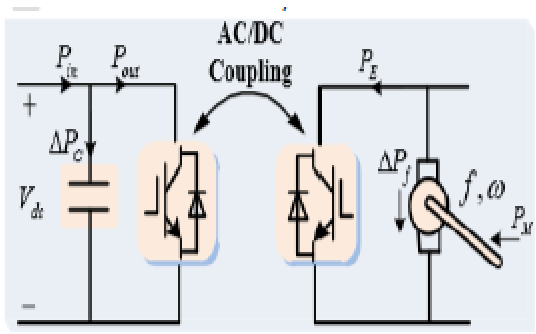
Fig.3 The power relationship between AC and DC.

FUZZY METHOD

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

Flexible voltage control with DESS

In this study, we consider the overall requirements of various interfaces in terms of operational characteristics and control goals. Power going from a microgrid or the utility grid's AC to a DC network is indicated in Table I as being in a charge state, while power flowing in the other direction is shown as being in a discharge state. The inner characteristics characterize the shifts in the DC network's electrical parameters, such the frequency of the AC grid and the voltage of the DC grid, that are interfaced with the element. This table summarizes the control goals of this study, which include maintaining a DC voltage variation of no more than 5% and an absolute frequency deviation of no more than 1%. The DC microgrid's voltage fluctuation is denoted by Vdc, while the DC distribution network's voltage variation is denoted by Bus. Note that when catastrophic power events occur and the power quality cannot be assured, as shown by the aforementioned delta values exceeding their limitations, standard emergency actions, such as load shedding or microgrid disconnection, are initiated to maintain the DC distribution system' stability.



The number and range of fields where fuzzy logic has been used have grown substantially in recent years. Digital cameras, video recorders, washing machines, and microwave ovens are just a few examples of consumer devices that include this

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technology. Other examples include industrial process control, medical instruments, decision-support systems, and portfolio selection. You need to know what is meant by "fuzzy logic" before you can appreciate why its usage has increased. The term "fuzzy logic" may refer to two distinct concepts. Strictly speaking, fuzzy logic is an extension of multivalve logic that may be thought of as a logical system. On the other hand, in a more general sense, fuzzy logic (FL) is almost equivalent with the theory of fuzzy sets, which is concerned with classes of objects with fuzzy borders and where membership is a question of degree. From this vantage point, fl includes just the most specific forms of fuzzy logic. Even in this narrower sense, fuzzy logic is conceptually and practically distinct from more conventional multivalve logical systems. Fuzzy logic, when used within the context of fuzzy Logic Toolbox, should be taken to mean FL, or fuzzy logic in its broadest possible sense. Foundations of Fuzzy Logic is an excellent introduction to the fundamental concepts behind fuzzy logic (FL). The idea of a linguistic variable, where the values are words rather than numbers, is central to FL, it could be said. Much of FL may be seen of as an approach to computation that uses words rather than numbers. Words are less accurate than numbers but more in line with our natural intuition. Further, the cost of solving a problem may be reduced by taking use of the tolerance for imprecision while calculating with words. The fuzzy if-then rule, or fuzzy rule, is another fundamental concept 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 handling fuzzy consequents and fuzzy antecedents. As a mechanism, the calculus of fuzzy rules is provided by fuzzy logic. In what could be called the Fuzzy Dependency and Command Language, fuzzy rule calculus plays a central role.

