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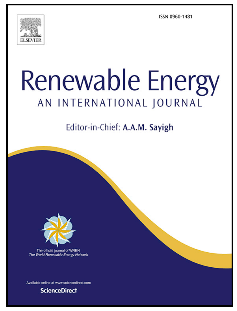

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Simulation of a Power System with Large Renewable Penetration

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Abstract This paper presents a simulation software initially developed by the author for educational purposes. The computational tool supports the design of power systems with large penetration by renewable energy sources. In particular, the problematic of power intermittency and its counter strategies are targeted. The main innovation of this simulation is the detailed transient analysis of the essential balance between power generation and consumption. Even so, the focus of the simulation tool is simple usage and interpretation of results, it successfully captures important characteristics of renewable power systems. The user selects the composition of a power system from conventional power plants, photovoltaic, windpower and tidal power. Following system definition, power generation and power demand are calculated based on local weather data. Energy storage can be added to balance mismatches between power demand and supply. Following the completion of a simulation system autonomy, carbon emission and electricity cost are evaluated to assess the performance of energy systems.

Keywords Renewable Energy; Power System; Penetration Factor; Power Intermittency; Computational Simulation; Education.

1. Introduction

Power systems require a careful balance between electricity generation and consumption. Both must be carefully matched as electrical power transmission systems cannot safely store large amounts of electrical energy. Insufficient power generation results in brown-outs and eventually black-outs that, unless contained, cause the collapse of the entire power system. Conversely, excess power supply may damage expensive equipment (e.g. generator motoring due to frequency increase).

Power demand varies throughout each day and power generation must be continuously adjusted to maintain this essential balance. This challenge is not new but dates back to the origin of connected power systems [1]. Typical solutions are fast-response (e.g. gas turbines) or spinning-reserve power plants that allow for the quick adjustment of power generation.

The introduction of intermittent renewable power sources significantly increases the complexity of maintaining this balance. The reason are frequent and, most importantly, stochastic changes in renewable power generation. For example, the maximum available electricity output of a windpower plant is limited by the current windspeed. This phenomenon is known as power intermittency and occurs for the most common renewable energy sources. Therefore, the control of power generation becomes far more complex: in addition to power demand variation, sudden changes in power generation must be compensated. Renewable power plants may also provide excess electricity during times of low power demand. In order to prevent the loss of this valuable commodity, energy storage solutions gain in importance.

Simulation tools have been widely used to study the integration of renewable energy sources into modern power systems. Holistic software packages such as ETAP [2], Eurostag [3], and PSAPAC [4] allow the detailed simulation of complex power systems and their components. However, these programs often focus on electrical system characteristics (e.g. harmonics, short circuit analysis, device protection, …). The current paper instead focuses on the dynamic relationship between weather conditions, power generation, and power