Integrating renewable energy in power systems: Challenges and solutions

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INTEGRATING RENEWABLE ENERGY IN POWER SYSTEMS: CHALLENGES AND SOLUTIONS

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1. OVERVIEW

Energy issues, such as greenhouses gas (GHG) emissions, resource scarcity and energy independency, are challenging the way we currently produce, transport and consume energy. For the long term, the EU has proposed a “Roadmap for moving to a competitive low-carbon economy in 2050”, which aims at an 80% to 95% reduction in GHG emissions compared to 1990. To achieve this goal, the main focus will be on renewable energy sources and the electrification of energy consumption [EUC11].

In the EU, the electricity and heat sectors accounted for 32% of total CO_2 emissions in 2008 [EEA10] making them the leading source of CO_2 emissions. This sector is also considered to be a main driver for reducing CO_2 emissions.

We propose here to explore technical options for the integration of renewable energy in power systems with a focus on reliability issues. We will rely on energy planning models, such as the TIMES family, which are useful tools to provide plausible options for the long-term development of power systems [LOU05]. We also developed a model based on a thermodynamical description of power systems that enables the assessment of power system reliability [DRO08, DRO11, DRO14].

2. METHODS

TIMES models are bottom-up technological models that enable a very accurate representation of energy systems. In our study we use a model of the French power system representing all the existing power plants, new power plant technologies and a disaggregated demand sector. The prospective horizon of the study is 2050 and the model optimizes the power system consistently between today and this time horizon. Each year is divided into 84 time slices, which allows us to represent approximate typical load-curves and the supply-demand balance complexity [ASS13].

Power supply reliability is addressed by considering the power system’s ability to supply the overall electricity demand at all times, together with its ability to withstand sudden disturbances such as the unanticipated loss of system elements (e.g. load or production fluctuations, network contingencies). This is usually enforced with appropriate management of voltage and frequency, of which significant deviations can lead to brownouts [BER00, BRO05].

Unfortunately, the stability studies used to check real-time power supply reliability involve time scales ranging from a few milliseconds to a few hours, whereas planning models deal with several years. We apply variational principles deduced from thermodynamics [MAZ04] that come down to a one-loop circuit, lumping together the dynamic properties of a wide power system [DRO08, MAZ12]. We find that reliability relies on the dynamic properties of production and transmission capacities, which are assessed through the magnetic and kinetic reserve of the whole system.

Using this approach, we are able to calculate those reserves in our knowledge of the elements constituting the power system under study, and thus reconcile the very short times of power systems dynamics and the very long term of energy prospective.

Several options could help maintain power system reliability. Today, grid operators rely on conventional generators that can be operated in a very short lead-time or that have very good inertia which allows them to absorb fluctuations in power supply or demand. However, they may also use load-shifting or other Smart Grid technologies to control demand and make it more flexible [IEA11]. By implementing all the different options in a single model, we assess which are the most efficient to fulfill operating requirements in regard to contrasted energy scenarios [BOU13a, BOU13b].

3. RESULTS

We demonstrated that high-share of renewable energy in power production make power system reliability decrease dramatically. Indeed, significant shares of renewable energy sources in electricity production include large shares of intermittent sources: mostly photovoltaic and wind energy. Photovoltaic and wind production cannot participate in maintaining sufficient levels of magnetic and kinetic reserves, which are nevertheless crucial to power system reliability [BRO05].

On the contrary, some Smart Grid options could increase the flexibility of power systems and thus their reliability.

In our study, we describe the impact on reliability indicators of different penetration levels of all of these technologies in order to assess the evolution of power system reliability in contrasted low-carbon scenarios.

4. CONCLUSIONS

Classical energy planning models can not properly assess the integration of intermittent renewable energy in power grids since they are not able to catch the very short term dynamics that lead the management of power systems. Using an aggregate approach based on thermodynamics we can find a solution to this drawback and thus assess power systems reliability evolution with renewable energy integration. We find that power systems are strongly affected by renewable energy but that it can be partially overcome with new flexibilities such as smart grid options or new interconnections.

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