UNCERTAINITY AND INTERMITTENT OF WIND AND WAVE POWER USING DC MICROGRID

L.Siva Kumar Reddy[1]

[1](Dept of EEE, M.Tech Scholar, Global College of Engineering & Technology, Kadapa, A.P, INDIA)

Abstract— *Linear power damping synchronizing controller mechanically synchronizes with VSC to grid which enables full power injection under weak grid condition providing by damping with controllers stable and smooth operations also. But whenever sudden large disturbances occur in the system this controller may leads to affect the system stability. To overcome this difficulty a nonlinear controller is implemented. Thus the linear controller needs a nonlinear controller to improve the system stability under transient conditions. Nonlinear controller is used to supplement the linear controller and enhances the system stability and performance under large disturbances such as self-synchronization, disturbances in grid frequency, high power injection in very weak grids and fault ride through conditions. The main theme of this project to develop a new controller topology to connected to a voltage source converter to weak grids. The controller has two parts Linear power damping synchronizing controller. Non-linear controller.*

Keywords— ***Bidirectional DC/DC Converter; Bidirectional Grid-Tied Inverter; DC Microgrid; Load DC/DC Converter; Stability; Voltage-Source Converter (VSC); Wave Power Generator; Wind Power Generator***

1. INTRODUCTION

Around the world today recognizing both the environmental and climate hazards to be faced in coming decades and the gradual depletion of conventional power sources .These troubles lead to new treads of power generation and distribution with renewable sources. A new typical procedure rise in distribution generation unit with huge safe and good power vigour. Constant development of renewable generations of distribution arranges with wind and PV arrays, which results new power supply to the loads.

Voltage source converters (VSCs) are connected with non conventional and neat vigour resources in state of the art grids. The main topologies of VSC are vector and direct manipulates to get current and voltage parts in a rotating synchronous reference body with phase locked loop to extract grid frequency and converter grid. Nevertheless, the PLL is balance the transients with balance method along vector and direct method of topologies. The VSCs are connected to weak grids to synchronization and provide steady state to overcome the difficulties in DG.

Among targeted problems in DG integration with very weak grids the beneficial objectives are important base on high and speedy development stage of off-shore wind turbines and pv iteration models. Actually, the grid stiffness is a measure of the connecting line potential to switch vigour to a grid.

However, the developed techniques for weak grid integration are based on linearized models and lack the self-synchronization and plug-and-play ability. Furthermore, islanded operation of DG units can be allowed to enhance service reliability. However, this approach causes a permanent frequency offset. Thus, when self-synchronization control is applied, frequency and angle mismatch between a VSC and grid at the moment of connection may cause severe transients.

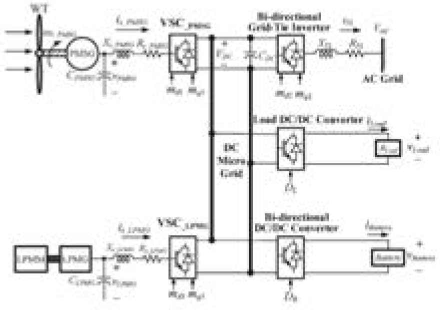

Fig 1.1 Proposed Integrated Wave and Wind power Generation.

One other predominant hindrance involving VSC operation in weak grids is the dearth of bodily inertia in conventional VSCs leading to terrible total frequency and load angle legislation; accordingly, islanded operation of micro grids (MGs) with high penetration of VSCs can be prone to frequency instability. Accordingly, significant efforts have been recently devoted to introduce some dynamics for frequency using virtual inertia. In the virtual inertia is emulated by the proper dc-link control.

2. PROBLEM DESCRIPTION

Now a days the increase in power demand, the depletion of the fossil fuel resources and the growth of the environmental pollution. New trends are lead by the problems in Demand to generate power to local distribution of renewable sources. DG unit is well suitable when non-conventional energy sources are available. Each DG unit to unbalanced local and nonlocal loads due to inclusion of 1- ϕ load.

