Severe Weather Event Grid Damage Forecasting

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On behalf of

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Background

- The grid is highly vulnerable to external extreme events that seem more prevalent than before;
- Tools available for preparation and recovery from severe weather events are very crude and of limited capability;
- Outage management systems (OMSs) are passive and focus only on reported or known outages after they occur.
  - Lack analytic capabilities needed for predicting weather impacts and dispatching repair crews in a preemptive manner.

Objective

- The objective is to develop both planning and operational tools capable of assessing impacts of extreme weather events to enable
  - offline prediction of susceptible areas of the grid to different weather scenarios to allow preemptive actions to harden those areas before severe weather events are experienced and
  - online prediction of grid impacts during operation to facilitate positioning of recovery crews.

Highlights of the Proposed Study

- Why:
  - There is a strong need for utilities to have access to both a planning tool for hardening the system and an operational tool for facilitating recovery from severe weather events.
- What:
  - Weather radar coverage in northeast region is almost 100% and high resolution weather condition data is free;
  - Availability of detailed multi-year stormed-induced outage data from New York utilities including Orange & Rockland and Central Hudson Gas and Electric.

Highlights of the Proposed Study (cont'd)

- How:
  - Under severe weather events, outages are directly related to adverse weather conditions and forecasting of impact on equipment is statistically meaningful;
  - high resolution radar weather data and detailed outage data enables the development of an improved correlation model for predicting failure/repair rates;
  - Such a prediction model is applicable as both planning and operation tools.

A Statistical Framework for Severe Weather Impact Forecasting

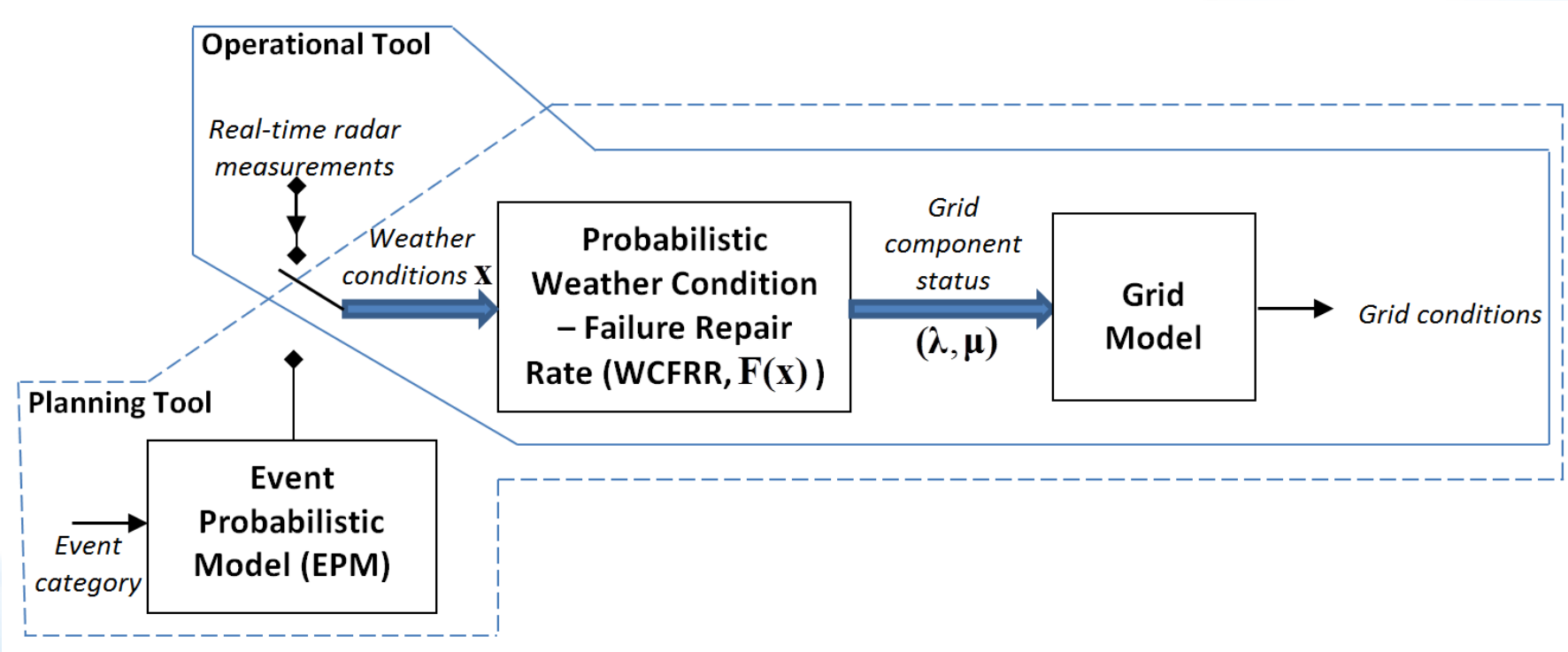
- Due to the stochastic nature of weather events and a large amount of uncertainty, a statistical framework is proposed;
- The complexity and difficulty are reduced by dividing the entire analysis into multiple subtasks that are less complicated and domain specific
  - Meteorology, statistical correlation analysis of outages and weather data, and grid modeling
  - Take advantage of existing knowledge in these domains, e.g., data analysis techniques, the weather forecasting capabilities, and grid modeling.

