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Integration of Wind Power and Wave Power Generation Systems Using a Dc Microgrid

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Abstract:

In order to study the uncertainty and intermittent characteristics of wind power and wave power, this paper proposes an integrated wind and wave power generation system fed to an ac power grid or connected with an isolated load using a dc microgrid. The proposed dc microgrid connects with a wind power generator through a voltage-source converter (VSC), a wave power generator through a VSC, an energy storage battery through a bidirectional dc/dc converter, a resistive dc load through a load dc/dc converter, and an ac power grid through a bidirectional grid-tied inverter. The studied integrated wind and wave system joined with the dc microgrid is modeled and simulated using the written program based on MATLAB/Simulink. Root-loci plots of the studied system under various speeds of the wave generator are analyzed. To examine the fundamental operating characteristics of the studied integrated system joined with the dc microgrid, a laboratory- scale platform is also established. Comparative simulation and experimental results reveal that the studied integrated system can maintain stable operation to supply power under different operating conditions using the proposed dc microgrid.

Keywords:

Wind power, wave power, voltage-source converter, MATLAB/Simulink

1. INTRODUCTION:

IN recent years, renewable energy and distributed generation systems (DGSs) have attracted increasing attention and have been extensively researched and developed. They gradually alter the concepts and operations of conventional power generation systems. The rise in several countries makes it possible that this kind of DGS can be practically applied to a grid-tied system or an isolated system with wind power, solar energy, hydropower, etc. The output of DGS usually includes two kinds: dc and variable ac. Moreover, the generating capacity of DGS comparing with conventional large synchronous generators is much smaller, and hence, the dc microgrid can be practically applied to convert the generated time-varying quantities of natural renewable energy and DGS into smooth dc electricity that can then be converted back into ac quantities delivered to other power systems.

The simulated results of an Archimedes wave swing (AWS) power convertor coupling with a linear permanent magnet generator (LPMG) were compared with the experimental outcomes using the measured data obtained from a 2-MW AWS test system along the coastline . A configuration of a marine power plant with two AWSs connecting to a power grid was proposed in , and the outputs of the two AWSs were converted to dc quantity by individual diode bridge rectifiers and then subsequently converted into ac quantity by an inverter to reduce the fluctuation of the combined rectified output power. A hybrid electric vehicular power system in utilized two motors connected to a dc bus through a voltage-source converter (VSC), and a bidirectional converter was connected between a battery and the dc bus. The dynamic average model was used in for all power electronics models by neglecting the switching phenomena to reduce simulation computational intensity. A nonisolated bidirectional zero-voltage switching dc/dc converter was proposed in , and the converter utilized a very simple auxiliary circuit consisting of an additional winding of a main inductor and an auxiliary inductor to reach zero voltage switching and reduce the reverse-recovery problem of power diodes. Modeling and testing the data centers of a dc microgrid using PSCAD/EMTDC were proposed in and since most data centers were sensitive to the variations of electronic loads. The proposed dc microgrid was also used to supply sensitive electronic loads during ac grid outages in order to offer uninterruptible power system protection . To achieve power sharing and improve economic benefit, a dcbus voltage control technique for parallel integrated permanent magnet wind power generation systems was proposed in , and the technique was based on a master–slave control to system was constructed in to confirm the effectiveness of the proposed scheme. In order to achieve power sharing and to optimize the dc microgrid, the control strategies for an islanded microgrid with a dc-link voltage control were developed in and , while the control strategies were combined with P/V droop control and constant-power band to avoid frequent changes and voltage-limit violation on generation devices. A battery/ultra capacitor hybrid energy storage system was proposed in for electric-drive vehicles. To satisfy the peak power demands between the ultra capacitor and battery, a larger dc/dc converter was necessary. The studied system utilized two storage devices to compensate mutually in order to prolong the life of the battery. The simulated and experimental results were carried out to verify the proposed control system