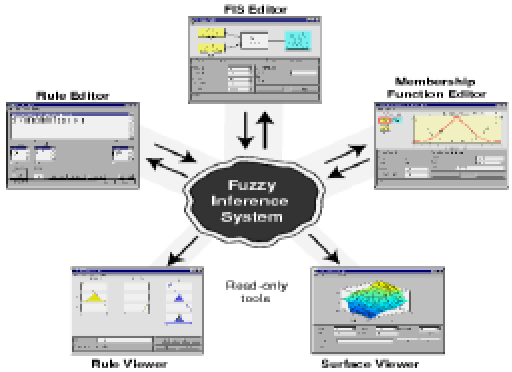
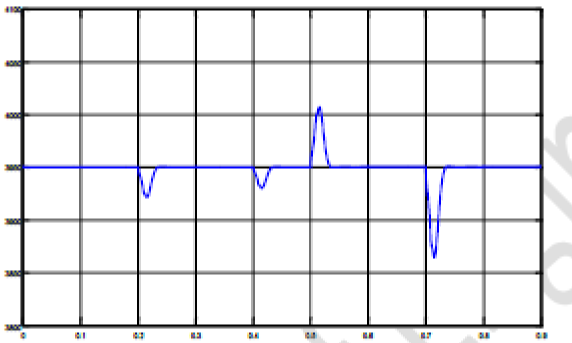
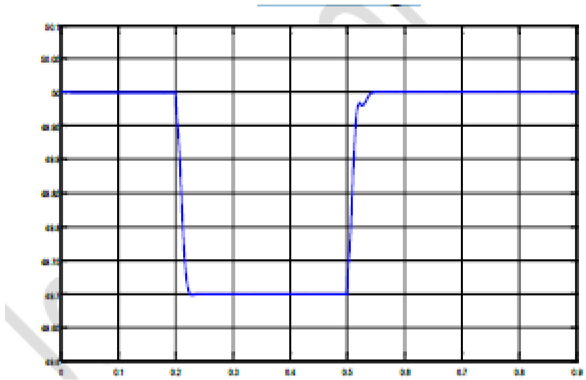


Fig.4 The Primary GUI Tools of the Fuzzy Logic Toolbox

SIMULATION OUTCOMES



Voltage



(b) Frequency

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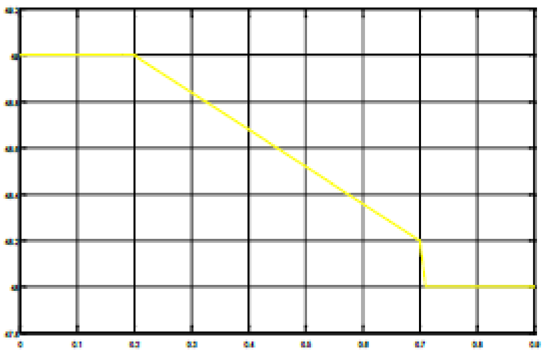
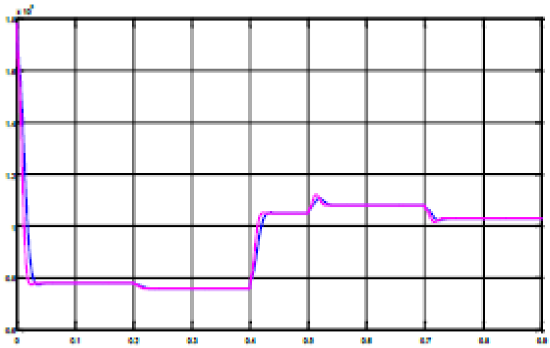
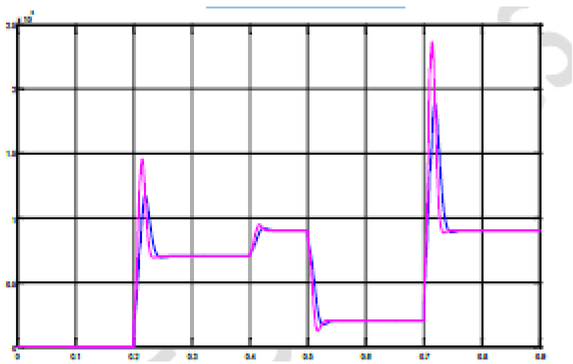


