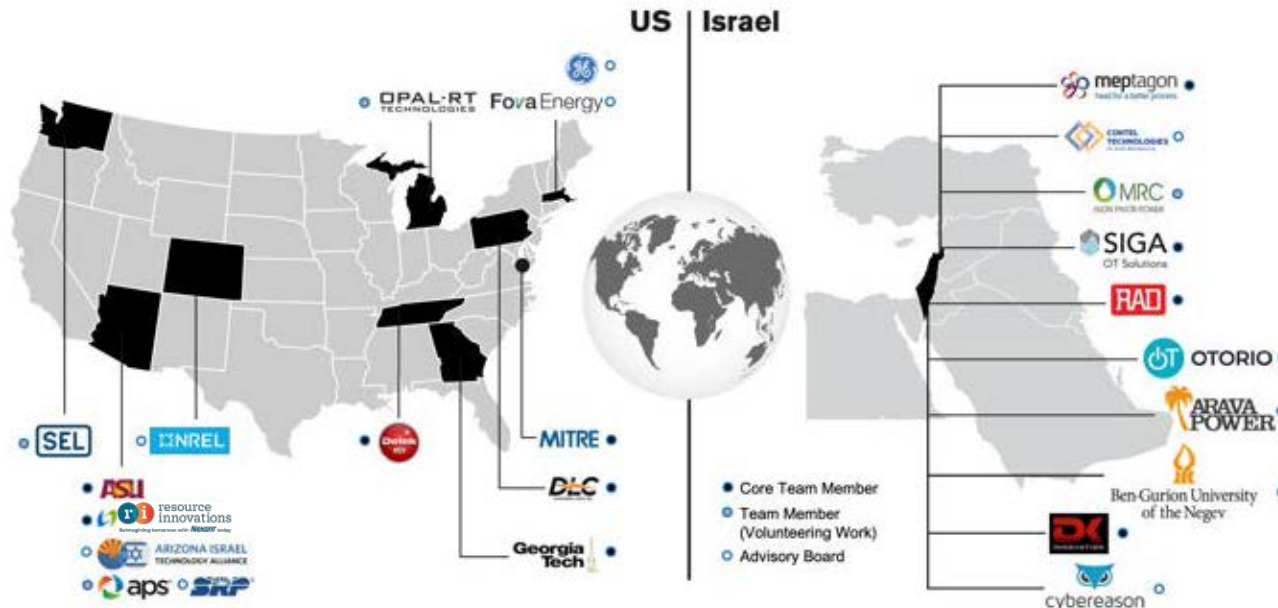


BIRD-ICRDE Comprehensive **Cybersecurity** Technology for Critical Power Infrastructure **AI-Based** Centralized Defense and Edge Resilience



**Converging Cybersecurity Solutions
for Energy Systems to Practice**

**Grid360 Platform for Cybersecurity Threat
Simulation, Detection, and Mitigation**

John Dirkman P.E.
VP Product Management
Resource Innovations
jdirkman@resource-innovations.com

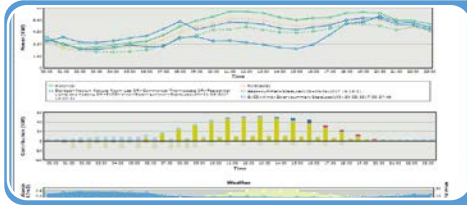
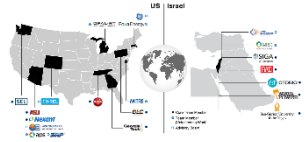
1 March 2022

Webinar Agenda



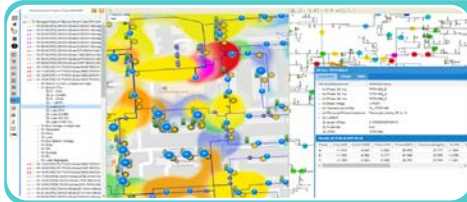
1. Grid360 Overview
2. Commercialization Approaches
3. State Estimation Applicability
4. Q&A