Structure of the Statistical Framework

- The framework consists of different domain specific models for planning or operational tool implementation
  - WCFRR Model: a statistical weather condition – failure and repair rate model correlating the weather conditions as input and thereby providing their impacts on grid components in terms of both failure and repair.
  - The Grid Model that is capable of accounting for the component status in simulating the grid responses.
  - EPM Model model: an event probabilistic model that relates the historic events of different categories (e.g., Category I hurricane) to the probability distribution for the subsequent weather conditions.

Applications of the Statistical Framework

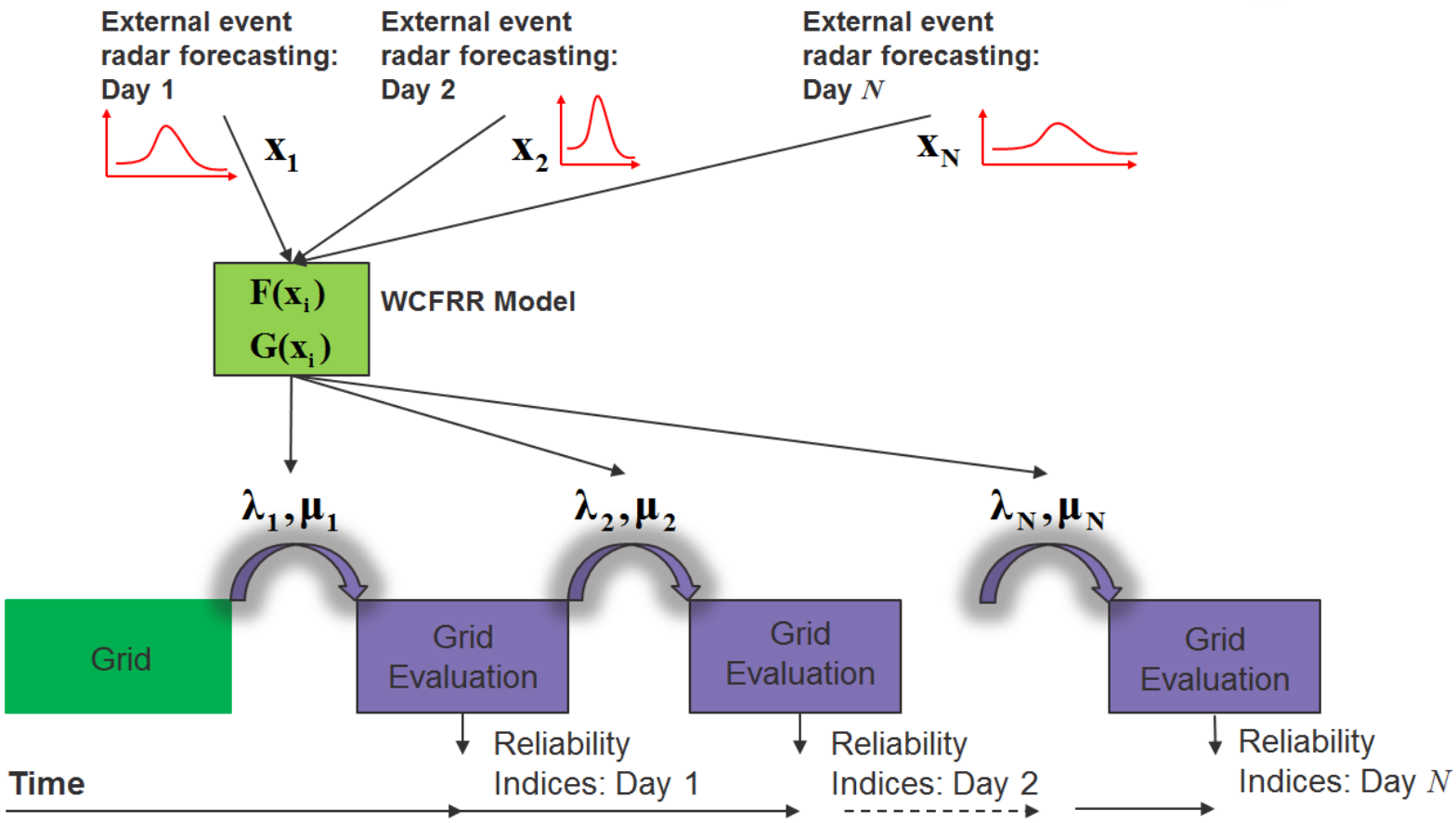
- The framework implementations for planning and operational tools