3. WIND ENERGY CONVERSION SYSTEMS

3.1 Wind Turbine Technology

The wind turbine is the first and foremost element of wind power systems. There are two main types of wind turbines, the horizontal-axis and vertical-axis turbines.

3.1.1 Horizontal-axis Turbines

Horizontal-axis Turbines (see Figure 2.1) are primarily composed of a tower and a nacelle mounted on top of tower. The generator and gearbox are normally located in the nacelle. It has a high wind energy conversion efficiency, self-starting capability, and access to stronger winds due to its elevation from the tower. Its disadvantages, on the other hand, include high installation cost, the need of a strong tower to support the nacelle and rotor blade, and longer cables to connect the top of the tower to the ground.

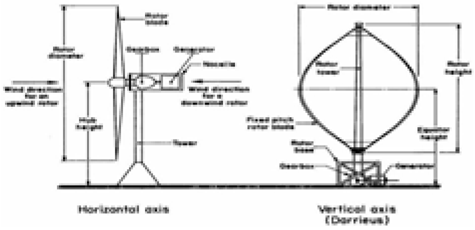

Figure 2.1: illustration of a horizontal axis and a vertical axis wind turbine.

3.1.2 Vertical-axis Turbines

A Vertical axis Turbines' spin axis is perpendicular to the ground (See Figure 3.1). The Wind Turbine is vertically mounted, and its generator and gearbox is situated at its base. Contrasted with even hub turbines, it has decreased establishment cost, and upkeep is less demanding, in light of the ground level apparatus box and generator establishment. Another preferred standpoint of the vertical pivot turbine is that its operation is autonomous of wind course.

3.2 Types of Horizontal-Axis Wind Turbines

3.2.1 Pitched Controlled Wind Turbines

Pitch Controlled Wind Turbines change the introduction of the rotor sharp edges along its longitudinal hub to control the yield control. These turbines have controllers to check the yield control a few times each second, and when the yield control achieves a most extreme edge, a request is sent to the cutting edge water driven pitch component of the turbine to pitch (or to turn) the rotor somewhat out of twist to back off the turbine.

3.2.2 Stalled Controlled Wind Turbines

The rotor blades of a Stall Controlled Wind Turbine are bolted onto the hub at a fixed angle. The blades are aerodynamically designed to slow down the blades when winds are too strong. The stall phenomenon caused by turbulence on rotor blade prevents the lifting force to act on the rotor. The rotor blades are twisted slightly along the longitudinal axis so that the rotor blade stalls gradually rather than suddenly when the wind reaches the turbines' critical value.

3.2.3 Active Stall Controlled Wind Turbines

Active Stall Turbines are very similar to the pitch controlled turbine because they operate the same way at low wind speeds. However, once the machine has reached its rated power, active stall turbines will turn its blades in the opposite direction from what a pitch controlled machine would. By doing this, the blades induces stall on its rotor blades and consequently waste the excess energy in the wind to prevent the generator from being overloaded. This mechanism is usually either realized by hydraulic systems or electric stepper motors.

4. SYSTEM DESCRIPTION AND MODELING

This project focuses on the development of a nonlinear power damping control strategy for Voltage Source Converter units in weak grids with applicability to both grid-connected and islanded modes of operation. Fig. 1 shows the schematic view of a grid –connected VSC supplying a local load. he most critical issue for controller design is the complexity of the system due to nonlinear behaviour of the power transfer dynamics. Usually, Linear controllers are developed established on small-sign linearization; however, the manage performance inherently depends on designated working elements. In this paper, a two-level topology with co-operative non-linear and linear controllers is developed. The first level is a energy synchronizing-damping controller. The second level is a nonlinear controller assisting the linear phase to increase approach steadiness in susceptible grids or for the period of self-synchronization where load perspective is giant and process works in the nonlinear region.