Grid360 Overview



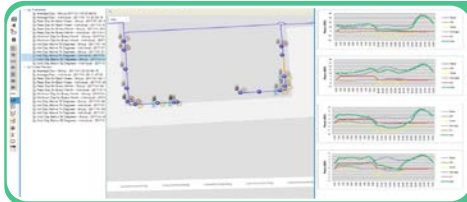
State estimation, optimal power flow, contingency analysis, fault analysis

- Determine the current operating state of networks using AMI/SCADA/sensor data, discover and eliminate data/topology/latency errors, and recommend sensor placement
- Calculate and display system loading and voltage warnings and violations, including contingency analysis, calculate fault level, run optimizations, generate alerts, recommending switching, and dispatch resources



Analysis of DR, DG, DER, PED, EV, microgrids, improved customer engagement

- Evaluate the current and near-term energy and economic state of distribution grids including demand response (DR), distributed generation (DG - solar and wind, including smart inverters), distributed energy resources (DER - energy storage), power electronic devices, electric vehicle (EV) supply equipment, microgrids, volt/VAR optimization (VVO), and Grid Interconnection programs, improving customer service



Load profiling, short-term, and long-term load and DER forecasting

- Create load profiles, develop short-term (days ahead) and long-term (months to years ahead) energy and economic forecasts including DR, DG, DER, PED, EV, and microgrids
- Generate alerts and dispatch resources based on forecast conditions



Management of independent grids and microgrids, reliability coordination/market operations

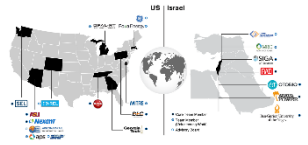
- Manage independently-owned commercial and industrial grids and microgrids
- Coordinated capacity calculation and security analysis, outage planning coordination, short- and medium-term adequacy forecasts



Advanced security, data quality, and reliability analytics

- Track critical and vulnerable assets, communication channels, protocols and encryption, patches and mitigations, ownership, and access and safety
- Analyze and improve transformer to meter assignment, phase assignment, sizing of devices and conductors, asset health forecasting, energy theft, outage causes and prediction, and other data quality and operational factors based on AMI/SCADA/sensor data and network models

