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# Modelling and simulation of a high penetration wind diesel system with battery energy storage

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ABSTRACT

Wind Diesel Hybrid Systems (WDHS) are isolated power systems which combine Diesel Generators (DG) with Wind Turbine Generators (WTG). Depending on the generators which are supplying, high penetration (HP) WDHS have three operation modes: Diesel Only (DO), Wind Diesel (WD) and Wind Only (WO). The HP-WDHS presented in this article consists of a Diesel Engine (DE), a Synchronous Machine (SM), a Wind Turbine Generator, the consumer load, a Ni-Cd Battery based Energy Storage System (BESS) and a Dump Load. The DE can be engaged (DO and WD modes) or disengaged (WO mode) from the SM by means of a clutch. All the models of the previously mentioned components are presented and the performance of the WDHS has been tested through dynamic simulation. Simulation results with graphs for the frequency and voltage of the isolated power system, active powers generated/absorbed by the different elements and the battery voltage/current/state of charge are presented for a load change in WO mode and for the transition from WO to WD mode in order to substitute a supplying BESS for the DE as the active power source.



## 1. Introduction

A Wind Diesel Hybrid System (WDHS) is any autonomous electricity generating system using Wind Turbine Generators(s) (WTG) with Diesel Generator(s) (DG) to obtain a maximum contribution by the intermittent wind resource to the total produced power, while providing continuous high quality electric power [1]. The main goal with these systems is to reduce fuel consumption and in this way to reduce system operating costs and environmental impact. If the WDHS is capable of shutting down the Diesel Generators during periods of high wind availability, the WDHS is classified as high wind penetration. High penetration (HP) WDHS have three operation modes: Diesel Only (DO), Wind Diesel (WD) and Wind Only (WO) [2]. In DO mode the Diesel Generators supply the active and reactive power demanded by the consumer load (WTGs are disconnected). In WD mode, in addition to DG(s), WTG(s) also supply active power. In WO mode the Diesel Generators are not running, only the wind turbines are supplying active power, so that no fuel is consumed in this mode.

Several papers have been published on the subject of WDHS dynamic simulation. In [3] the interaction between one DG and a constant/variable speed WTG is studied. In [4] a no-storage WDHS is simulated against several perturbations, among them the connection of a WTG to the DG isolated grid (DO to WD transition). In a previous work [5] a HP-WDHS with a BESS is simulated in WO mode, but the battery is modelled by a simple constant voltage source. In [6] the modelled HP-WDHS has a DG with a locked-disengaged simplified clutch model and it is simulated the mandatory transition from WO to WD when the active power generated is less than consumed. During this type of WO to WD transition the power system is without control until the DE is added to the system.

In the present article the WO mode is also simulated, but a more elaborated model for a Ni-Cd battery is used and the main battery variables: current, voltage and state of charge are presented during the simulation. Additionally, in the present article a more realistic clutch model is also used to transition from WO to WD, but in this case the transition simulated is controlled and it is done in order to substitute a supplying BESS by the DE.

After this introductory Section 1, this article is organized as follows: Section 2 presents the HP-WDHS architecture discussed in this article along with its control requirements, Section 3 presents the control system that has been used, Section 4 shows the modelling of the WDHS components, Section 5 presents the WDHS response in WO mode against a load step and the controlled WO to WD transition simulation and Section 6 emphasizes the effectiveness of using the Ni-Cd BESS.

## 2. The isolated power system (WDHS architecture)

The high penetration WDHS of Fig. 1 comprises one DG and one WTG. The DG consists of a Diesel Engine (DE), a Synchronous

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