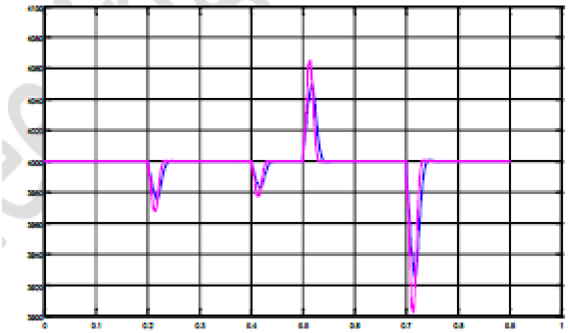
(c) SoC



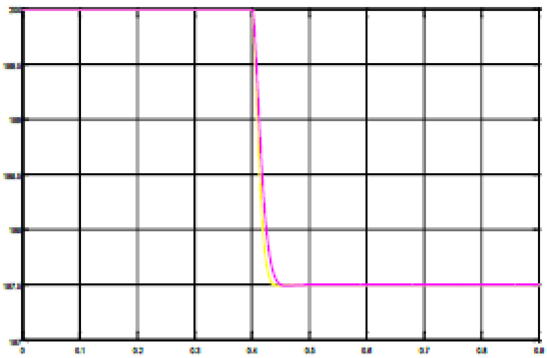
(d) Net Power



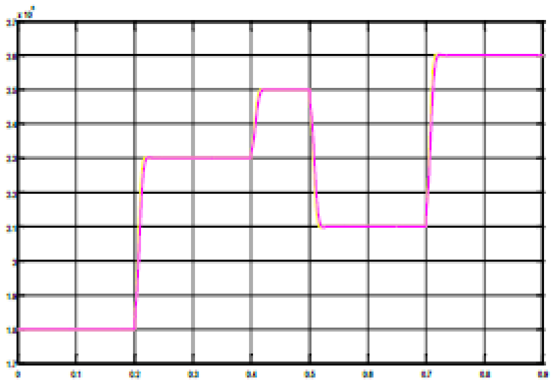
(e) Output Power



(f) DC link Voltage



(g) Voltage variation



(h) VSC active power

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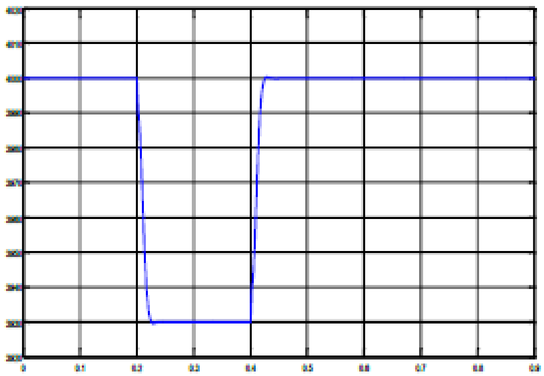
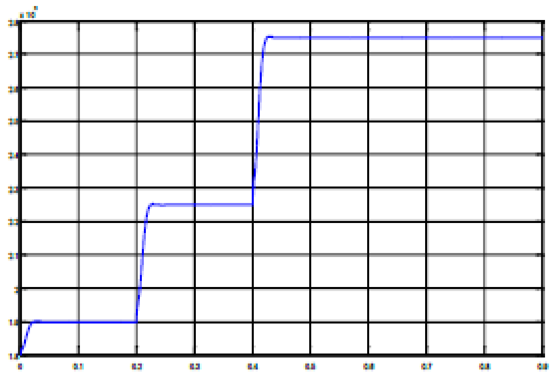
Fig.5 Simulation results of the DC microgrid for case 1with fuzzy



Voltage



(b) Power

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

CONCLUSION

The research herein suggests a method of flexible voltage control that improves the controllability of DES units in a DC distributed network. When applied to different networks, the suggested strategy always provided optimal performance. In addition, the shown virtual inertia and capacitances are evaluated briefly, together with the AC and DC network parameters. 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 ease the burden of DC network voltage decline, a cascading droop control approach using fuzzy logic is proposed for DES in 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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