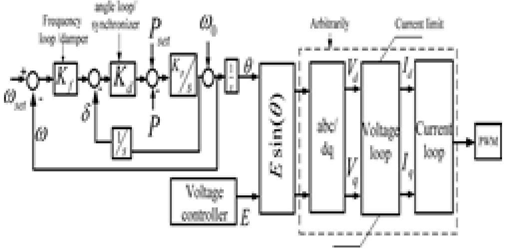

Fig.3.1. Proposed linear control scheme

The voltage iteration precept is much like an SG where the voltage frequency and load attitude are tuned with the aid of vigour damping-synchronizing loop, whereas the voltage amplitude is given via voltage regulation loop equivalent to an automatic voltage regulator (AVR). The VSC's output real power is controlled directly by adjusting the load angle using the power-damping loop, whereas the reactive power (or alternating voltage) is controlled by adjusting the voltage magnitude. Considering that the VSC is voltage-controlled one, an inner current loop just isn't vital except throughout colossal transients similar to faults where the control approach should be modified to current control mode to limit the current amplitude. It should be noted that the proposed outer-loop controller may also be additionally integrated with cascaded voltage-current control loops to make certain high power excellent injection and inherent present challenge throughout faults. On this case, the synchronization perspective for dq-body transformation is bought from the proposed outer-loop controller alternatively of a PLL as shown Fig.4.1

4.1. Power Damping Concept

The base of power damping control of a grid-connected VSC is that the controller provides active damping and synchronization power to attenuate power, frequency and load angle oscillations, and synchronize the VSC with the grid during steady-state operation. With the aid of changing the manage approach of VSCs to comply with the power damping traits, VSCs can also be integrated to weak grids and also cooperate with SGs in energy grids. Fig. 2 demonstrates the elemental precept of the proposed controller in the polar method. It has three cascaded loops, specifically frequency, angle and power loops. Based on the frequency error, the reference of the burden angle is determined and the real vigour reference is received as a function of the weight perspective error. Eventually, the power synchronization loop adjusts VSC's instantaneous frequency and cargo angle. The angle and frequency loops generate synchronization and damping power components for the VSC, thus it can inherently track frequency and angle deviations of the grid and automatically synchronizes itself with the grid. The reference frequency in the frequency loop is set equal to the grid frequency, and in steady-state conditions, the VSC produces the reference power. This can be the case in dispatch able DG units or VSC-based HVDC transmission systems. In the case when the primary source falls short to supply the output power, short-term energy storage can be added to the dc-link to compensate for the energy shortage during transients. The transferred real power is expressed by the well-known equation

$$P = \frac{E}{R^2 + X^2}(XV_L \sin\delta + R(E - V_L\cos\delta)) \qquad \text{.......(1)}$$

This equation shows that the real power that can be transmitted from a VSC is limited. To represent the strength of the connecting line, the SCR is defined as

$$SCR = \frac{\text{short circuit capacity}}{\text{rated dc power}} \qquad \text{.......(2)}$$

Where the short-circuit capacity of the ac system is given by

$$S_{SC} = \frac{E_0^2}{Z} \qquad \text{..... (3)}$$

And Z is the circuit equivalent Thevenin impedance. This implies that the weaker the grid, the lower the power transfer capacity of the line. In a weak grid with, the theoretical maximum power transfer capacity is 1.0 p.u. The power –damping control law for a VSC is proposed as

$$\frac{d\Delta\omega}{dt} = -K_p K_f K_d EI(\omega - \omega_{sd}) - K_p K_f \delta - K_p(P - P_{sd}) \qquad \text{.. (4)}$$

As it can be seen, the controller presents controlled dynamics for the angle and frequency. To eliminate the switching effect superimposed on the real power, a low-pass filter can be adopted and the altered power (average power) is fed to the controller. This low-pass filter also gives more degrees of freedom in the control design and may introduce more damping for angle and frequency oscillations. The damping and synchronization power components are given by

$$Damping\,power = \Delta P_{damp} = -K_f K_d \Delta\omega \qquad \text{.. (5)}$$

$$Synchronizing\,power = \Delta P_{synch} = -K_d \Delta\delta \qquad \text{.......(6)}$$