Progressive Analysis Using the Framework Concept

- Based on the observation that a weather event may last for several days, and the grid may be continuously affected by the event while the weather conditions constantly evolve;
- Enabled by the operational tool consisting of the WCFRR Model and the Grid Model to project the grid status along the evolution of the event;
- Utility personnel, aided by the progressive analysis, will be able to have a better picture of risk measures and select the most suitable action among alternatives for better recovery.

Progressive Analysis of Event Impacts for Grid Operation



Implementation of the Statistical Framework: Data Processing Procedure

- Identify a storm-induced outage of a component including its occurrence time, repair time, and location;
- Identify the starting time (and/or end time) of the outage-associated storm;
- Acquire weather data during the storm for the area (e.g., a 5 by 5 miles area) containing the outage location;
- Identify all other outages of different components in this area (again including occurrence times, repair times);
- Acquire inventory data of different types of components in this area.

Implementation of the Statistical Framework: Regression Analysis for WCFRR

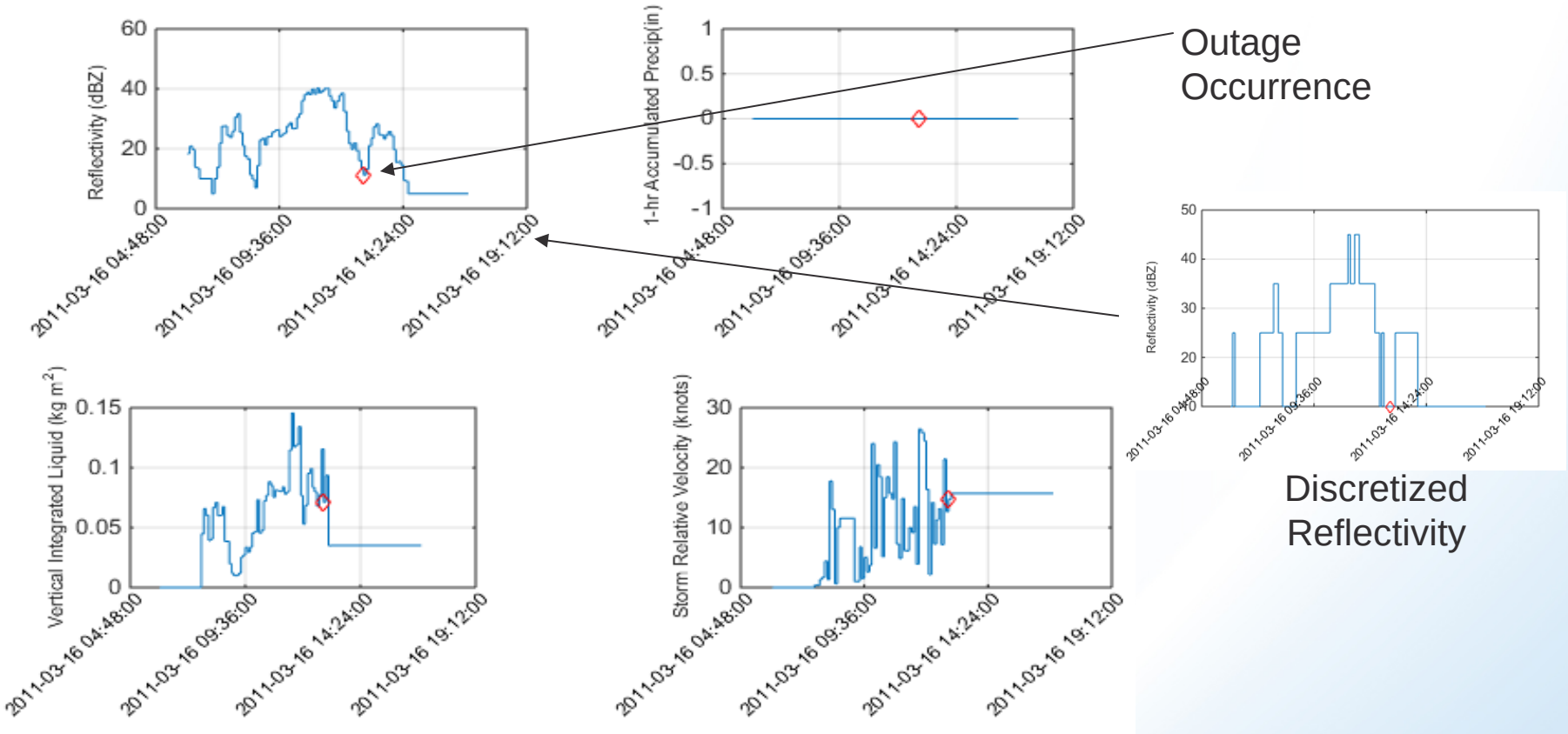
- Regression analysis often becomes the only feasible means to examine the impacts of some variables on other variables because, e.g., the functional relationship is too complicated to capture or describe in simple terms;
- Wide applications of regression analysis were achieved even for a lack of data
  - E.g., fragility curves used in seismic probabilistic risk assessment (PRA) and other external events PRA in nuclear industry.

A Poisson Regression Model

- A counting process can usually be described by a Poisson process;
