Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 61 (2014) 1703 – 1706
Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Adaptive power control method considering reactive power reserve for wave-offshore hybrid power generator system

S. Jung[a], H. W. Kim[a], G. Jang[a]*

[a]School of Electrical Engineering, Korea University, Seongbuk, Seoul, 136-713, Korea

Abstract

The combined generator system with the wind and wave power can share the off-shore platform and therefore have the advantage of constructing the transmission system as well as the power conversion system. The established wind power generator systems do output determination by following the transmission system operator's directions and control the turbine by focusing at PCC, but when connected with the wave-power generator; it is needed to do the complex control. Especially, since the method and impact of active power control are different, it is required to distribute demanding power and responsibility to each turbine by considering the grid condition. In this paper, the control system is formed to do output determination of the combined generator system by paying attention to reactive power reserve of utility grid with the analysis of the controllable elements of the wind and wave power generator. And the comparison with the existing system is carried out based on the real system information. Through using the PSCAD/EMTDC simulation, the suitability of the new control technique of the combined system is estimated by proposing the active power control according to the reference signal of TSO and the reactive power capability followed by it.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: Combined generator, reactive capability, optimal power flow, system dynamic, wave energy.

1. Introduction

As the interest in renewable energy sources is recently increasing, there has been a growing interest in not only doing research on the existing renewable sources but forming the combined generator system which can lead to construction cost minimization. Each combined generator technologies is focused on improving the reliability issues of renewable sources, which can affect not only power supply plan but also a voltage fluctuation of utility grid [1]. The wave combined power generator system is being considered in wind energy field due to the effectiveness of composing hybrid system in offshore region.

* Corresponding author. Tel.:+82-10-3412-2605; fax: +82-2-3290-3692.
E-mail address: gjang@korea.ac.kr

Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.12.196

In case of the wave-offshore wind hybrid system, the advanced control logic about each generator is required because the expected reserve power and impact by each system are not equal. Moreover, the control logic for the large-scale generator system should consider the reactive power reserve (RPR) which is necessary for utility grid to stabilize system operation. The wind generator and the wave generator have different characteristics of the reactive power output because the power conversion system (PCS) should be constructed according to the output power characteristics of each system [2].

This paper deals with the hybrid system which is built on the shared offshore platform for economic advantage. The system is currently studied and has relatively large-scale output power characteristic by being composed of several wave and wind systems. The adaptive power control method is discussed in this paper by considering RPR and verified through the transient simulation tool.

2. Wave-offshore combined generator system

The wave-offshore combined generator system is a planned system for reducing construction cost and efficiently using both PCS and transformer by building a number of wind turbines and wave generators in one platform [3]. Currently, it is in progress to form the generator system over 10 MW. Doubly fed induction generator (DFIG) wind turbine and permanent magnetic synchronous linear generator (PMSLG) wave generator are the main devices of the proposed system and power generator would be transferred to the utility grid through the inner transfer system. Since the capacity of the proposed generator is relatively greater than that of the previous distribution generator, the system should follow the order of transmission system operator (TSO) and the output power of each generator is designated according to the reference signal. Fig. 1 represents the conceptual image of the proposed system and the process of power flow analysis which is described in this paper. Unlike the current power flow formulation which is not including RPR control method, the proposed control method includes an algorithm to maximize RPR which is necessary for these kinds of large distribution systems.

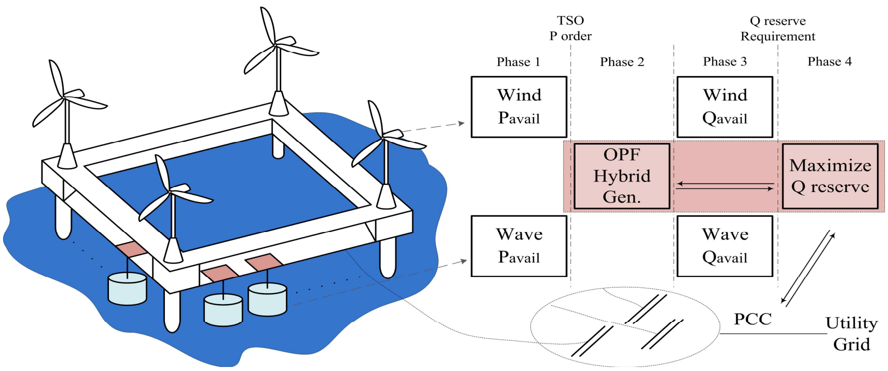

Fig. 1. The concept of the wave-offshore combined generator system and power flow process