2. LITERATURE SURVEY:

1. This paper" DC microgrid based distribution power generation system" describes an autonomous-control method for a DC microgrid system having distribution power generators. This system consists of following five generation and control units; a solar-cell generation unit, a wind-turbine generation unit, a battery energy-storage unit, a flywheel power-leveling unit, and an AC grid-connected power control unit. The proposed control method intended for suppression of circulating current detects only the DC grid voltage. Each unit could be controlled autonomously without communicating each other. This method brings high reliability, high-flexibility and maintenance-free operation to the system. Experimental results from a 10 kW-prototype system verify the validity and effectiveness of the proposed control method

2. This paper "Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer "presents power-control strategies of a grid-connected hybrid generation system with versatile power transfer. The hybrid system is the combination of photovoltaic (PV) array, wind turbine, and battery storage via a common dc bus. Versatile power transfer was defined as multimodes of operation, including normal operation without use of battery, power dispatching, and power averaging, which enables grid- or user-friendly operation. A supervisory control regulates power generation of the individual components so as to enable the hybrid system to operate in the proposed modes of operation. The concept and principle of the hybrid system and its control were described. A simple technique using a low-pass filter was introduced for power averaging. A modified hysteresis-control strategy was applied in the battery converter. Modeling and simulations were based on an electromagnetic-transient-analysis program. A 30-kW hybrid inverter and its control system were developed. The simulation and experimental results were presented to evaluate the dynamic performance of the hybrid system under the proposed modes of operation.

3. "Supercapacitor energy storage for wind energy applications, "As wind energy reaches higher penetration levels, there is a greater need to manage intermittency associated with the individual wind turbine generators. This paper considers the integration of a short-term energy storage device in a doubly fed induction generator design in order to smooth the fast wind-induced power variations. This storage device can also be used to reinforce the dc bus during transients, thereby enhancing its low-voltage ride through (LVRT) capability. The topology is evaluated in terms of its ability to improve the performance both during normal operation and during transients. Results show

that when storage is sized based upon the LVRT requirement, it can effectively damp short-term power oscillations, and it provides superior transient performance when compared with conventional topologies

4. This paper ""A hybrid ac/dc microgrid and its coordination control" proposes a hybrid ac/dc micro grid to reduce the processes of multiple dc-ac-dc or ac-dc-ac conversions in an individual ac or dc grid. The hybrid grid consists of both ac and dc networks connected together by multi-bidirectional converters. AC sources and loads are connected to the ac network whereas dc sources and loads are tied to the dc network. Energy storage systems can be connected to dc or ac links. The proposed hybrid grid can operate in a grid-tied or autonomous mode. The coordination control algorithms are proposed for smooth power transfer between ac and dc links and for stable system operation under various generation and load conditions. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature, and load are also considered in system control and operation. A small hybrid grid has been modeled and simulated using the Simulink in the MATLAB. The simulation results show that the system can maintain stable operation under the proposed coordination control schemes when the grid is switched from one operating condition to another.

3. IMPLEMENTATION:

The configuration of the studied integrated wind and wave power generation system connected to an ac grid through a dcmicrogrid. The wind power generation system simulated by a permanent-magnet synchronous generator (PMSG) driven by a wind turbine (WT) is connected to the dc microgrid through a VSC of VSC_PMSG. The wave power generation system simulated by an LPMG driven by a linear permanent magnet motor (LPMM) is also connected to the dc microgrid through a VSC of VSC_LPMG. A resistive dc load *R* Load is connected to the dc microgrid through a load dc/dc converter. To achieve stable power flow (or power balance condition) and load demand control of the dc microgrid under different operating conditions, a battery is connected to the dc microgrid through a bidirectional dc/dc converter, while an ac grid is connected to the dc microgrid through a bidirectional grid-tied inverter and a transmission line. When available wind power and/or wave power can be injected into the dc microgrid with a fully charged battery, the surplus power of the dc microgrid can be delivered to the ac grid through the bidirectional grid-tied inverter. When no wind power or no wave power is delivered to the dc microgrid with a low-energy battery, the insufficient power of the dc microgrid can be captured from the ac grid through the bidirectional grid-tied inverter. The power of the resistive dc load *R* Load can be obtained from the dc microgrid through the load dc/dc converter only when the dc microgrid has enough power. The load dc/dc converter with the resistive dc load *R* Load can also slightly adjust the power balance condition of the dc microgrid. The control functions of the bidirectional dc/dc converter, the bidirectional grid-tied inverter, and the load dc/dc converter must be adequately coordinated with each other to obtain stable operation of the dc microgrid. In this paper, the mathematical models of the studied integrated system with the proposed dc microgrid are derived in detail, including the wind WT-PMSG set with its VSC, the wave LPMM-LPMG set with its VSC, the bidirectional dc/dc converter with the battery, the load dc/dc converter with the resistive load, and the bidirectional grid-tied inverter. Both frequency-domain analysis and time-domain simulations are performed using MATLAB/Simulink.

