International Journal of Engineering In Advanced Research Science and Technology
ISSN: 2278-2566

VOLUME-2
ISSUE-5
OCT-2106
PAGE NO:12-18

INTEGRATION OF WIND POWER AND WAVE POWER GENERATION SYSTEMS USING A DC MICRO GRID

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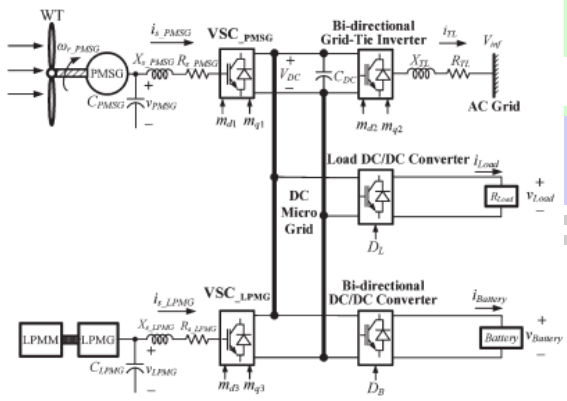
Abstract— Keeping in mind the end goal to concentrate on the vulnerability and irregular qualities of wind power and wave control, this paper proposes an incorporated wind and wave power era framework encouraged to an air conditioner power matrix or associated with a separated burden utilizing a dc miniaturized scale network. The proposed dc small scale lattice associates with a wind power generator through a voltage-source converter (VSC), a wave power generator through a VSC, a vitality stockpiling battery through a bidirectional dc/dc converter, a resistive dc load through a heap dc/dc converter, and an air conditioner power matrix through a bidirectional framework tied inverter. The contemplated incorporated wind and wave framework joined with the dc microgrid is displayed and recreated utilizing the composed system taking into account MATLAB/Simulink. Root-loci plots of the examined framework under different velocities of the wave generator are broke down. To inspect the major working qualities of the contemplated coordinated framework joined with the dc microgrid, a research facility scale stage is likewise settled. Relative reproduction and exploratory results uncover that the contemplated incorporated framework can keep up stable operation to supply power.

1. INTRODUCTION

Lately, renewable vitality and circulated era frameworks (DGSs) have pulled in expanding consideration and have been broadly scrutinized and created. They slowly adjust the ideas and operations of customary force era frameworks. The ascent in a few nations makes it conceivable that this sort of DGS can be for all intents and purposes connected to a framework tied framework or a disengaged framework with wind power, sun based vitality, hydropower, and so on. The yield of DGS more often than excludes two sorts: dc and variable air conditioning. In addition, the creating limit of DGS contrasting and traditional huge synchronous generators is much littler, and consequently, the dc microgrid can be basically connected to change over the produced time-shifting amounts of characteristic renewable vitality and DGS into smooth dc power that can then be changed over once again into air conditioning amounts conveyed to other force frameworks. Due to the irregularity of renewable vitality and DGS, bidirectional dc/dc converters are typically important to sustain the associated loads with smooth force [3]. With a specific end goal to reenact a half breed air conditioning/dc microgrid framework, photovoltaic and wind power generator models, a doubly sustained model were built up to

mimic the dynamic reactions of the considered framework in [4]. A down to earth low-voltage bipolar-sort dc microgrid was developed utilizing a gas motor as the force source, while a bi directional dc/dc converter shunting a supercapacitor was used as a vitality stockpiling gadget to adjust the force interest of the concentrated on framework in [5]. Unexplored vitality and assets sea warm vitality, sea wave vitality, saltiness inclination vitality, and so forth., are plentiful. The recreated consequences of an Archimedes wave swing (AWS) power convertor coupling with a straight changeless magnet generator (LPMG) were contrasted and the exploratory results utilizing the deliberate information acquired from a 2-MW AWS test framework along the coastline [6]. An arrangement of a marine force plant with two AWSs associating with a force framework was proposed in [7], and the yields of the two AWSs were changed over to dc amount by individual diode span rectifiers and afterward in this manner changed over into air conditioning amount by an inverter to lessen the variance of the consolidated redressed yield power.