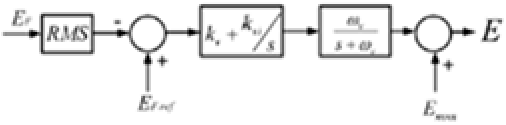

Fig 3.2 P V bus control topology for output voltage

The synchronization and damping powers attenuate load angle and frequency fluctuations around equilibrium point and synchronize the VSC with the grid. Beside the inherent synchronization with the grid in steady-state,

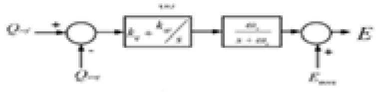

Fig.3.3 P -Q bus control topology for output voltage

It is important to take into account that the VSC's frequency and angle are internally available; therefore, there is no need for a PLL in steady-state operation and several transient conditions.

4.1.2 Voltage Amplitude Controller

The reactive power of a DG unit can be controlled to 1) regulate the terminal voltage (PV bus) or 2) achieve a specific output reactive power (PQ bus). Fig4.2&4.3 show these two different variants. In the first, the voltage reference is compared to the actual output voltage. In order to track the reference voltage, a proportional-integral (PI) controller is employed aiming at compensating the input error by proper adjustment of VSC's output voltage. The output of the PI controller is processed by a low-pass filter and finally the VSC's voltage amplitude reference is obtained. The low-pass filter plays two different roles; first, it offers more degrees of freedom to tune the low-pass filter cut-off frequency and PI controller parameters such that satisfactory transient and steady-state performances are achieved.

In weak grids, usually it is essential to regulate the grid-voltage at the point of common coupling, thus PV bus is the common approach in weak grids. An alternative to the voltage control is reactive power regulation as shown in Figure. However, this is not the common case in weak grids. This is due to the fact that the P-Q control strategy significantly degrades DG stability in weak grids as compared to the P-V control. Identical to Fig 3.2 , a low pass filter exists after the PI controller to mimic the flux decay nature of an SG

This low-pass filter allows the suppression of voltage oscillation while tracking time-response and steady state error are still kept within acceptable limits.

4.2 VSC CONNECTED TO GRID

VSCS are the main enabling technology for interfacing renewable and clean energy resources in modern grids. To obtain current and voltage components in a synchronously –rotating reference frame, a phase locked loop (PLL) is necessary. PLL can extracts the grid frequency and initial angle to get a stable and smooth operation However during the transients PLL affects the overall system stability. To overcome this difficulty another control topology is required which cannot affects the system stability and performance even under transients also which may leads to eliminate the PLL

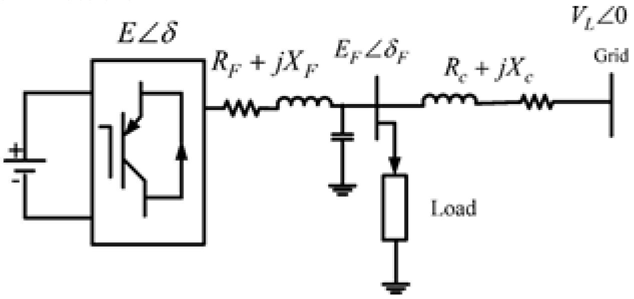

Fig 3.3 schematic view of a grid- connected VSC

Fig 3.3 shows the schematic view of a grid- connected VSC supplying a local load. In order to achieve the stable and smooth operation we need to implement a new control topology. The Controller has two parts the first level is a power synchronizing damping controller. The Second level is a nonlinear controller supporting the linear system to enhance the system Stability in weak grids where load angle is large and system works in the nonlinear region

Our existing system has only VSC is connected to grid system. Basically the grid efficiency is a measure of the connecting line capacity to transfer power to a grid? To represent the strength of a weak grid system short circuit ratio is considered the short circuit ratio can be represented as

SCR = short circuit capacity/rated dc power

In a weak grid with SCR=1, only 40% of the maximum power capacity of a VSC can be Used With significant control parameters and PLL this percentage can be increased to 60%. An alternative concept of power synchronization control is also applicable to enable more Power transformation by a VSC by emulating SGs. SGs don't have any limitations for Connecting a weak grid system.

