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Hybrid Energy Storage and Generator Control Monitoring Systems for Renewable Farms and its Applications

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Abstract: The interaction of offshore wind with the VSC-HVDC system may cause broadband oscillations, threatening the safety and stability of offshore wind power integration. This paper proposes a broadband oscillation monitoring system suitable for offshore wind power in light of the lack of detection ability of broadband oscillation, lack of processing ability of non-stationary signals, and difficulty in real-time to meet the monitoring needs of existing measurement technologies, builds a key technical system, and establishes a mathematical model based on local mean decomposition. Finally, the broadband monitoring system's hardware architecture was designed, providing technical assistance for making maximum use of offshore wind energy resources and achieving "carbon compliance and More electric aircraft are becoming the development trend in the aviation military industry, as high-power density generators and battery performance increase. Directed energy weapons efficiently increase the technical and tactical performance of the equipment at the tactical level. The pulsed power electronic loads, on the other hand, create greater demands on the stability of independent electric power distribution systems (EPDSs). This research focuses on the voltage stability of a 270 V high-voltage DC power system and offers a hybrid power storage classification base on droop management and a brushless DC motor smoothing technique that delivers a superior smoothing effect under high peak-to-average ratio pulsed power loads. The PLECS simulation model simulation results verify the efficiency of the suggested combined control strategy in improving the stability of the aircraft's EPDS with different loads.

Keywords: *AC, Hybrid, DC, Electric power distribution systems, Renewable Energy*

1. Introduction

The electric power distribution system (EPDS) of an airplane is a critical component in making contemporary aircraft safe, smooth, and comfortable to fly. Currently, programs such as the ICAO Global Coalition for Sustainable Aviation demand that aircraft emit less pollution and noise, and all-electric power for airplanes is one possible solution to this environmentally benign operation[1]This notion is driving more electric aircraft , and the electrification of electric motors and even propellers places increased demands on the stability of the onboard EPDS [2]. The onboard EPDS has gradually transitioned from traditional hydraulic and pneumatic systems to electrical systems in recent decades, and the trend of aircraft electrification is noteworthy. However, the electric driving of several electric motors and even aircraft thrusters raises the onboard EPDS's nonlinear load to dynamic load ratio, posing further problems to generator capacity and voltage stability. Furthermore, due to competition for the electromagnetic spectrum and the requirement for anti-unmanned warfare weapons, high-power pulse loads represented by Directed energy weapons are gradually evolving toward numaturization, mobility, and soft-kill trends [3], making them more suited for military use as conventional loads for multi-electric aircraft. As a result, independent power system leveling technology for complicated loads with high peak-to-average ratios must be investigated. Power management of the energy storage structure and the power-consuming load can reduce system power requirements and optimize the power transmission path, lowering overall losses. Power management strategies that are often utilized include predefined control, fuzzy logic control, and droop control. as well as clever algorithm control [4] Predetermined rule control [5] indicates that the distribution system ensures the functioning of high-priority loads and sheds non-major loads as needed, but it does not address the issue of continual load changes. The empirical design control logic underpins fuzzy logic control [6].The more rules and the higher the accuracy, the stronger the fuzziness. It will, however, increase control complexity and computation time. Based on droop control theory, virtual droop control [7] adjusts the output power of the converter by adjusting the droop coefficient. Intelligent algorithm control [8] is mostly dependent on developing mathematical models of optimization issues to meet control objectives, which necessitates a large amount of processing power.

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The virtual impedance droop control method with secondary voltage compensation is used in this paper. The remains of this work is prearranged as follows. The PLECS simulation of the onboard EPDS employed in this paper is explained in the virtual droop control theory and the proposed control mechanism are introduced in compares control outcomes obtained under various peak-to-average ratio loads and control parameters.