- A Poisson regression model can be used for estimating count or rate of failure occurrences by expressing the natural logarithm of number of events as a linear function of a set of predictors:

$$\log Y_i = \mathbf{X}_i^T \boldsymbol{\beta} = \sum_j \beta_j x_{ij}, i = 1, \ldots, N.$$

Weather Condition Evolution of an Example Outage: Overhead Wire/Cable



- A new regression model will be developed:
  - Number of outage $Y_i \sim$ (magnitudes and durations of Ref., VIL., Pre., and DVL during the storm).
  - Regression model can be simplified by discretization of the magnitudes of different conditions experienced before the outage.

Path Forward

- Continue the acquisition and extraction of available outage data and corresponding weather condition data under an existing NYSERDA funded project;
- Develop planning and operational tools under a new project proposed to NYSERDA PON 3026
  - Develop and evaluate regression models calculating number of outaged components and failure and repair rates during storm;
  - Collect historical data and develop EPM for planning purpose;
  - Integrate the probabilistic models for development of a planning and an operations tool.

Summary

- Utility use of the Statistical Framework based tools:
  - simplifies subtasks
  - makes better use of the existing domain knowledge such as meteorological data interpretation;
- The tools and the progressive analysis described:
  - make a more accurate prediction of grid and component damage
  - enables a better deployment of resources for a more rapid recovery via the utility's use of sensitivity analysis provided in the tool;
- A proposal for PON 3026 was submitted to, and being reviewed by, NYSERDA
  - The proposal will advance the development of planning and operational tools using the statistical models.