4.3 NONLINEAR POWER DAMPING CONTROLLER

In weak grids with SCR less than 4, the load angle is usually large and approaches the steady-state stability limit; accordingly, in the case that a DG unit is required to supply its rated power, power stability may be significantly degraded. The proposed cooperative angle-frequency droop control can enable higher load angles. However, as a linear controller, it cannot guarantee large-signal stability in all operating conditions especially when system dynamics drifts to the nonlinear region. This is more pronounced in sudden large transients such as self-synchronization where any large mismatch between frequency and angle of both sides across the connecting breaker (or recloser) may contribute to poor performance and even instability. To overcome this issue, a nonlinear back-stepping power damping controller is proposed and augmented with the linear controller asshowninFig.4.4.

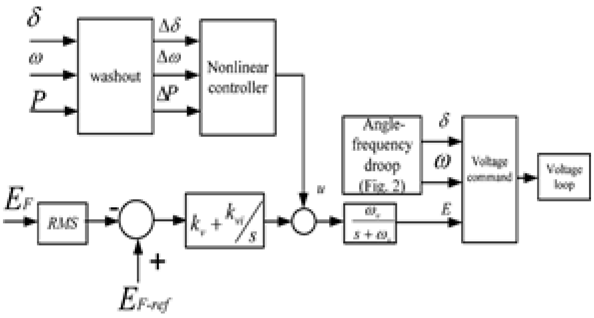

Fig. 3.4. Nonlinear supplementary control structure.

The overall system model is

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = a_1x_1 + a_2x_2 + a_3x_3$$

$$\dot{x}_3 = u_f + E\frac{V_L}{X}x_2\cos x_1 - \omega_v x_3$$

Where $a_1 = -K_pK_d$, $a_2 = -K_pK_dK_f$ and $a_3 = -K_p$ $[x_1, x_2, x_3] = [\Delta\delta, \Delta\omega, \Delta P]$, and $u_f = (u\omega_c V_L \sin x_1)/X$

where u is control output

The control objective is to ensure the convergence of the error $e_i = x_i - x_{iref}$ to zero. The first step is to stabilize, thus the Lyapunov function

$$V_1 = \frac{1}{2}x_1^2$$

Is defined and the reference of frequency deviation value and V1 are given by

$$x_{2ref} = -k_1x_1 \quad k_1 > 0$$

$$V_1 = -k_1x_1^2 + x_1e_2$$

In the next step, the Lyapunov function is defined as

$$V_2 = \frac{V_1 + 1}{2e_2^2}$$

And to stabilizes V1 and V2

$$x_{3ref} = c_1x_1 + c_2e_2$$

$$c_1 = \frac{(1 - k_1(-a_2 + k_1) + a_1)}{a_3}$$

$$c_2 = -\frac{(k_1 + k_2 + a_2)}{a_3}$$

Finally, by defining $V_3 = V_2 + \frac{1}{2}e_3^2$

And following the approach presented in [23] and [25], it can be shown that the stability of the overall system is confirmed if

$$u_f = \left(A + k_1 \frac{EV_L}{X}\cos x_1\right)x_1 + \left(B - \frac{EV_L}{X}\cos x_1 - a_3\right)e_2 + \left(C - k_3\right)e_3$$

, where $k_3 > 0$

Where

$$A = K_f - k_1^2 K_f + k_1 K_d K_f - 2k_1 K_p + \frac{k_1^3}{K_p} - \frac{k_2}{K_p}$$

$$B = \left(k_1 + k_2 - K_d\right)K_f + \frac{1 - k_1^2 - k_2^2 - k_1 k_2}{K_p}$$

$$C = -k_1 - k_2 + K_p K_f$$

$$\dot{V} = -k_1 x_1^2 - k_2 e_2^2 - k_3 e_3^2$$

However, as a linear controller, it cannot guarantee large-signal stability in all operating conditions especially when system dynamics drifts to the nonlinear region. This is more pronounced in sudden large transients such as self-synchronization where any large mismatch between frequency and angle of both sides across the connecting breaker (or recloser) may contribute to poor performance and even instability. To overcome this issue, a nonlinear back-stepping power damping controller is proposed and augmented with the linear controller asshowninFig.4.4.

