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Introduction to a Metrics and Validation Framework Assessing the Performance of Distributed Energy Resource Management System Platform

ComEd | Smart Grid | Emerging Technology
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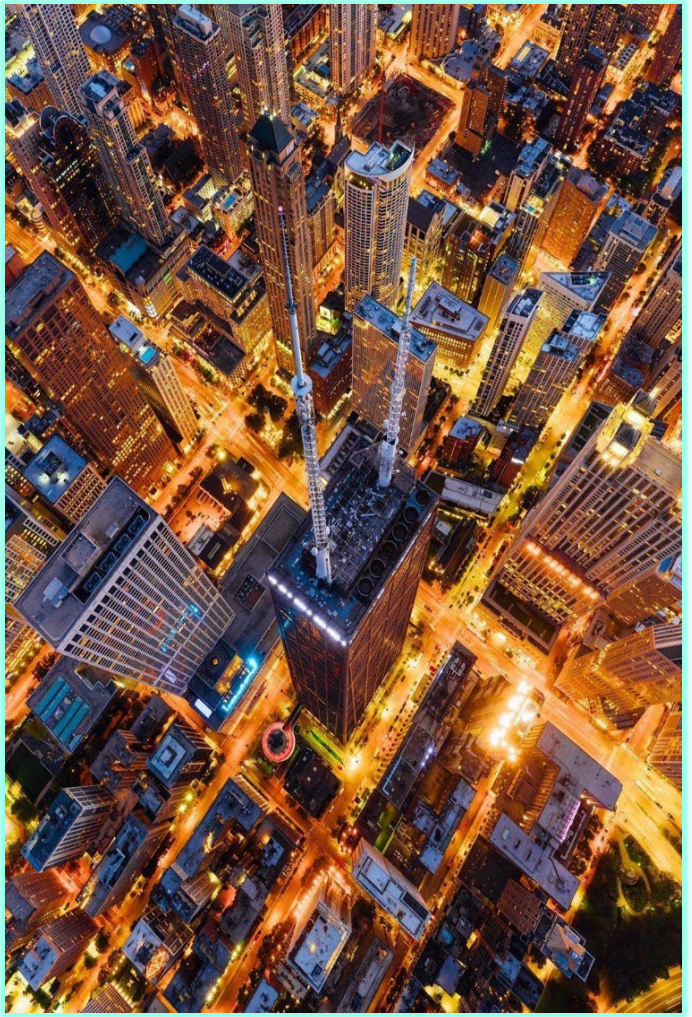
ComEd, An Exelon Company

Our Company:
- One of six utilities owned by Exelon
- 6,400 Employees
- Service Territory: 11,428 square miles

Our Customers:
- 4 million customers in northern Illinois, including the City of Chicago

Our Grid:
- Peak Load: 23,753 MW (7/20/2011)
- 553,800 distribution transformers
- 66,200 circuit miles of primary distribution
- 52% overhead, 48% underground
- 5,800 circuit miles of transmission
- 93% overhead, 7% underground