Commercialization - ASU Topology Processor Engine



```
print("Extracting Connectivity from OpenDSS models")
# os.chdir("APS_model/")
exec(open('1connectivity_extract.py'.encode('utf-8')).read())

print("Extracting Grouped Loads Features from OpenDSS models")
os.chdir("../")
exec(open('2grouped_loads_features_extract.py'.encode('utf-8')).read())

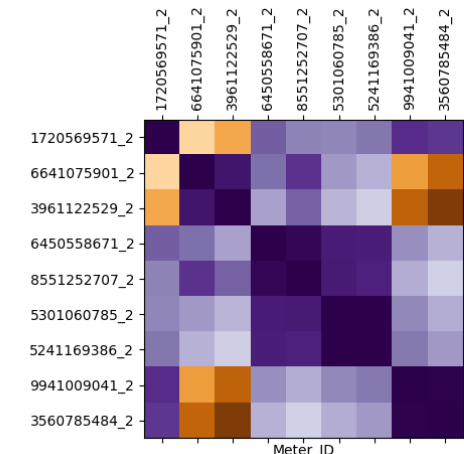
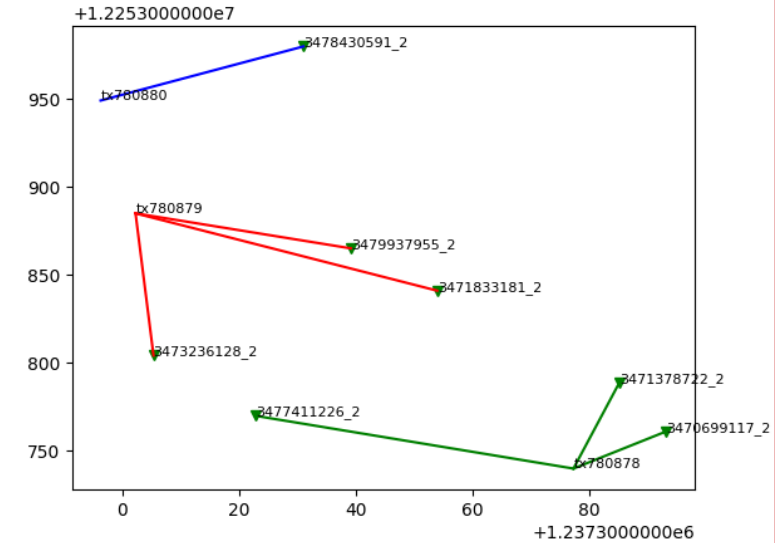
print("Creating Distance Features")
os.chdir("../")
exec(open('3distance_features.py'.encode('utf-8')).read())

print("Generate Voltage Data using Connectivity and Consumption data and Extract it")
os.chdir("../")
exec(open('4vpu_extract.py'.encode('utf-8')).read())

print("Spectral Clustering to obtain clusters of meters corresponding to transformers")
os.chdir("../")
exec(open('5spectral_cluster_multiview_regular_merged2 - Confidence_Metric.py'.encode('utf-8')).read())

print("Computation of Accuracy and Generation of Complete Plot")
os.chdir("../")
exec(open('6spectral_cluster_accuracy_confidence_matrix.py'.encode('utf-8')).read())

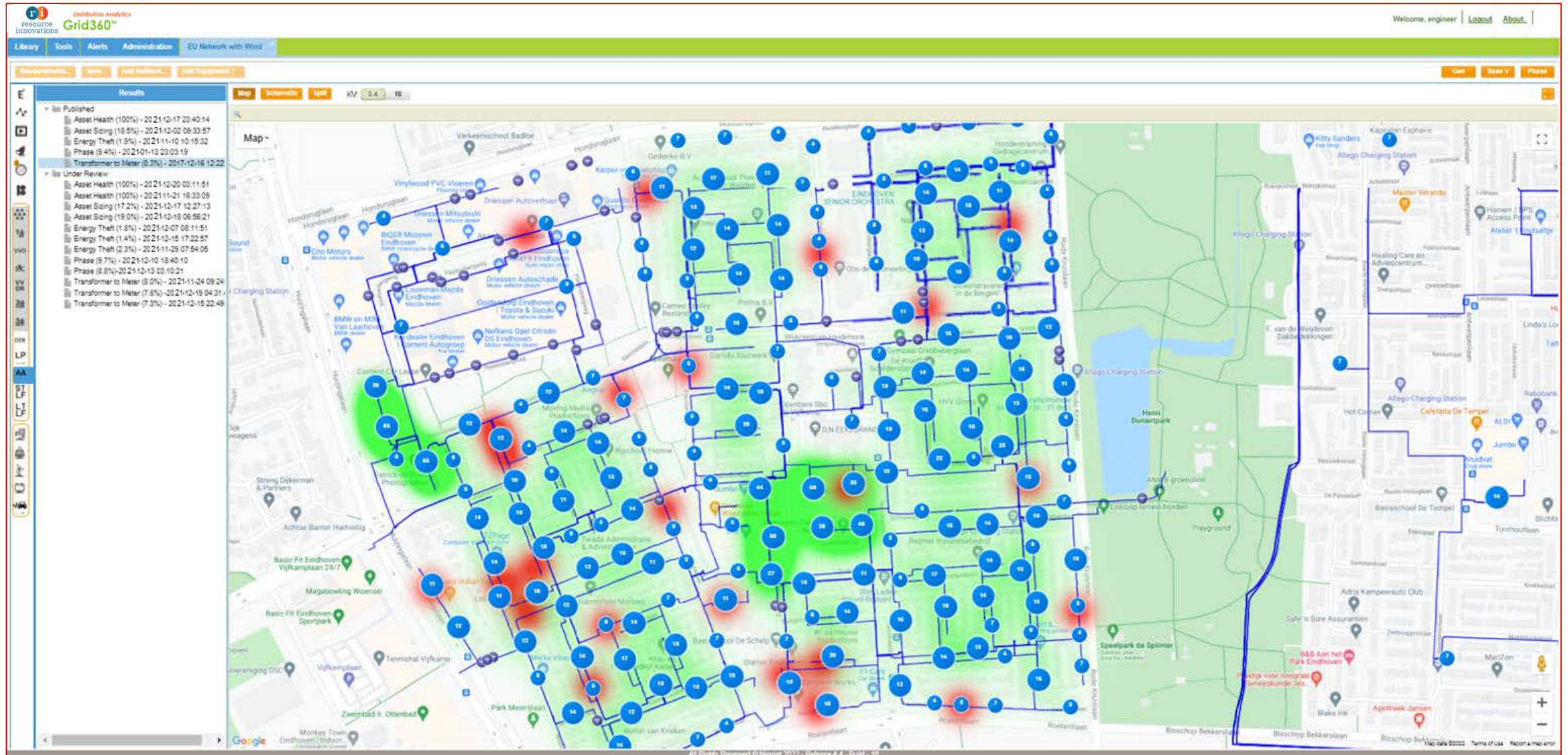
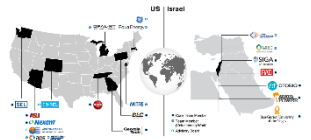
elapsed=(time.time() - t)
print('Total time for execution: %s seconds' %elapsed)
```