Fig shows the simulated system with linear and non linear supplementary controllers

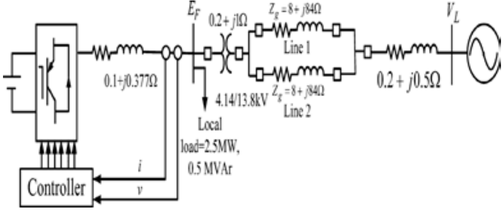

Fig. 3.5. Simulated system.

Since the nonlinear controller is a supplementary one providing an additional signal for the linear controller, the designs of the controllers are decoupled. The practicality of the nonlinear controller is also discussed.

5. SIMULATION RESULTS

The simulation model of the proposed dc grid based wind power generation system shown in Fig. 4.1 is implemented in MATLAB/Simulink. The effectiveness of the proposed design concept is evaluated under different operating conditions when the microgrid is operating in the grid-connected or islanded mode of operation.

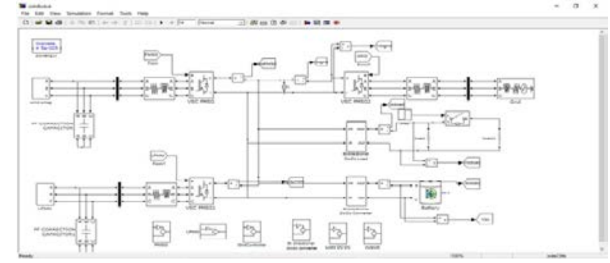

Fig: 4.1 Configuration of the studied integrated wind and wave power generation system connected to a power grid through the proposed dc microgrid