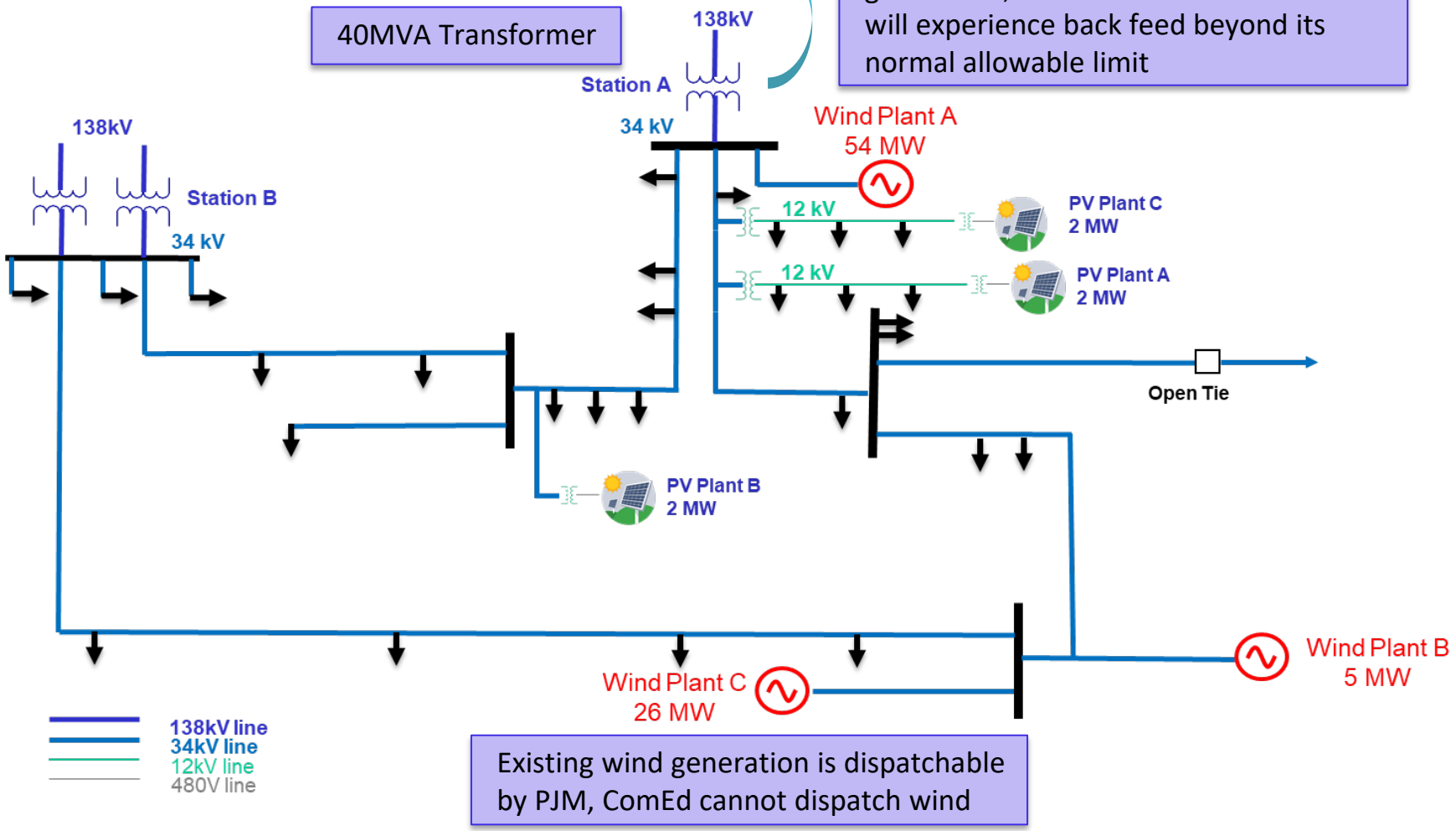


DERMS Demonstration Project

- DERMS is a software platform that provides forecasting, monitoring, and coordinated control of DERs on the distribution system.
- DERMS Benefits both the customers and the company in the following ways:
  - Mitigating the new challenges to the distribution system brought by the increasing level of DERs
  - Increase reliability, operations efficiency, system utilization and hosting capacity
  - Maintain power quality within prescribed limits for distribution circuits
  - Develop and offer new solutions to customers/stakeholders
  - DERMS as a module within ADMS for future real-time operation