OUTPUT:

Total Number of Correctly Predicted Connections = 1514
Total Number of Incorrectly Predicted Connections = 70
Total Number of Connections = 1584
Total Accuracy [%]= Correct\Total * 100 = 95.5808
Total time for execution: 263.06036 seconds

Commercialization - Topology Processor Visualization



Commercialization - Cyber Metrics API

Grid360 APIs

[illegible]

POST

/networks/device/cybermetrics/cybermetricsData

Parameters

Cancel

Name	Description
cybermetrics required	cybermetrics
string (body)	Edit Value Model
<pre><div class="x-panel x-box-item x-panel-default x-tree-panel x-tree-arrows x-grid" style="height: 350px; left: 0px; top: 0px; margin: 0px; width: 482px;" role="treegrid" aria-hidden="false" aria-disabled="false" aria-randomly="false" aria-multiselectable="true" id="piAttributeGrid-1795"> <div id="piAttributeGrid-1795-bodywrap" data-ref="bodywrap" class="x-panel-bodywrap" role="presentation"> <div class="x-grid-header" <= x-docked x-grid-header <= default x-docked-top x-grid-header <= default-docked-top x-box-layout <= x-scroller x-unselectable" style="border-width: 1px; overflow: hidden; width: 482px; left: 0px; top: 0px;" role="rowgroup" aria-hidden="false" aria-disabled="false" id="headercontainer-1796" data-attachment="14"> <div id="headercontainer-1796-innerCt" data-ref="innerCt" role="row" class="x-box-inner" style="width: 480px; height: 29px;"> <div id="headercontainer-1796-targetEl" data-ref="targetEl" class="x-box-target" role="presentation" style="width: 480px;"> <div class="x-column-header x-column-header-align-left x-box-item x-column-header-default x-unselectable x-column-header-first" style="border-width: 1px; left: 0px; margin: 0px; width: 160px; top: 0px;" role="columnheader" aria-hidden="false" aria-disabled="false" aria-randomly="true" id="treecolumn-1798" tabindex="0" data-componentid="treecolumn-1798"> <div id="treecolumn-1798-titleEl" data-ref="titleEl" role="presentation" class="x-column-header-inner x-leaf-column-header"> <div role="presentation" class="x-column-header-text-wrapper"> <div id="treecolumn-1798-textEl" data-ref="textEl" role="presentation" class="x-column-header-text"> <div role="presentation" class="x-column-header-text-innerEl" data-ref="textInnerEl" role="presentation" class="x-column-header-text-inner">Attribute/Equipment/span </div> </div> </div> </div> <div id="treecolumn-1798-dirty-cell-text" class="x-hidden-offsets">Cell value has been edited/span </div> </div> </div> </div> </div></pre>	