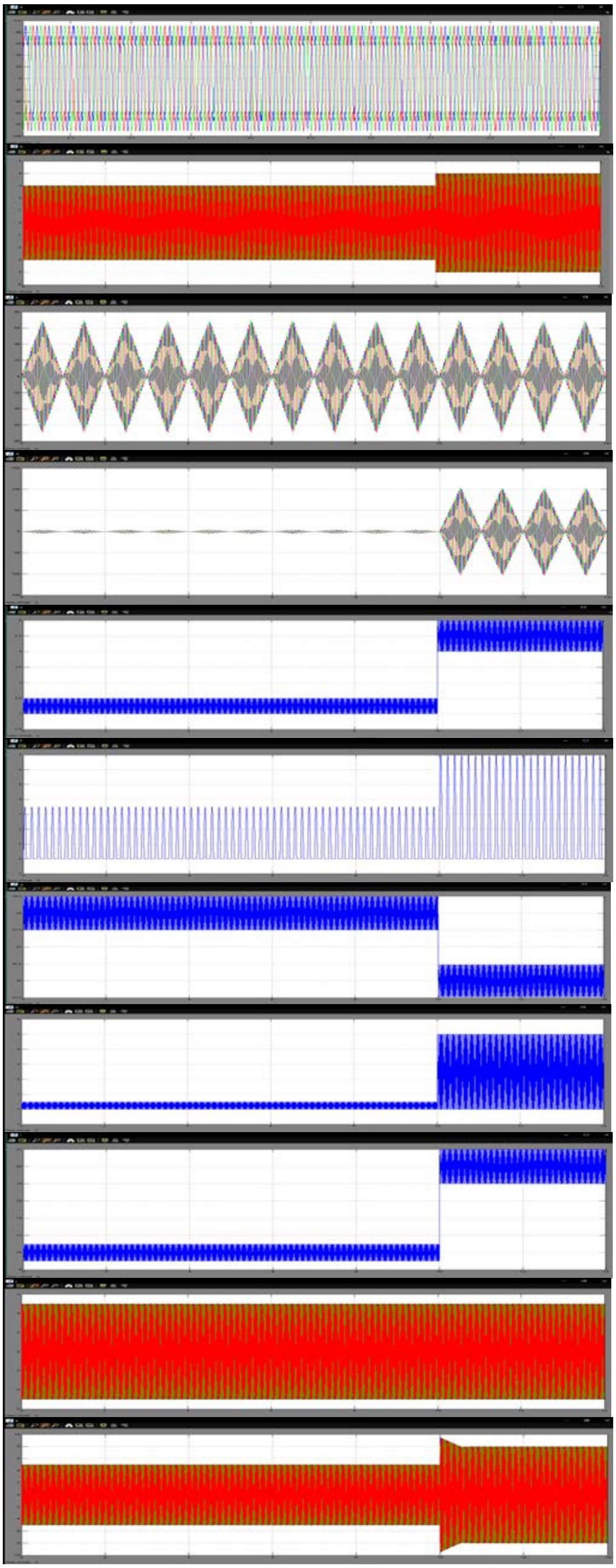

Fig 4.2 Measured (left) and simulated dynamic responses of the studied integrated system subject to a sudden load-switching condition. (a) Output voltage of PMSG. (b) Output current of PMSG. (c) Output voltage of the wind LPMG. (d) Output current of the wave LPMG. (e) Output dc current of the wind PMSG. (f) Output dc current of the wave LPMG. (g) DC voltage of the dc microgrid. (h) Output current of the bidirectional dc/dc converter. (i) DC current flowing into the dc/ac inverter. (j) Output voltage of the dc/ac VSI. (k) Output current of the dc/ac VSI.

6. CONCLUSION

In this paper, 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 project to examine the fundamental operating characteristics of the studied integrated system fed to the 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.

REFERENCES

[1] Y. Ito, Y. Zhongqing, and H. Akagi, “DC microgrid based distribution power generation system,” in *Proc. 4th IEEE Int. Power Electron. Motion Control Conf.*, 2004, vol. 3, pp. 1740–1745.

[2] S. K. Kim, J. H. Jeon, C. H. Cho, J. B. Ahn,& S. H. Kwon,“ Dynamic modelling and control of a grid-connected hybrid generation system with versatile power transfer,” *IEEE Trans. Ind. Electron.*, vol.55,no. 4, pp. 1677–1688, Apr. 2008.

[3] C. Abbey and G. Joos, “Supercapacitor energy storage for wind energy applications,” *IEEE Trans. Ind. Appl.*, vol. 43, no. 3, pp. 769–776, May 2007.

[4] X. Liu, P. Wang, and P. C. Loh, “A hybrid ac/dc microgrid and its coordination control,” *IEEE Trans. Smart Grid*, vol. 2, no. 2, pp. 278–286, Jun. 2011.

[5] H. Kakigano, Y. Miura, and T. Ise, “Low-voltage bipolar-type dc microgrid for super high quality distribution,” *IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 3066–3075, Dec. 2010.

[6] M. G. D. S. Prado, F. Gardner, M. Damen, and H. Polinder, “Modeling and test results of the Archimedes wave swing,” *J. Power Energy*, vol. 220, no. 8, pp. 855–868, Dec. 2006.

[7] B. Das and B. C. Pal, “Voltage control performance of AWS connected for grid operation,” *IEEE Trans. Energy Convers.*, vol. 21, no. 2, pp. 353–361, Jun. 2006.

[8] E. Tara *et al.*, “Dynamic average-value modeling of hybrid-electric vehicular power systems,” *IEEE Trans. Power Del.*, vol. 27, no. 1, pp. 430–438, Jan. 2012.

[9] H. L. Do, “Nonisolated bidirectional zero-voltage-switching dc–dc converter,” *IEEE Trans. Power Electron.*, vol. 26, no. 9, pp. 2563–2569, Sep. 2011.

[10] D. Salomonsson, L. Söder, and A. Sannino, “An adaptive control system for a dc microgrid for data centers,” *IEEE Trans. Ind. Appl.*, vol. 44, no. 6, pp. 1910–1917, Nov./Dec. 2008.

[11] D. Salomonsson and A. Sannino, “Low-voltage dc distribution system for commercial power systems with sensitive electronic loads,” *IEEE Trans. Power Del.*, vol. 22, no. 3, pp. 1620–1627, Jul. 2007.