3. Adaptive power control

Each generator is designated output power by through calculating process of optimal power flow (OPF) for reducing system loss. In case of OPF, there is a lack of the priority of reactive power in control process because the maximum reactive power quantity of each generator is determined by the active power output of generator. Furthermore, the DFIG has additional RPR limitation due to the power factor control responsibility [4]. The formula of OPF and maximum RPR of DFIG as follows:

$$\sum_{k=1}^{n} P_{\text{wind\_k}} + \sum_{i=1}^{m} P_{\text{wave\_i}} - \sum P_{loss} - P_d = 0 \quad (1)$$

$$\left|Q_{\max}\right| = P_{wind}\tan(\cos^{-1}0.95) \qquad (2)$$

Where n is the total no. of wind generator, and m is the total no. of wave generator, and P_{loss} is the line loss between generator and PCC, and P_d is the power demand at PCC.

The proposed control method pursues the adoptive power control between OPF and additional RPR control to maximize available quantity when the reactive power demand of the utility grid is increasing. The method is basically progressed based on OPF formulation but the additional power distribution algorithm shown in Fig. 2 is included in preparation for unexpected reactive power demand.

The DFIG and PMLSG have different characteristics about apparent power and maximum reactive power due to the dissimilar PCS systems which only can control d-axis current. If the TSO request additional voltage compensation, the algorithm calculates each turbine's available control quantity by focusing on a balance point of required active power and maximum RPR. After finding available control value, the algorithm determines the order of each generator and assigns reference signal for system operation.

Basically, the system mainly considers TSO order to respond to grid requirement and the time interval between updating signals might be longer than electrical operation. Therefore, the algorithm should check the difference quickly from the previous phase and proceed to next sequence by minimizing signal values.

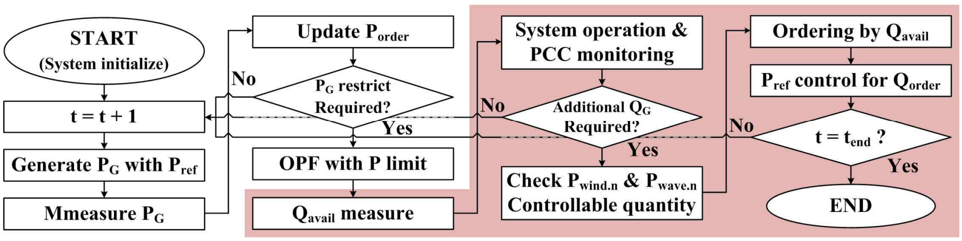

Fig. 2. RPR maximizing control algorithm

4. Simulation

4.1. System design

In this paper, it is assumed that the combined generator is composed of 4 DFIG wind generators and 24 wave generators which are currently designed. The system data is shown in Table 1 and it's needed for the simulation. The main purpose of the simulation is to confirm the response of adoptive control according to the system condition. By using the PSCAD/EMTDC, the composed system can be verified regarding transient fluctuation with reference signal by TSO.