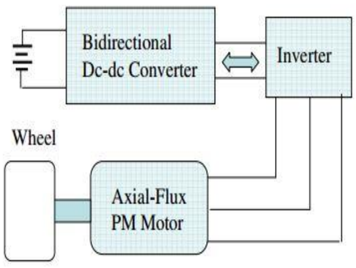

Figure 1.1 Bidirectional dc-dc converter in energy regenerative system

The bidirectional dc-dc converter along with energy storage has become a promising option for many power related systems, including hybrid vehicle [1], fuel cell vehicle, renewable energy system and so forth. It not only reduces the cost and improves efficiency, but also improves the performance of the system. In the electric vehicle applications, an auxiliary energy storage battery absorbs the regenerated energy fed back by the electric machine. In addition, bidirectional dc-dc converter shown in Figure 1.1 is also required to draw power from the auxiliary battery to boost the high-voltage bus during vehicle starting, accelerate and hill climbing [1]. With its ability to reverse the direction of the current flow, and thereby power, the bidirectional dc-dc converters are being increasingly used to achieve power transfer between two dc power sources in either direction. In renewable energy applications, the multiple-input bidirectional dc-dc converter can be used to combine different types of energy sources [2-8]. Figure 1.2 shows a fuel cell based system for domestic applications [2]. The multi-input bidirectional dc-dc converter is the core that interconnects power sources and storage elements and manages the power flow [5]. This bidirectional dc-dc converter features galvanic isolation between the load and the fuel cell, bidirectional power flow, capability to match different voltage levels [9], fast response to the transient load demand, etc.

4. Related Work:

The brief introduction of different modules used in this project is discussed below:

I. BIDIRECTIONAL GRID-TIE INVERTERS: At the heart of energy storage PCS is the grid-tie inverter. Parker manufactures a modular solution with proven efficiency and uptime. Designed to be easily maintained and serviced, the inverter racks deliver high power density and small footprint, and feature highly efficient two-phase evaporative liquid cooling technology.

Classification of Active Power Filters An unfavorable but inseparable feature of APF is the necessity of fast switching of high currents in the power circuit of the APF. This results in a high frequency noise that may cause an electromagnetic interference (EMI) in the power distribution systems.

SHUNT ACTIVE POWER FILTER

Shunt active power filter (SAPF) is commonly used as an effective method in compensating harmonic components in non-linear loads. Fig. 2.4 shows the basic principle of SAPF in which APF is connected in parallel to the power system at a point of common coupling (PCC) between metropolitan electricity authority (MEA) and power users. The objective of SAPF is to minimize the distortion in power supply using four main components – harmonic detection, compensating current control, DC bus voltage control, and active power filter – as shown in Fig. 2.5 In the harmonic detection component, the distorted signal can be detected by several harmonic detection techniques, i.e., the instantaneous reactive power theory (PQ), the synchronous reference frame (SRF), the d-q axis with Fourier (DQF), and the synchronous detection (SD) etc. Then, APF injects the compensating currents into the power system. The current control techniques are hysteresis current control, Pulse Width Modulation (PWM), and Space Vector Modulation (SVM)etc. For dc bus voltage control, proportional integral (PI) is employed. Commonly, APF uses 6 IGBT devices to build the voltage source inverter for injecting the compensation current to the system at PCC.

