Dynamic performance assessment of wind energy pump storage units in Crete's power system

KARAPIDAKIS Emmanuel[1, a], GEORGILAKIS Pavlos[2,b] , TSIKALAKIS Antonis[3, c], KATSIGIANNIS Yiannis[1,d] and MOSCHAKIS Marios[4,e]

[1]Technological Educational Institute of Crete, Greece

[2]National Technical University of Athens, Greece

[3]Technical University of Crete, Greece

[4] Technological Educational Institute of Larissa, Greece

[a] karapidakis@staff.teicrete.gr, [b] pgeorg@power.ece.ntua.gr, [d] katsigiannis@chania.teicrete.gr

Abstract. Large scale integrating of wind power generation into a grid may raise serious stability issues. In this case energy storage systems seem to be suitable for balancing power and energy between the inconstant wind parks generation and the grid. In this paper, the impact of high wind power penetration on the dynamic performance and stability of power systems is investigated. More precisely, the focus of this study is to assess the operation of pump storage systems in the autonomous power system of a large island such as Crete. Results of this study show that it is possible to achieve a large wind power penetration without significant dynamic security problems, if wind energy pump storage units are in operation.

1. Introduction

In island systems, production, transportation and distribution of electrical energy face increased problems related to their operation and control. In most of these systems, electricity production cost is much higher than in interconnected systems due to their more stretched and complex operation. Additionally stability is also a major concern, since mismatches in generation and load and/or unstable system control might lead to frequent system failures. Although, renewable and especially wind parks exploitation appear particularly attractive, they present an unpredictable character and problems may appear when integrating it in a large scale. Moreover, the integration of a substantial amount of wind power in autonomous power systems needs careful consideration, so as to maintain a high degree of reliability and security of the system operation.

The main problems identified concern operational scheduling (mainly unit commitment) due to high production forecasting uncertainties, as well as steady state and dynamic operating problems. These problems may considerably limit the amount of wind generation that can be connected to the island systems, increasing the complexity of their operation. Thus, next to the more common angle and voltage stability concerns, frequency stability must be ensured. This depends on the ability of the system to restore balance between generation and load following a severe system upset with minimum loss of load. Energy storage could eliminate these problems. Especially, pumped storage units can contribute, as the extra energy provided by the wind turbine is used to pump water from an inferior basin into a superior one, which is then released when more power and/or energy is needed. Pumped storage presents many advantages like long time storage period without losses, fast response in load demand, high storage capacity, and good efficiency at high power level, while it is the only successfully implemented storage method for high power levels.

In this case, dynamic simulation studies must be among the first steps in determining the level of wind power penetration in isolated power systems. Thus analytical studies are required in order to derive security rules and guidelines for the optimal operation of these complex systems. Studies on the dynamic stability of the isolated power system are necessary, monitoring voltage and frequency calculations under several abnormal operating conditions, e.g. start-up or sudden disconnection of wind generation, wind fluctuations, short circuits on the network etc, hydro units and pumps operation. The new operating and planning policies imposed by the current demands for increased efficiency and economy, dictate the need to operate the power system in a more stressed way and to consider more effective means of providing a given level of reliability and stability. Moreover, in order to operate optimally within the new conditions, the possibilities of providing a required level of security have to be accounted for. This is directly linked to the provision of remedial actions, in case of insecure situations. For dynamic security, unlike steady state security, remedial actions can only be preventive leading to load shedding or generation rescheduling. Results of this study show that wind

energy pump storage units could successfully provide adequate and fast spinning reserves and/or pumps load disconnections as potent remedial actions to improve system stability.

2. Energy Pump Storage Units

Energy Storage system: A group of pump storage units (PSUs) are considered in operation with nominal power equal to 100MW. These units are used both as pumps and as hydro generator contributing to the operation planning and control of the examined power system. Extensive transient analysis studies are conducted in order to assess the dynamic behavior of the system under various disturbances. Fig 1 depicts the frequency change in five different scenarios under same disturbance.

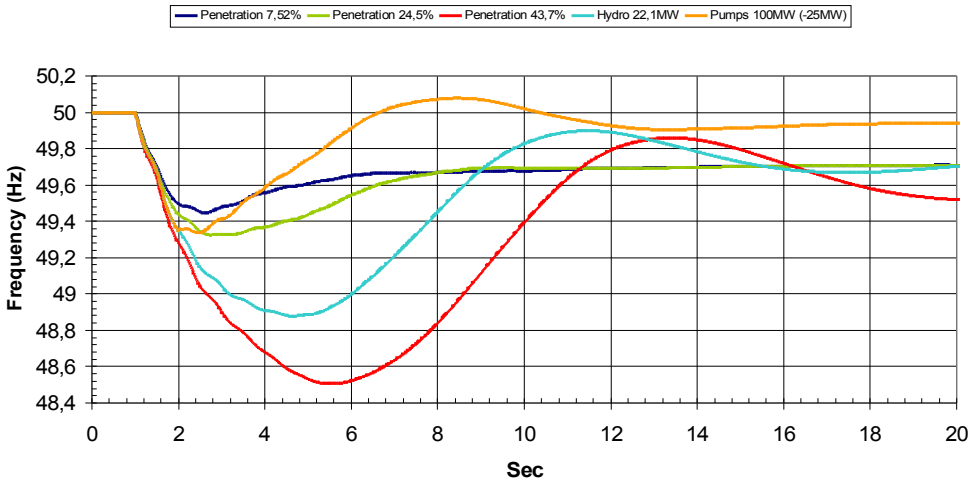

Fig. 1 Frequency fluctuations in five different operation scenarios of Crete power system

More precisely, the first three scenarios correspond to the three levels of RES penetration: (a) 7.52%, (b) 24.5% and (c) 43.7%. While in the next two scenarios the pump storage units are considered to operate (d) as hydro generators in their technical minimum and (e) as pumps that consume exclusively wind energy. The frequency behavior and the dynamic performance in general of the examined power system are clearly improved by the use of PSUs. Especially in case of PSUs operation as pumps the use of controlled load shedding enforce significant system stability..

4. Acknowledgement

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: ARCHIMEDES III. Investing in knowledge society through the European Social Fund.

References

[1] Papathanasiou; S., Boulaxis, N., (2006). Power limitations and energy yield calculation for wind farms operating in island systems, Elsevier, Renewable Energy, 31, (4), pp. 457-479.

[2] Georgilakis; P.S., (2008). Technical challenges associated with the integration of wind power into power systems, Renewable and Sustainable Energy Reviews, Vol. 12, No. 3, pp. 852-863.

[3] Karapidakis; E.S., Thalassinakis, M. (2006). Analysis of Wind Energy Effects in Crete's Island Power System, 6th International World Energy System Conference, Turin, Italy, July 2006.

[4] E.S. Karapidakis, Y.A. Katsigiannis, P.S. Georgilakis, E. Thalassinakis, (2011). Generation expansion planning of Crete power system for high penetration of renewable energy sources, Mater. Sci. Forum, Vol. 670, pp. 407-414.

[5] E.S. Karapidakis, A.G. Tsikalakis,Y.A. Katsigiannis, M. Moschakis, (2012). Impact of increased RES generation on power systems dynamic performance, Mater. Sci. Forum, Vol. 721, pp. 185-190.