Table 1. Numerical data of the performed simulation

t_{sim}	System voltage	P_{total}	P_{wind}	P_{wave}	PCS	$p.f._{wind}$	$t_{limit-1}$	$P_{limit-1}$	$t_{limit-2}$	$P_{limit-1}$
11 [sec]	0.69 [kV]	10.4 [MW]	8 [MW]	2.4 [MW]	2 [MVA]	-0.95~ 0.95	2-7 [sec]	8 [MW]	7-11 [sec]	6 [MW]

4.2. Case studies

The historical value of JEJU Island in Korea is applying in the entire simulation process. Fig. 3 shows the original power curve by the combined generator and regarding RPR curve with previous control system. The system generates output power less than reference signal but there is no available plan

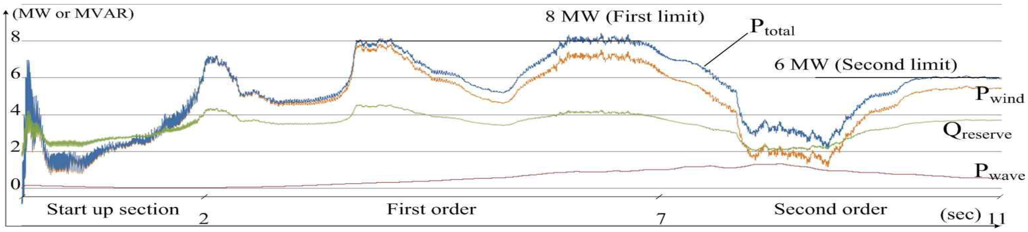

Fig. 3. The output power and RPR of hybrid generator with previous control

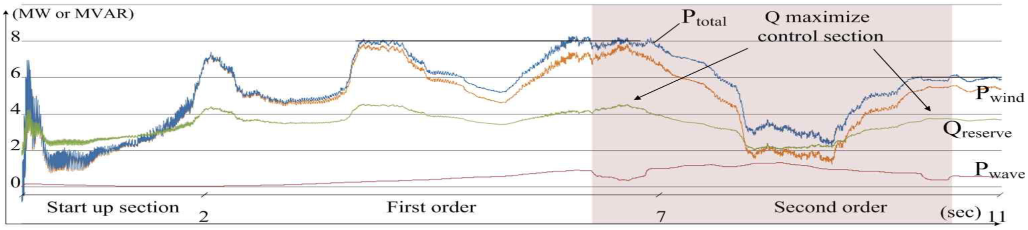

Fig. 4. The output power and RPR of hybrid generator with proposed algorithm

regarding RPR for considering grid condition. Fig. 4 indicates the new power curve with proposed algorithm for the same time period and operational condition. The designated section show higher RPR quantity than previous one. The system can be operated by according to the TSO order for maximizing RPR. The active power profile of each generator is adjusted within the designated quantity as shown at the beginnings and endings parts of the highlighted control section. However, the considerable limitation about wave power through adjustable resistance can generate overload to PMSLG, thus additional constraint might be required.

5. Conclusion

This paper suggests the new power control algorithm on the hybrid generator system to respond to the situation of lack of RPR. Through case studies, it is verified that the proposed algorithm contributes to the response of TSO order. As the variation of TSO order, the system changes the reference signal by calculating available control values and adopting it for maximum RPR. The impact of the algorithm would be huge with the high penetration of the hybrid generator system. Small-scale RPR compensation might be useful for the large-scale offshore generator system.

Acknowledgements

This work was supported by the MOF grant (Development of the design technologies for a 10MW class wave and offshore wind hybrid power generation system and establishment of the sea test infra-structure) and by Human Resources Development of KETEP grant (No. 20114010203010) funded by the Korea government.

References

[1] Srinivasa Rao J., Murthy B. K.. A new control strategy for tracking peak power in wind or wave energy system, Renewable Energy, 34, 2009, 1560-1566.

[2] Stoutenburg E.D., Jacobson M. J., Reducing Offshore Transmission Requirements by Combining Offshore Wind and Wave Farms, IEEE Journal of Oceanic Engineering, 36, 2011, 552-561.

[3] Beerens J., Offshore Hybrid Wind-Wave Energy Converter System. 2007.

[4] Konopinsky R. J., Vijayan P., Ajjarapu V., Extended Reactive Capability of DFIG Wind Parks for Enhanced System Performance, IEEE Trans. Power Systems, 24, 2009, 1346-1355.

Seungmin Jung

He received B.S. and M.S. degree in electric engineering from Korea University. He is currently pursuing Ph.D. degree at Korea University graduate school. His research interests include railway system and wind power system.