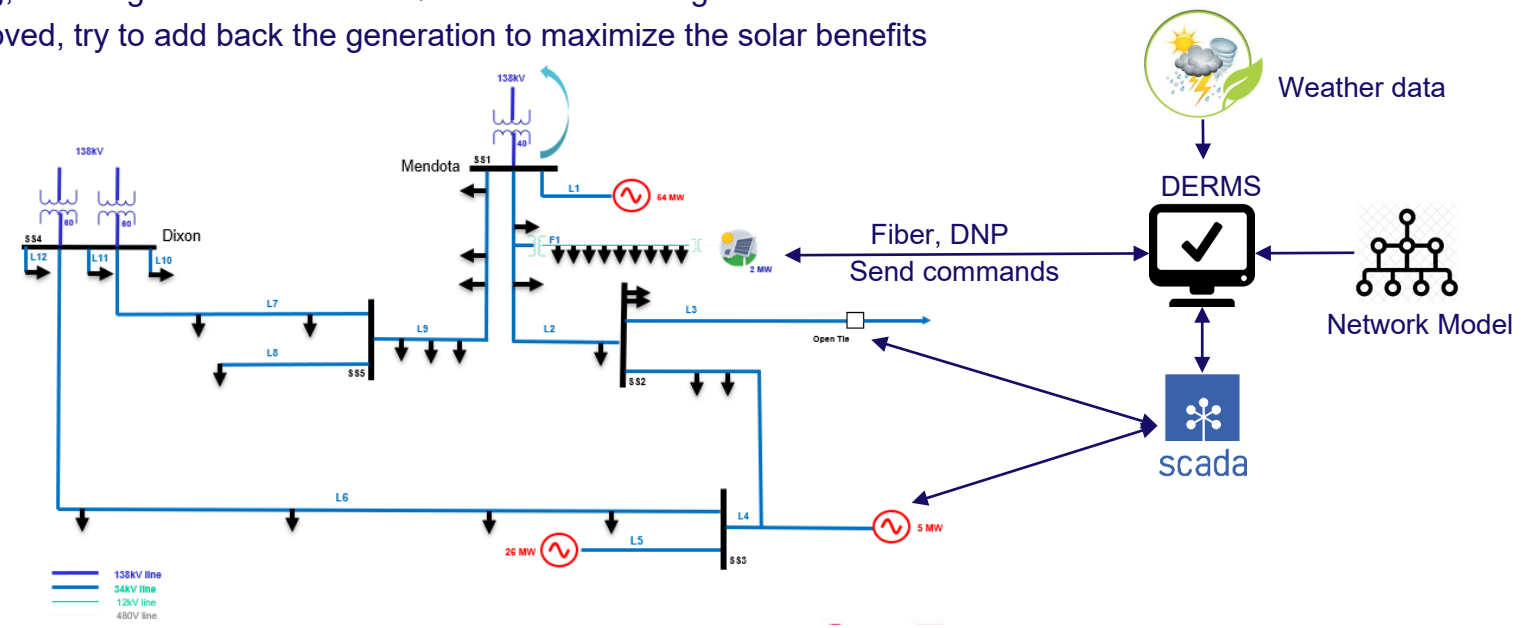
Mendota Substation Issue with Added Solar Generation

- Existing conditions don't allow new DER interconnection without system upgrade
- However, there are lots of new DER development interests due to large area of land in Mendota area