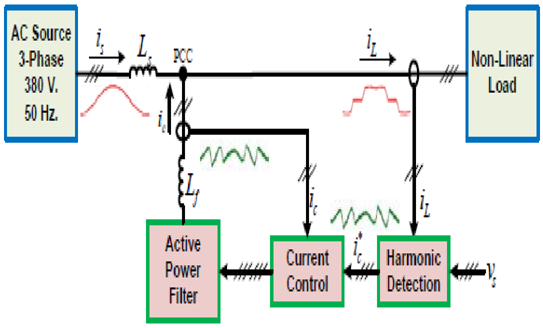

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Fig. The system using shunt active power filter

II. DIFFERENT TYPES OF ON OF ACTIVE FILTERS

Converter-based classification-

• VSI (Voltage Source Inverter) bridge structure:

The voltage source inverter topology uses a diode rectifier that converts utility/line AC voltage (60 Hz) to DC. The converter is not controlled through electronic firing like the CSI drive. The DC link is parallel capacitors, which regulate the DC bus voltage ripple and store energy for the system. The inverter is composed of insulated gate bipolar transistor (IGBT) semiconductor switches. There are other alternatives to the IGBT: insulated gate commutated thyristors (IGCTs) and injection enhanced gate transistors (IEGTs). This paper will focus on the IGBT as it is used extensively in the MV VSI drives market. The IGBT switches create a PWM voltage output that regulates the voltage and frequency to the motor. The design in a neutral point clamped (NPC) Three-level inverter topology. The IGBT switching devices are cascaded to achieve a 4160V system rating.

• CSI (Current Source Inverter) bridge structure:

The way each of the drive building blocks operates defines the type of drive topology. The first topology that will be investigated is the current source inverter (CSI). The converter section uses silicon-controlled rectifiers (SCRs), gate commutated thyristors (GCTs), or symmetrical gate commutated thyristors (SGCTs). This converter is known as an active rectifier or active front end (AFE). The DC link uses inductors to regulate current ripple and to store energy for the motor. The inverter section comprises gate turn-off thyristor (GTO) or symmetrical gate commutated thyristor (SGCT) semiconductor switches. These switches are turned on and off to create a pulse width modulated (PWM) output regulating the output frequency.

Topology-based classification

• Shunt APF, • Series APF

• UPQC : Shunt APF + Series APF

• Hybrid APF : Shunt or Series Active Filter + Passive Filter

Supply-system-based classification

• Two-wire APF

• Three-wire APF

• Four-wire APF

III. SUPPLY-SYSTEM BASED CLASSIFICATION

Two-wire APF

• Single-phase nonlinear loads, such as domestic appliances

• Smaller rating

Three-wire APF

• Three-phase nonlinear load without neutral, such as ASD's

Four-wire APF

• Single-phase nonlinear loads fed from four-wire supply system, such as computers, commercial lighting

• Eliminate excessive neutral current and unbalance Capacitor midpoint four-wire shunt APF

• Used in smaller ratings, because entire neutral current flows through dc bus capacitor

IV. MATLAB:

The name MATLAB stands for matrix laboratory. MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

MATLAB can be used in a wide range of applications, including control design, test and measurement, financial modeling and analysis, MATLAB is the language of technical computing.

5. CONCLUSION:

An integration of both wind power and wave power generation systems joined with a dc microgrid has been proposed. A laboratory-grade test system has been presented in this paper to examine the fundamental operating characteristics of the studied integrated system fed to isolated loads using a dc microgrid. For simulation parts, the results of the root-loci plot and the time-domain responses have revealed that the studied integrated system with the proposed dc microgrid can maintain stable operation under a sudden load-switching condition. Comparative simulated and measured results under a load switching have been performed, and it shows that the studied integrated system with the proposed dc microgrid can be operated stably under different disturbance conditions, while both measured and simulated results can match with each other.

6. ACKNOWLEDGEMENT

We would like to thank all the authors of different research papers referred during writing this paper. It was very knowledge gaining and helpful for the further research to be done in future.