Cancel

Parameter content type
application/json

networkId required

integer (\$int64) (query)

networkId

1001

rfId required

string (query)

rfId

_07790_RMUT1_TXT1

riskFactor required

number (\$double) (query)

riskFactor

3.6

userId required

integer (\$int64) (query)

userId

1

Execute

Clear

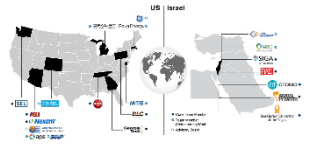
Responses

Response content type
/

Curl

curl -X POST "https://dev01.grid360.nxnet-dev.com/networks/device/cybermetrics/networkId=1001&rfId=07790_RMUT1_TXT1&riskFactor=3.6&userId=1" -H "accept: */*" -H "Content-Type: application/json" -d '{
 "cybermetrics": {
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 "x-box-item": {
 "x-panel-default": {
 "x-tree-panel": {
 "x-tree-arrows": {
 "x-grid": {
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 "x-docked-top": {
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 "x-leaf-column-header"
 },
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 },
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 },
 "Attribute/Equipment/span"
 },
 "div": {
 "id": "treecolumn-1798-dirty-cell-text",
 "class": "x-hidden-offsets",
 "Cell value has been edited/span"
 }
 }
 }
 }
 }
 }
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 }
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 }
 }
 }
 }
 }
}

Commercialization - Cyber Metrics Visualization



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Library Administration Trial1_TC1

Measurements Load/Gen Updates Optimization Updates Switch Status Updates PED Updates Branch Updates Save... Add Network... Add Equipment

Equipment

Search

AC line [3161]
Breaker [213]
Energy source [4]
Load [149]
Power Electronic Device [1]
Switch [1301]
TopologicalNode [399]
Transformer [151]

Map Schematic Split KV: 0.4 11 33 0-1 1-2 2-3 3-4

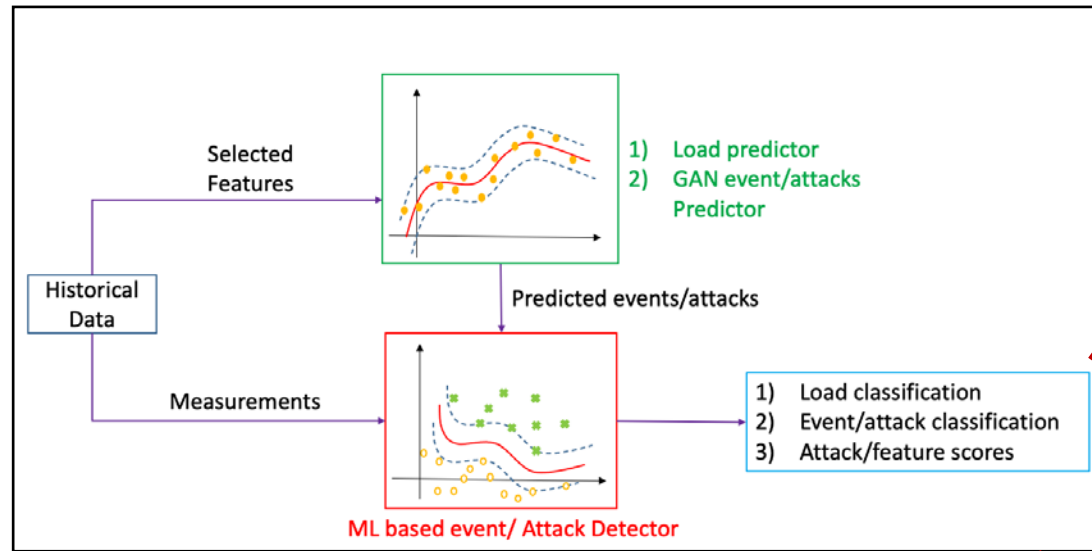
Transformer: TXT2

Attachments Load Profiles Load Forecast Cyber Metrics

Attribute/Equipment	Attribute Value
Device Name	NPort 5100 Series
Risk Score 0-10	6.122
Vendor	Moxa
Device Family	NPort 5100 Series
Device Catalog	NP5110
Firmware Ver...	2.9
Ethernet Interf...	[{'ip': '192.168.101.60', 'mac': '00:90:e8:70:4e:b7'}]
Cyber Alerts c...	3