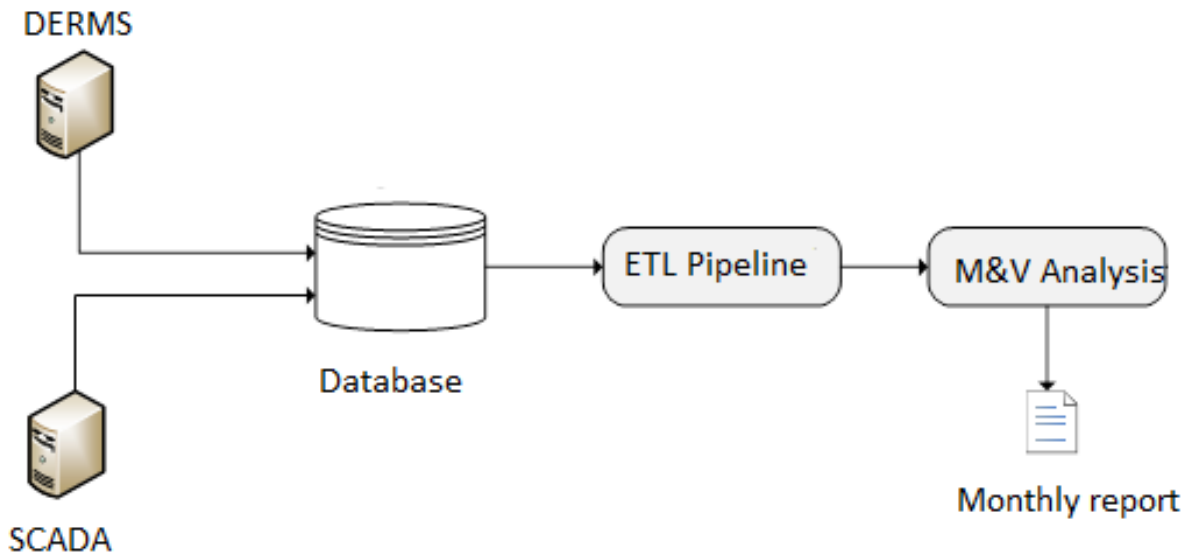
DERMS Solution

- ComEd is deploying DERMS to mitigate the overloading of substation transformer
- Fiber connection is available at Mendota substation, and is extended to solar sites
- Real-time DNP3 connection to smart inverters at solar site
- Real-time SCADA data integration for wind farms/transformer monitoring
- CYME model and breaker/switch status integration for system topology
- Integrate weather data and build generation forecasting model for wind and solar
- Send commands to solar based on the real-time information to avoid Mendota transformer overloading
  - When there is overloading, cut the generation to reduce/remove overloading
  - When overloading is removed, try to add back the generation to maximize the solar benefits



DERMS Assessment KPI

- ComEd's Smart Grid Emerging Technology team developed a metrics and validation (M&V) framework to quantify and assess the performance of DERMS
- 2 indicators are tracked to assess the performance of DERMS
  A. Threshold Backfeed Exceedance at the Substation Transformer
    - Type 1: Exceedance of reverse power threshold 1, activating DERMS
    - Type 2: Exceedance of reverse power threshold 2, when DERMS exhausts its controlled resources
  B. Control Analysis of DER by location



Threshold Backfeed Exceedance at the Substation Transformer

- Type 1 event at any time interval, t, is defined as cases when there is reverse power flow $P_{TR,\mathrm{A}} < 0$ and magnitude of the apparent power exceeds threshold 1 (TR1) on transformer A

$$e_{t,type1} = \left|S_{TR,\mathrm{A}}\right| - \mathrm{TR1}, when\ P_{TR,\mathrm{A}} < 0, \left|S_{TR,\mathrm{A}}\right| > \mathrm{TR1}$$

- Similarly, Type 2 exceedance given by threshold 2 (TR2)

$$e_{t,type2} = \left|S_{TR,\mathrm{A}}\right| - \mathrm{TR2}, \mathrm{when}\ P_{TR,\mathrm{A}} < 0, \left|S_{TR,\mathrm{A}}\right| > \mathrm{TR2}$$

- Maximum exceedance for event n - considers all intervals within that event and is defined as the vector of exceedances $e_{n,0}$ to $e_{n,T}$, and defines $E_{n,max}$ as the maximum value of that vector

$$E_{n,max} = max(e_{n,0} \quad \cdots \quad e_{n,T})$$

- Event duration - measures time from start of event to when the exceedance is resolved and all the PV curtailment is released

$$D_n = t_{n,T+1} - t_{n,0}$$

Control Analysis of DER by Location

- PV Production Estimation – a random forest regression model that was trained on local weather station data and historic production is used to estimate PV generation if the PV had not been curtailed during a DERMS event.