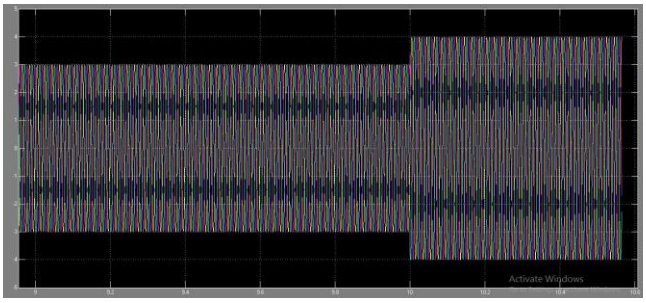
7. FUTURE SCOPE

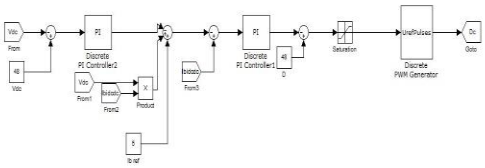
The objective of the IC controller is to regulate the frequency of the AC subgrid and the bus voltage of the DC subgrid by the control of the active power injection via the IC. The change in the power injection is followed by the support of the BESS in the DC subgrid because of its DC bus voltage regulation. Thus, when the SOC of the BESS is exhausted or fully charged, the change in the active power injection needs to be managed along with the physical limits of the battery SOC. The proposed coordination control strategy can provide a smooth transition on power transfer through the IC of the microgrid in stand-alone mode, and from the simulation results, one can notice that the control strategy can manage the power transfer effectively, even when a load shedding is applied in weak conditions.

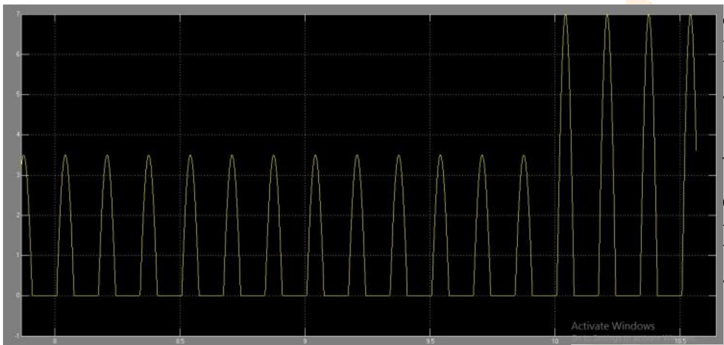
8. RESULTS:

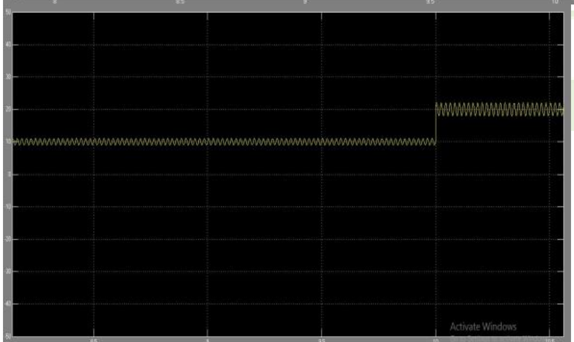
Specify the constant value output of the block.

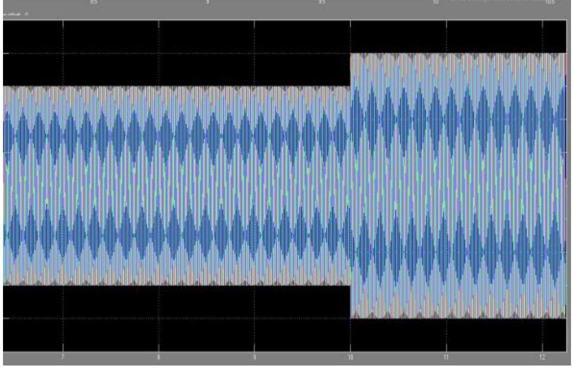
SIMULINK FILES SIMULATION RESULTS:











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