2. Wind power.

Along with its progress, the flexible VSC-HVDC transmission system with technological and economic feasibility is becoming mainstream in the long-distance transmission of offshore wind power. However, the interaction between the control device and the wind turbine generators VSC-HVDC may result in oscillations with frequencies ranging from several Hz to over a thousand Hz [9].The Fig 1 prominent problem of oscillations at a wide frequency becomes a key element inhibiting the practical consumption of renewable energy from wind power due to its serious collision on the security and constancy of the influence arrangement as the size of storm form expands. The current research on wide-area monitoring of wide-frequency oscillation is centered on modeling analysis and suppression tactics [10]. Simultaneously, non-stationary signals are monitored and analyzed by existing equipment schemes, which are generally carried out within the linearization and harmonization are approximated analyses. As a result, the physical process of actual signal creation cannot be explained without taking into account the dynamic process of signal amplitude and frequency, imposing certain constraints. [11] Proposes a method for detecting oscillations based on the flatness of the spectrum rather than the magnitude of its energy. To recognize the fluctuation mode characteristics from extensive group alternation signal, [12] proposes a information determined method recognition approach or expansive group oscillation signals.

To deal with the aforementioned conditions, a monitoring model is built based on elements of broadband signal capture, data transmission, and processing. Furthermore, non-stationary signals are processed for establishment using a mathematical model based on the restricted indicate breakdown. Furthermore numerical examples demonstrate its precision and efficacy. Finally, a wide-area monitoring system suitable for wide-frequency oscillation of offshore wind power is developed based on the proposed hardware architecture scheme, which will provide strong support for maintaining power grid stability during grid connection with offshore wind power[13].

3. Power System

Appropriate models should be constructed first in order to examine the stability of an onboard power supply. The onboard EPDS is modeled in PLECS in this paper[14]. Unlike other power electronics simulation software, such as Multisim or Simulink, PLECS is highly compatible with a wide range of power simulation software and offers a variety of functions, such as integrating modules and writing special device characteristic equations, resulting in high flexibility and expandability[15]. A high peak-to-average ratio aircraft power system model with a high-voltage DC motor, a three-phase AC motor, low voltage linear loads, and a pulse power load is developed in this part. A brushless DC motor, a battery energy storage system, and a super-capacitor energy storage system are included in its energy supply and storage components. A Module Generator to imitate the characteristics of an aircraft generator driven by the engine, the generator module consists of a brushless DC generator, an unregulated rectifier, a buck converter, and a huge driving torque with fixed mechanical damping. Under these conditions, the speed is primarily dictated by engine power and mechanical load torque, which is always kept high. Module for batteries because of its great stability and safety, lithium iron phosphate batteries have been employed in aircraft. This study chooses three parallel battery groups, each consisting of lithium iron phosphate batteries connected in series to make an aviation battery module[16].

Battery options thevenin circuit model is used to model the battery, and the charge state of a single cell is solved using the ampere-time integration approach. Its open route electrical energy is thus planned using the observed condition of charge unlock circuit energy function, to which the cell parameters are fitted using [17].

Module Super capacitor the parameters of the Maxwell BCAP0310 single super capacitor are provided in the similar concept is shown by connecting three groups in parallel and nine single super capacitors in each group in series.

4. Power Distribution

A pulse load, a high-voltage DC motor, a low-voltage linear load, a three-phase AC motor, and the matching converters and inverters comprise the load module. The Fig 2 controlled current source temporarily accesses the pulse load for equivalency. When no pulse load is attached, the average load power is roughly 2.78 kW under the premise of voltage stability. When a pulse load is connected, it rises to around 16.13 kW[18].Depicts the load power spectrogram of these two states, and the peak-to-average power ratio (PAPR) of this load system is secondary Voltage Compensation Droop Control Droop control is a technique extensively used in multi-converter parallel systems to alter the exterior properties of converters using droop coefficients in order to achieve equal converter outputs. Droop factor is also known as virtual resistance. Because a super-capacitor has a high power density and can respond to transient power faster than a generator or battery, a virtual capacitor is used instead of a virtual resistor to regulate the super-capacitor in a HESS.

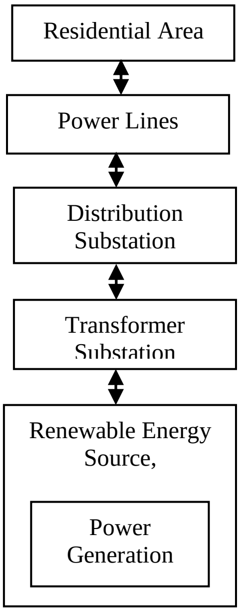

Fig. 1 Power distribution

The control approach is based on the virtual resistance structure of classic droop control, Le, and the battery converter uses virtual resistance droop control (VRDC) while the super capacitor converter uses virtual capacitor control[19] . The cutoff frequency f of an equivalent first-order low-pass filter made out of a virtual resistor R and a virtual capacitor C[20].