$$p_{PVest,kt} = p\left(W_{kt}, \boldsymbol{p}_{PVhist,kt}\right)$$

- Curtailment calculation – is given by the following to find the total energy management for PV site, k

$$p_{curt,n,kt} = p_{PVest,kt} - p_{PV,kt}$$

$$E_{curt,n,k} = \sum_{t=0}^{T} p_{curt,n,kt} t$$

$$E_{curt,k} = \sum_{n=0}^{N} E_{curt,n,k}$$

- Event duration – duration of the exceedance

$$D_{curt,n} = t_{n,T} - t_{n,0}$$

DERMS Performance

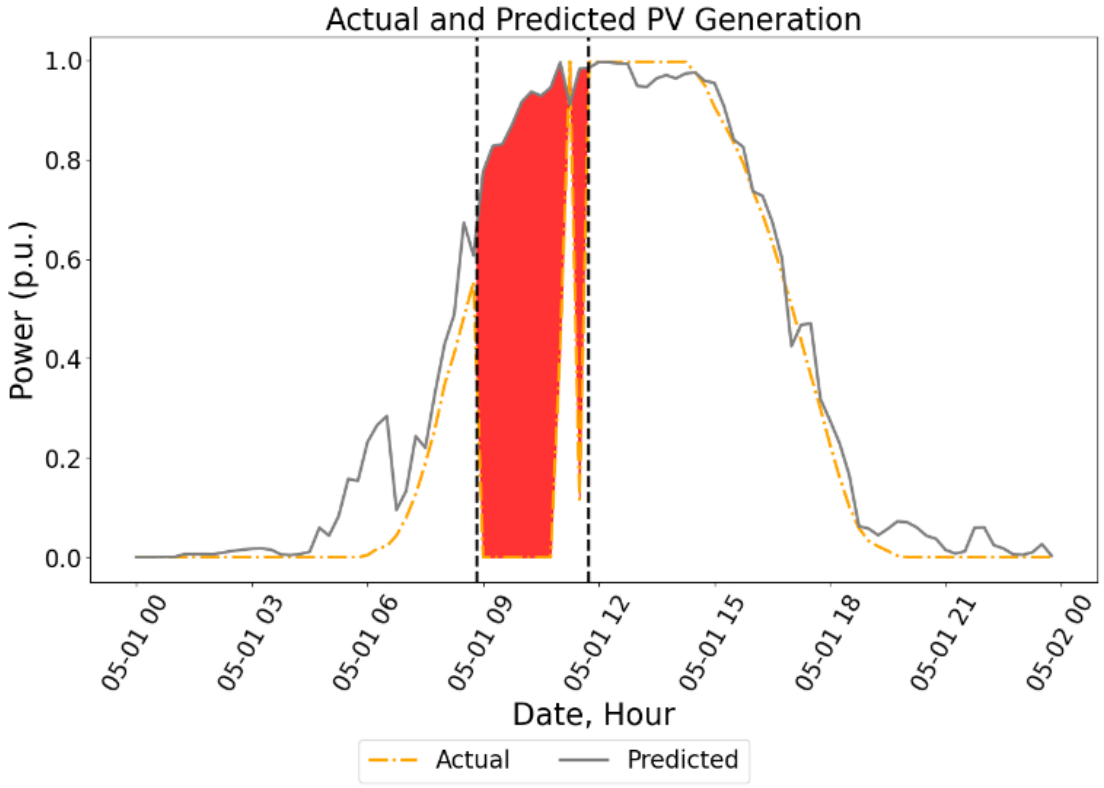
- DERMS success rate – whether DERMS worked as designed during the backfeed exceedance events or control events
- $e_{i,n}$ - Control occurred and the reverse power flow was reduced/relieved
- $e_{j,n}$ - The reverse power flow limit was exceeded while the PVs were fully curtailed
- $e_{k,n}$ - Exceedance but PVs were not controlled to relieve the exceedance (unsuccessfully managed events)