This paper proposes a coordinated wind and wave power era framework sustained to a force framework or associated with a disconnected burden utilizing a dc microgrid. A bidirectional dc/dc converter is proposed to accomplish the combination of both wind and wave power era frameworks with instability and discontinuous attributes. This paper is sorted out as takes after. Segment II presents the framework design and utilized models. Area III portrays the framework setup of the research facility - grade incorporated wind and wave power era framework. Root-loci plots of the contemplated incorporated framework under different rates of AWS are appeared in Section IV to analyze the solidness of the concentrated on framework. Near mimicked and N trial aftereffects of the contemplated framework under a sudden burden exchanging condition are exhibited in Section V. The particular critical finish of this paper.II.

CONFIGURATION OF THE STUDIED SYSTEM

A. System Configuration

The configuration of the studied integrated wind and wave power generation system connected to an ac grid through a dc microgrid. 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 equivalent circuit model of the studied wind PMSG. 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 RLoadis 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

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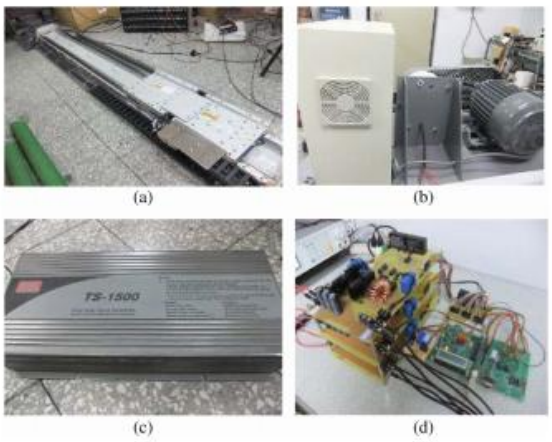
connected to the dc microgrid through a bidirectional grid-tied inverter and a transmission line. When available wind power and/or wave power can be injected into the dc microgrid with a fully charged battery, the surplus power of the dc microgrid can be delivered to the ac grid through the bidirectional 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 loadRLoadcan 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 RLoad 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.

B. Models of WT and PMSG

The WT model employed in this paper includes the following operation conditions: the cut-in wind speed of 4 m/s, the rated wind speed of 13 m/s, and the cut-out wind speed of 24 m/s. The detailed characteristics and expressions for the captured mechanical power Pw, the dimensionless power coefficient Cpw, the mechanical torque Tw, the tip speed ratio λw, and the blade pitch angle βw of the studied WT can be seen in [16].studied wind PMSG [17]. The per-unit (p.u.)q- and d-axis statorwinding voltages of the studied PMSG can be expressed by, respectively,

$$v_{qsP} = -r_{sP} i_{qsP} + p(\lambda_{qP})/\omega_b + \omega_{rP}\lambda_{dP}/\omega_b$$
$$v_{dsP} = -r_{sP} i_{dsP} + p(\lambda_{dP})/\omega_b - \omega_{rP}\lambda_{qP}/\omega_b$$

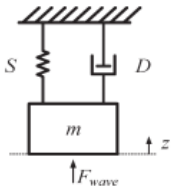


Fig. 3. Equivalent mass-spring-damper model of the studied AWS.

where

$$\lambda_{qP} = -(X_{mqP} + X_{lsP}) i_{qsP}$$
$$\lambda_{dP} = -(X_{mdP} + X_{lsP}) i_{dsP} + X_{mdP} i'_{mP}$$

are theq- and d-axis stator-winding magnetic fluxes, respectively; iqsP and idsP are the q- and d-axis stator-winding currents, respectively; d-axis magnetizing reactances, respectively;XlsP is the leakage reactance ;I mPis the magnetizing current;rsPis the statorwinding equivalent resistance; andωrPis the rotor speed of the studied PMSG,

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whilepis the differential operator with respectto time t(i.e.,p=d/dt), andωb is the base angular speed inradians per second

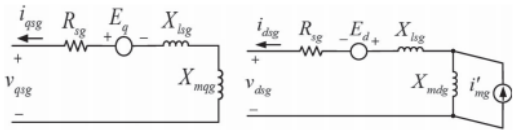
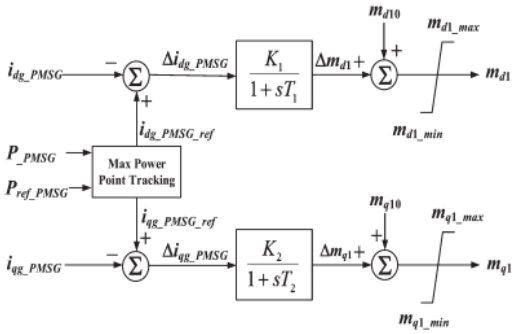


Fig. 4. *q–d*-axis equivalent circuit model of the studied LPMG.