However, because of the sag factor, VRDC for converter control will result in steady-state inaccuracy, and VCDC will result in the super capacitor terminal voltage being unable to be recovered. As a result, the following response would be impacted[21]. To avoid this circumstance, secondary voltage compensation (SVC) is used for droop management in order to keep the bus voltage and super capacitor SOC[22] .The performance of two alternative techniques, namely the independent voltage and current double closed-loop control and the virtual impedance droop control, is compared for battery and super capacitor converters. According to the load specified in Section II, the battery's initial SOC is set to 75% and the super capacitor's starting voltage is set to 63 V[23]. Following that, the EPDS simulation process is initiated, and the pulse load is introduced for 0.3s to 0.6s, after which the bus voltage response is detected.

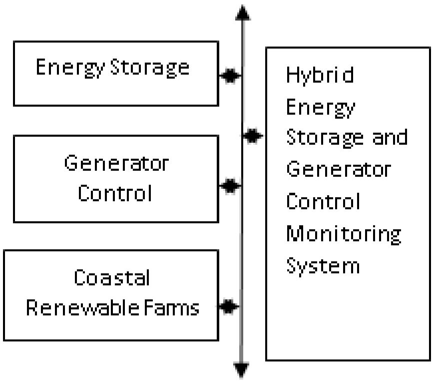

Fig. 2 Energy Storage

As combining the droop factor and SVC improves EPDS bus voltage stability, with less voltage drop and faster recovery under the same pulse load. This demonstrates the effectiveness of the proposed control method[24]. Enhancement of Control Coordination Despite the fact that the installation of droop control enhances the because of the voltage stability of the onboard EPDS, the VRDC causes the battery to have a non-zero steady-state current. As a result, when the bus voltage falls below its steady-state value, the battery converter's integral control loop accumulates positive excitation. Meanwhile, the generator converter will maintain the bus voltage at 270 V.

This has various repercussions, including the battery converter's ability to sustain positive excitation, the continual increase of battery current, and the generator output voltage[25]. The results will cause the generator output voltage to exceed the generator converter control range after a certain amount of time, resulting in synchronous overshoot of the bus voltage. The Fig 3 approach will result in significant power waste and deterioration of battery performance[26]. The droop control in this process does not eliminate, but rather exacerbates, this impact. Comparison of droop control generator output voltages with SVC.As a result, a better battery control approach based on VRDC is proposed, in which the secondary voltage compensation in VRDC is replaced with generator output voltage compensation (GOVC)[27]. This innovative control solution minimizes repetitive bus voltage regulation while also increasing generator output voltage stability.

