# Renewable Energy Integration and the Impact of Carbon Regulation on the Electric Grid

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***Abstract* — This panel session paper outlines one of the research thrust areas in the Power System Engineering Research Center's (PSERC) new initiative funded by the US Department of Energy (DOE) to investigate requirements for a systematic transformation of today's electric grid to enable high penetrations of sustainable energy systems. The proposed research under this thrust area aims at understanding and quantifying the impact that massive integration of wind power will have on the power system in terms of efficiency, operational reliability, economic consequences and environmental outcomes. It also focuses on the design and evaluation of technological and market based approaches to mitigation the adverse impact of such integration. The analysis will be based simulation models designed to explore and evaluate technological and market solutions that can facilitate the integration of renewable resources. Specifically, the potential of harnessing the inherent flexibility of certain load types such as heating and cooling and PHEV charging and the deployment of distributed and system level storage devices to mitigate the variability and uncertainty of renewable resources will be explored and evaluated.**

***Index Terms*—Future Grid Initiative, renewable integration, market integration, operating constraints, planning tools, stochastic analysis methods.**

## I. Introduction

THE integration of renewable energy resources into the power grid is driven, largely, by environmental regulation aimed at promoting sustainable energy resources and reducing carbon emission resulting from energy use. Price and quantity controls of carbon emissions through taxation and cap and trade policies, along with renewable portfolio standards (RPS) are the primary drivers for massive penetration of renewable resources such as wind and solar power into the mix of electricity resources and electrification of transportation. However, the economics and environmental regulation underlying such resources as well as the operating characteristic of these resources which are strongly influenced by weather patterns has a profound impact on the planning and operation of the power grid. There are two characteristics of power supply from renewable energy resources which present significant obstacles to their large scale integration into the power grid. Renewable energy production is uncertain and cannot be forecasted accurately. Furthermore, it is highly variable over time so that even if perfect forecasts were possible, integrating massive amounts of such resources into the power grid presents significant challenges in terms of the dispatch, reserves, and ramping requirements. These problems are particularly acute with respect to wind power whose availability is adversely correlated with demand.

The unpredictability of wind power supply which may change rapidly due to cold fronts and wind shifts can cause large deviations from hour-ahead dispatch schedules. Starting up units to compensate for a sudden shortage in wind power supply may take hours, necessitating curtailments of load. Furthermore, the need for emergency startups leads to increased emissions, and increased maintenance cost due to added wear on these units. Such emergency startups also disrupt market operations and increase dispatch cost due to the minimum load constraints of these units. Unanticipated increase in wind power supply is also problematic since it may require shutting down units due to minimum load constraints and over generation.

The minute-by-minute and intra-hour variability of wind power generation exacerbates the need for spinning reserve, non-spinning reserve, and regulation in order to compensate for the inability to perfectly forecast wind and mitigate potentially adverse impact on system reliability. Since wind tends to vary rapidly and in great magnitude it becomes necessary to invest in and dispatch fast starting generators with sufficient ramping capabilities and those are typically more expensive to operate. The California Independent System Operator (CAISO) has estimated that meeting a 20% renewable energy integration target will require generators which can ramp twice as fast as existing generators, in order to keep up with the abrupt changes in wind power supply [1]. The ramping challenge due to intraday variability of renewable resources and the scheduling challenge due to unpredictability are complex.

Yet, regardless of the challenges of large scale wind power integration, after 30 years of rapid technological development and owing to current economic, political and environmental circumstances, wind power is poised to become a mainstream energy source capable of supplying bulk quantities of power to the electricity grid. Environmental regulation aimed at reducing carbon emissions are setting aggressive targets that will require high levels of renewable penetration. For instance assembly Bill 32 in California has set goals of cutting back greenhouse gas emissions to 1990 levels by 2012 and the Renewable Portfolio Standard (RPS) mandates 33% integration of renewable energy in California by 2020. As wind penetration increases the aforementioned challenges may impact system reliability, dispatch efficiency, cost of operation and may even undermine the environmental goals that renewable port-

The author acknowledges the support of the Power Systems Engineering Research Center under grant NSF EEC-0001880.

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978-1-4673-2729-9/12/$31.00 ©2012 IEEE

folio standards (RPS), aim to achieve, unless the adverse impact of such penetration can be mitigated through the harnessing of demand flexibility and deployment of storage.

Studies have placed an estimate of wind integration costs of up to $7/MWh for integration levels between 2.4% to 20% [2]. On the other hand, significant amounts of wind power are spilled by system operators in Denmark, Texas and California. This can happen for reliability reasons during load pickup, in order to avoid oversupply, in the case of abrupt shifts in renewable supply, or at night time when other generators need to maintain a minimum output level.

The proposed research under this thrust area aims at understanding and quantifying the impact that massive integration of wind power will have on the power system in terms of efficiency, operational reliability, economic consequences and environmental outcomes. It also focuses on the design and evaluation of technological and market based approaches to mitigation the adverse impact of such integration. The analysis will be based simulation models designed to explore and evaluate technological and market solutions that can facilitate the integration of renewable resources. Specifically, the potential of harnessing the inherent flexibility of certain load types such as heating and cooling and PHEV charging and the deployment of distributed and system level storage devices to mitigate the variability and uncertainty of renewable resources will be explored and evaluated. The distinct projects described below complement each other in terms of their scope and methodological approaches to addressing the issues raised above. The results will be disseminated through academic journal publications, industry publications, trade conferences with electricity industry market participants, and through PSERC stakeholder processes.

## II. Research topics

This thrust area has four specific topics that will be examined and analyzed. These include:

1. Direct and Telemetric Coupling of Renewable Energy Resources with Flexible Loads
2. Mitigating Renewables Intermittency Through Non-disruptive Distributed Load Control
3. Planning and Market Design for Using Dispatchable Loads to Meet
   Renewable Portfolio Standards and Emissions Reduction Targets
4. Probabilistic Simulation Methodology for Evaluating the Impact of Renewables Intermittency on Operation and Planning

This panel paper will highlight the objectives of each of these research topics and also describe the research activities being conducted in each of these topics.

## III. references


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