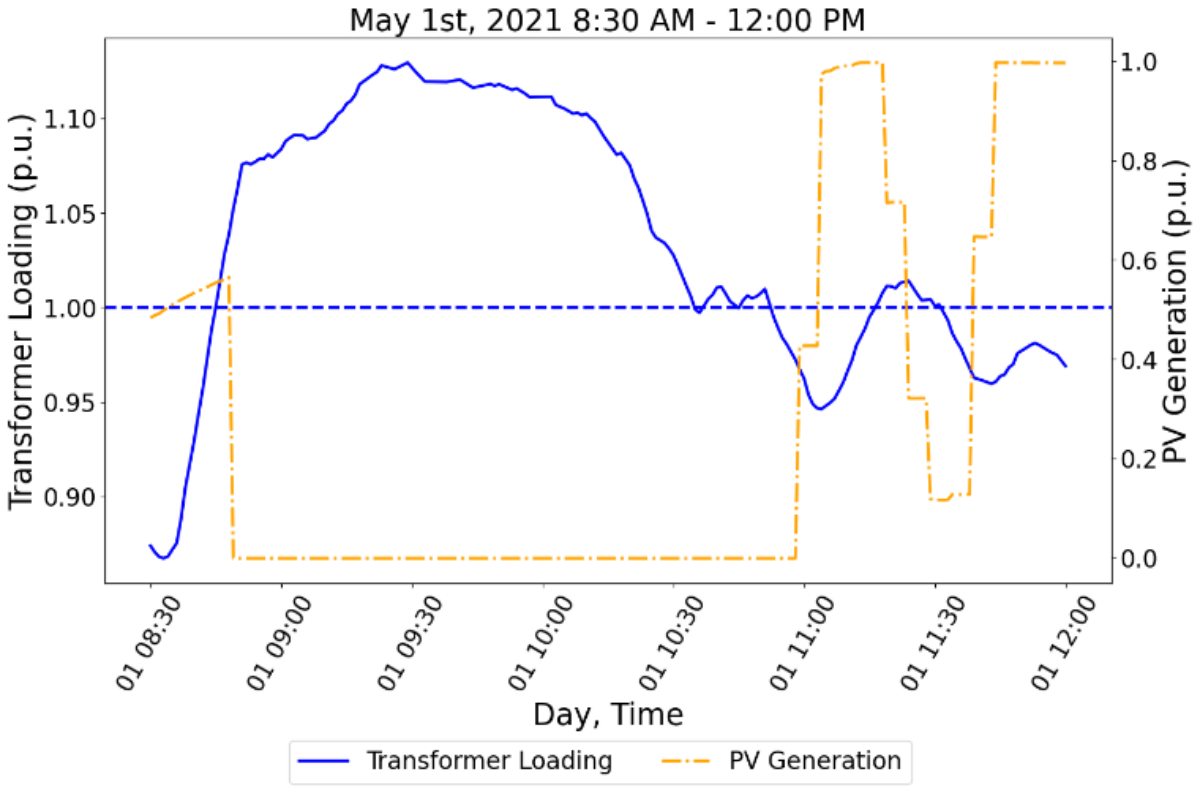
$$R_{DERMS} = \frac{\sum_{n=1}^{I} e_{i,n} + \sum_{n=1}^{J} e_{j,n}}{\sum_{n=1}^{I} e_{i,n} + \sum_{n=1}^{J} e_{j,n} + \sum_{n=1}^{K} e_{k,n}}$$

- Additionally, erroneous data was removed from the data set to perform the assessment:

Negative when impossible	Zero when not expected
Non-numeric (NaN)	Missing
For MW: greater than 110% of expected capacity	For MVA: above 110% of nameplate capacity

DERMS Real Performance





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Thank you