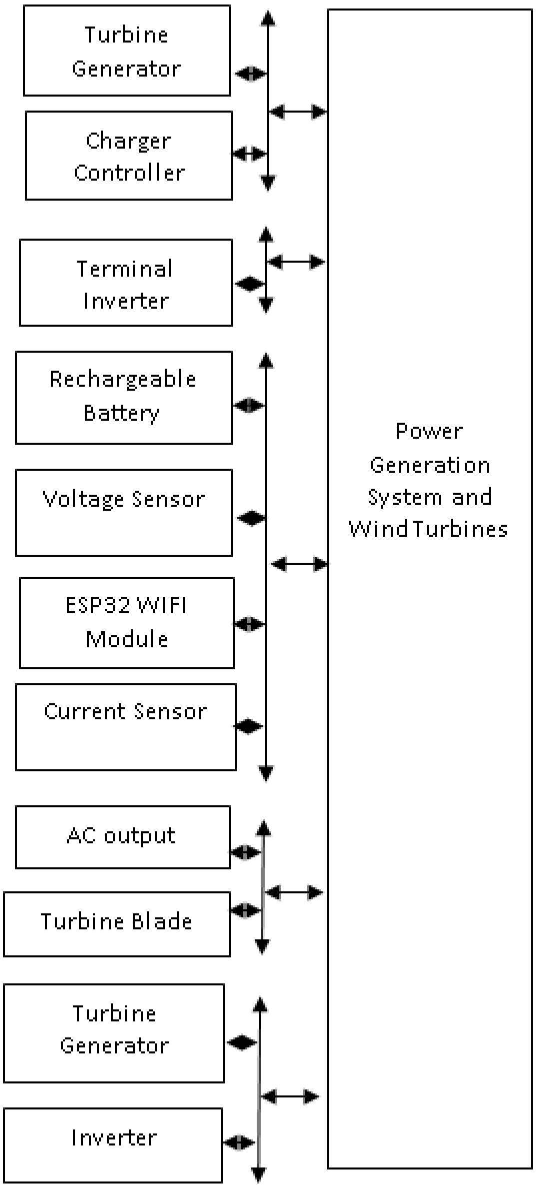

Fig. 3 Block diagram

When a pulse load occurs, the generator output voltage compensation can give more positive excitation than the secondary voltage compensation and improve overall power quality[28]. The variable reference voltage in output voltage compensation section is intended to allow the system to leave a power buffer for possible pulsed loads by pre-exciting the battery.

The system bus voltage and generator output voltage are with the current parameter values[29]. Under present load, the droop control with GOVC stores enough energy in advance for the possibility of pulsed loads and reacts rapidly, so that the bus voltage remains almost steady and the generator output voltage remains close to the reference voltage.

5. Suitability in Multiple Situations

To investigate the impact of GOVC on system performance in greater depth, this part will simulate and analyze the outcomes of various loads and generator outputs[30].

A comparison of GOVC performance under various loads are obtained using the load system by altering the amount of the pulse load only at the same spike pulse time (0.3 s to 0.6 s).

Simulating each of the three loads yielded the automobile electrical energy plot in and the generator output power plot When load A is connected, the EPDS does not exceed the top limit of energy supply[31]. The generator output voltage and bus voltage then oscillate with the control link adjustment, which is caused by the control system's faulty parameter design. EPDS has reached the upper limit of energy supply and the battery output current when loads B and C are coupled is saturated, therefore the oscillation is hidden. When pulse load C is connected, the EPDS is no longer sufficient to maintain bus voltage stability, resulting in voltage deregulations. Furthermore, even if the bus voltage does not change while the pulse loads are coupled, the drop in generator output voltage will build positive excitation in the battery control system. upon the duration of the pulse load is long, the possibility of overshoot upon disconnecting the load must be examined further. The influence of the GOVC reference value on energy loss

The effect of different GOVC reference values on the control effect will be addressed in this section. Three sets of parameters with reference values of 450, 650, and 900 will be simulated with load A connected. The generator output voltage and battery SOC will be compared.

Generator output voltage at 450 as a reference

Generator output voltage at 650 as a reference

Generator output voltage at 900 as a reference

The larger the buffer area of the EPDS system for pulse GWS load, according to Fig 13, the higher the GOVC reference value. During the system startup phase, the battery is pre-excited to increase its initial output power. After the system enters a stable steady state, the GOVC reference value has no effect on battery output power, resulting in no power waste. Nonetheless, the precise reference value is chosen based primarily on the system parameters and the available pulse load power for calculation[32]. This seeks to protect the battery by ensuring the system for the peak power leveling impact and minimizing the size of the reference value.

6. Real-time Monitoring Output.

A wide-frequency oscillation measurement method is proposed against oscillations at multiple frequency bands generated by offshore wind power via flexible DC transmission [33]. Furthermore, the key technologies and hardware design are introduced, with a focus on explaining the signal analysis of AM and FM signals created by broadband oscillation. More crucially, the AM and FM signals are treated in a unique manner using the LMD signal decomposition[34]. In this manner, the time-frequency characteristics of the signals can be obtained and then evaluated using numerical examples in simulation tests.

The terminal with a 5G connection module communicates with the master station and the measuring instrument[35]. The Fig 4 transmission rate is substantially increased, and the signal delay is decreased, allowing for real-time monitoring.