Control Blocks of Bidirectional Grid-Tied Inverter

Fig. 7 draws the control block diagram of the modulation indices mq2 andmd2 of the grid-tied voltage-source inverter generated power of the renewable-energy systems to the power grid

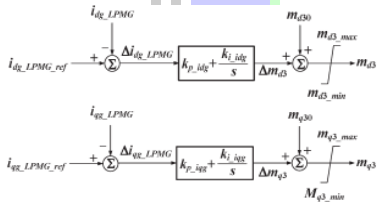
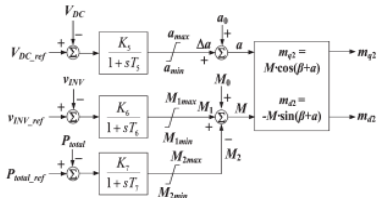


Fig. 6. Control block diagram of the modulation indices of the VSC of the studied LPMG.



$$V_{C1} = \frac{(kn+1)D}{1-D} V_I \tag{8}$$

$$V_{C2} = \frac{knD}{1-D} V_I. \tag{9}$$

Substituting (8) into (2), yields

$$V_{C3} = \frac{kn+1}{1-D} V_I. \tag{10}$$

Substituting (9) and (10) into (6), the voltage gain is achieved s

$$M_{CCM} = \frac{2+kn+knD}{1-D} V_I. \tag{11}$$

Model of Bidirectional DC/DC Converter:

The basic schematic diagram of the employed bidirectional dc/dc converter with a synchronous-buck structure. The converter consists of two power switches (S1 andS2) and an energy-store inductance L Battery. The design purpose of this converter is that the energy storage inductance. To create sag, source voltage is lowered by 20% from its nominal value at 0.6 s as shown in Fig. Since voltage regulation capability does not depend upon reference voltage, it

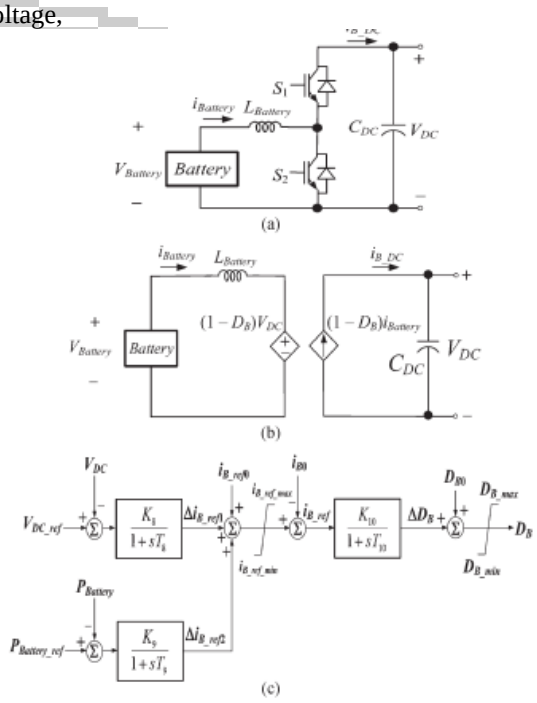


Fig. 3 shows the proposed control system of the

The input current waveform with and without an input filter is also shown in Fig. 8(g).The input current ripple is as much as other proposed high-step-up converters such as the converters in [27]–[29]. However, as it is shown in Fig. 8(g) (iSource), a low-pass filter can be used to reduce the input current ripple. The experimental conversion efficiency of the presented converter is given in Fig. 9. The peak value of efficiency is 96.9% which is achieved atPO= 200W. The efficiency of the presented converter at full loadPO= 300W is 96%. The results show the high conversion efficiency of the presented converter. The experimental conversion efficiency of the presented converter is given in Fig. 9. The peak value of efficiency is 96.9%, which is achieved atPO= 200W. The efficiency of the presented converter at

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VI. 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.

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