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Coupling Wind Farm with Nuclear Power Plant

A Thesis

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Statement

This dissertation is submitted as partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

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Abstract

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Climate change has been identified as one of the greatest challenges facing nations, governments, businesses and citizens of the globe. The threats of climate change demand an increase in the share of renewable energy from the total of energy generation. Meanwhile, there are tremendous efforts to decrease the reliance on fossil fuel energies which opens the venue for increasing the usage of alternative resources such as nuclear energy. Many countries (e.g. Egypt) are planning to meet increasing electricity demands by increasing both renewable (especially wind energy) and nuclear energies contributions in electricity generation.

In the planning phase of siting both new Wind Farms (WFs) and Nuclear Power Plants (NPPs), many benefits and challenges exist. An important aspect taken into consideration during the NPP siting is the existence of ultimate heat sink which is sea water in most cases. That is why most NPPs are sited on sea coasts. On the other hand, during WF siting, the main influential aspect is the existence of good wind resources. Many coastal areas around the world fulfill this requirement for WF siting. Coupling both NPPs and WFs in one site or nearby has many benefits and obstacles as well. In this thesis, based on international experience and literature reviews, the benefits and obstacles of this coupling/adjacency are studied and evaluated. Various case studies are carried out to verify the coupling/adjacency concept.

Index Terms – Coupling NPP and WF, Reliability and Availability using Markov Process, WFs' grid requirements WFs' Capacity Credit and geographical distribution.

Summary

This thesis studies and evaluates the benefits and obstacles of coupling of Wind Farms (WFs) with Nuclear Power Plants (NPPs). The dissertation is divided into five chapters organized as follows:

Chapter One: It is an introduction to the idea of coupling of WF with NPP. Motivation of the idea and the thesis outline are discussed.

Chapter Two: This chapter presents the literature survey, and the characteristics of the site that can accommodate both NPP and WF are illustrated. It also evaluates different sites in Egypt that can accommodate coupling. Finally, advantages and disadvantages of coupling of WFs with NPPs are explained.

Chapter Three: It illustrates the benefits of connecting WF and NPP to the same point of the grid. Two case studies are conducted to verify two main benefits of this adjacency, which are the impact of high short circuit power level on the voltage quality aspects of WF, and increasing reliability and availability of NPP Emergency Power Systems (EPSs) by the on-site WF.

Chapter Four: The benefit of helping in geographical distribution of WFs in the grid is discussed in details. A case study is conducted to illustrate the smoothing effect of WFs geographical distribution in the Egyptian grid. After that, wind energy capacity credit assessment is done considering the case in Egypt. Finally, Strategic plan for the coupling in Egypt is illustrated, considering the coordination between WFs and NPPs new installations.

Finally, the thesis ends by extracting conclusions and stating future work that might be done based on this work.

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List of Symbols

$\%P_{WF}$ (V_t)	The power generation from WF in percentage of installed capacity
$\underline{A}$	Transition rate matrix
C	Scale parameter of the 2-parameter Weibull distribution
$c(\Psi_k, Va)$	Flicker coefficient
dso	Switching operations voltage change of the grid at PCC (normalised to nominal voltage)
dss	Steady state voltage change of the grid at PCC (normalised to nominal voltage);
F	Set of failure states of the system
f(v)	Probability density function of the 2-parameter Weibull distribution of wind speed (v)
K	Shape parameter of the 2-parameter Weibull distribution
$k_f(\Psi_k)$	Flicker step factor;
$k_u(\Psi_k)$	Voltage change factor
N	Number of states
n	Reading number;
N_{120}	Number of switchings within a 2 hours period
N_r	Total number of readings for each case (24*12=288)
N_{WT}	Number of WTs in the WF
Ø	Phase angle between voltage and current
$Ø_{06}$	Probability that wind speed is in the region of S_0 (V_i <V< V_r) and decreases to be in the region of state S_6 (V< Vi)
$P(V_t)$	Power output of the WT at wind speed (V_t)
$P_0(t)$	Probability function in time of state S_0
P_E	Equipment installed capacity (MW)
$P_i(t)$	Probability of system to be in state (i) function in time
P_{lt}	Flicker distortion
P_n	Output power (% installed capacity) according to reading number (n)
P_r	Rated power output of the WT
P_r $(V_i<V<V_r)$	Probability of wind speed to be above (Vi) and below (Vr)