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Increasing penetration of renewals in isolated power systems using energy storage systems

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Abstract. Frequency stability is one of the most relevant issues in operation of isolated power systems. High penetration of renewals may affect significantly frequency stability of isolated power systems since wind and solar photovoltaic generation have neither inertia nor primary frequency regulation. An alternative is the use of storage systems in the most critical operating conditions in such a way that if a generator trips, storage systems are subsequently tripped and the power balance is restored. This paper presents an approach to determine the maximum renewable generation in an isolated power system to prevent non-admissible frequency excursions in case of generator tripping. Moreover, such approach allows sizing an energy storage system to increase the penetration of renewals.

Keywords. Isolated power systems, Energy storage systems, Frequency stability

1 Introduction

The most relevant issue in operation of isolated power systems is frequency stability [1]. Frequency stability is concerned with the ability of the generators to supply the loads within acceptable frequency ranges in case of generator tripping. Frequency stability is governed by the kinetic energy stored in the generator-prime mover rotating masses and the prime mover frequency primary regulation. If frequency excursions are not within +/-2.5 Hz range (see [2]), cascade tripping of the remaining generators can occur because of generator over/under frequency protections tripping. High penetration of renewals may affect significantly frequency stability of isolated power systems since wind and solar photovoltaic generation have neither inertia nor primary frequency regulation. An alternative is the use of storage systems in the most critical operating conditions in such a way that if a generator trips, storage systems are subsequently tripped and the power balance is restored. The paper determines the critical operating conditions (maximum admissible renewable generation) and the renewable generation to be compensated.

2 Isolated Power Systems

Isolated power systems and interconnected power systems exhibit different features. Isolated systems are much smaller than interconnected systems. In addition, they cannot count with the support of the neighbour systems. That is, the size and the lack of external support make isolated systems more vulnerable than interconnected systems. It is especially true in case of disturbances. Hence, the system stability is at risk.

Power system stability is concerned with the ability of the generators to run in synchronism and to supply the loads at acceptable frequency and voltage ranges in case of normal (load variations) and abnormal disturbances (faults, generator tripping) that may occur in power systems. The power system stability problem is a very difficult one. Its study is facilitated by separating it into three subproblems: angle, frequency and voltage stability [3]. We will concentrate on the frequency stability problem since it will be present in all isolated power systems not matter how strong the power network is. Precisely, frequency stability analyzes the capability of generators to supply load at acceptable frequency ranges in case of generator tripping. Frequency results from the generator rotor speeds. Generator rotor speeds result from the equilibrium between the power supplied by their primer movers (either turbines or engines) and the power consumed by the loads. Frequency stability is governed by the inertia of the rotating masses of primer movers and generators and the gain and time constant of the primary frequency regulation of prime movers in such a way that:

- After a generator trips, frequency decays with a rate of change that depends of the inertia of prime mover-generator rotating masses and the magnitude of the generation lost.
- Prime mover primary frequency regulation reacts to the frequency decay increasing the output of the power supplied by the prime movers.
- Frequency stabilizes if two conditions are fulfilled: the remaining on line generators have enough reserve to supply the generation lost and they are also able to increase the power output fast enough to avoid that frequency is below the settings of generator underfrequency protections to avoid generator cascade tripping.

Frequency stability is at risk in isolated power systems because of the fact that the frequency rate of change in case of generator tripping is bigger than in an interconnected power system. The inertia or the kinetic energy of the rotating masses of an interconnected system is much bigger than the inertia of the rotating masses of an isolated system. In addition of, the magnitude of the