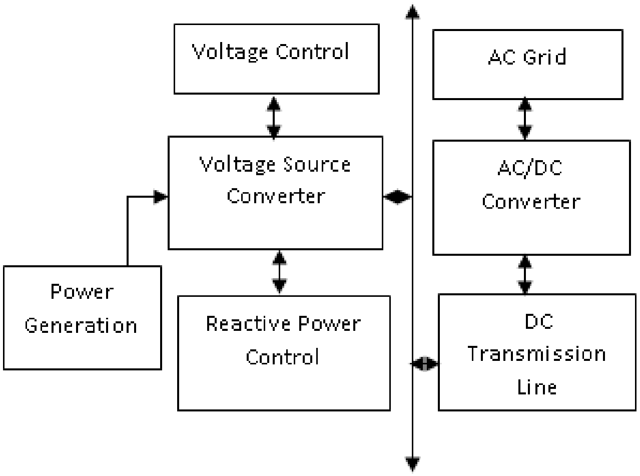

Fig 4 Successors of Voltage Source Converter (VSC): ['DC Transmission Line', 'Reactive Power Control', 'Voltage Control']Predecessors of Voltage Source Converter (VSC): ['Power Generation']

People's attention has steadily been drawn to the wide-frequency oscillation induced by the interaction between the offshore wind power system and the active fast control device in recent years. However, due to a paucity of evidence, its mechanism and influencing variables require additional investigation. Fig 5Furthermore, the report focuses on the monitoring of non-stationary signals; additional research Fig 6 on the monitoring of stationary signals is required. The wide-frequency oscillation monitoring system can capture oscillation data, assisting the wind turbine unit side in adjusting the wind power controller parameters. Furthermore, by optimization control, the additional damping control of the wind power converter and the grid side can be done more precisely, which can support the safe and stable functioning of the grid

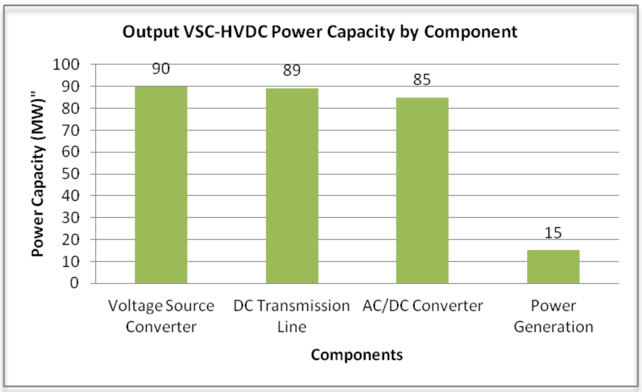

Fig 5 Output of VSC –HVDC

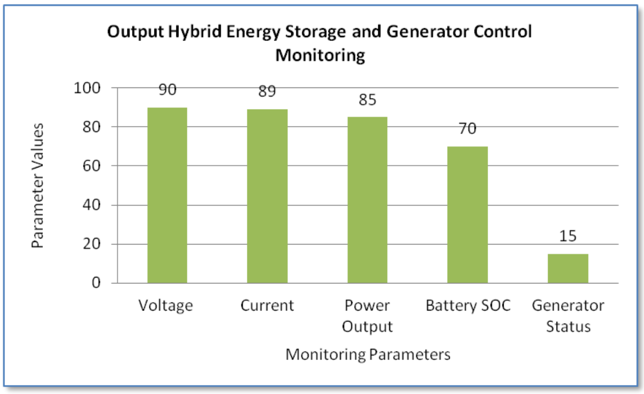

Fig 6 Hybrid Monitoring Systems

7. Conclusion

The purpose of this article is to investigate the control system optimization of a 270 V HVDC aircraft EPDS with generator and hybrid energy storage system. A virtual resistance droop control approach for the battery is developed, and its superior voltage smoothing effect when compared to secondary voltage control is validated using PLECS simulation. The effect of various generator output voltage references on the system is also investigated. The battery will be the principal electrical energy output component in the EPDS to follow the changes in loads with the proposed control mechanism. The optimization of the quantification of the generator yield power position assessment, on the added offer, is not covered in depth in this study. The significance of generator control in assuring the stability of the onboard EPDS can be explored further in our future study using this technology and its results.

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