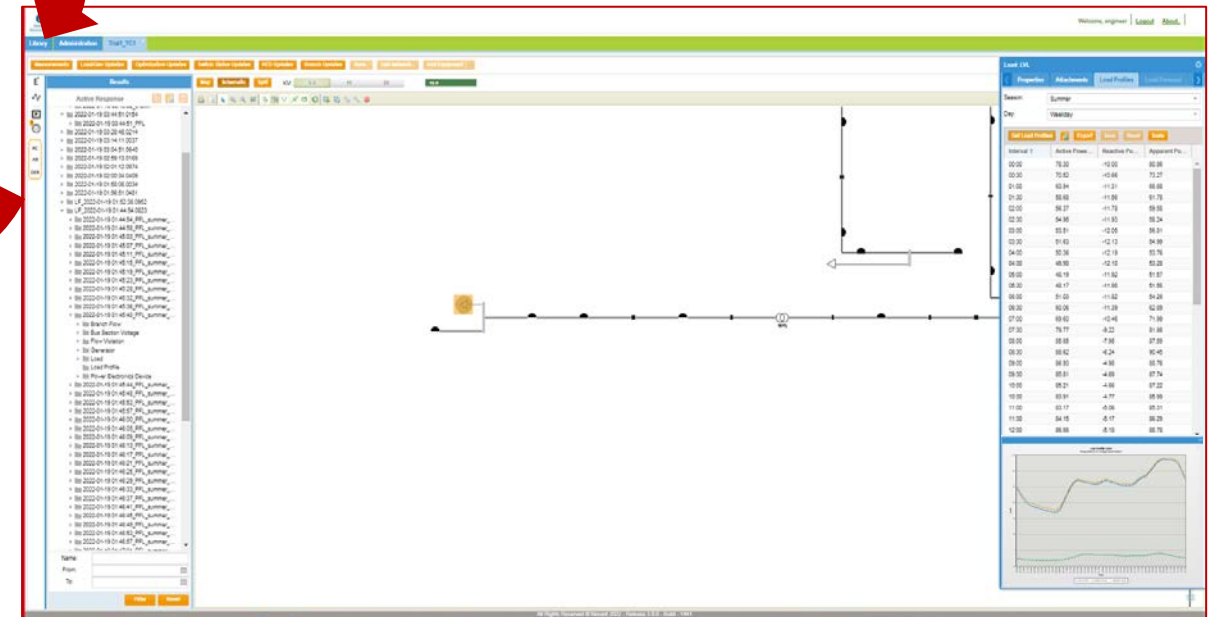
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Commercialization – From Detection to Anomaly Visualization



Intelligent and interpretable attack/event detector

RI Grid360: Load Anomaly Visualization



Commercialization - Alert Dashboard



resource innovations

Distribution Analytics

Grid360™

Library

Tools

Alerts

Administration

IEEE11_ES100K

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Details Alert

Alert Name	Case	Area	Event Time	Alert Status
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-02-04 15:58:20.0	Warning
No. of Violations	EuropeanNetwork	European	2019-02-04 16:01:57.0	Warning
No. of Violations	IEEE11_ES100K	France	2019-03-14 12:52:53.0	Warning

Page 1 of 1

Displaying 1 - 16 of 16

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Commercialization - Alert Configuration



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Library Tools Alerts Administration IEEE13_E5100K

Preferences

Import Network

Import Load Curve

Import DR Programs

Import Solar Programs

Import Storage Programs

Rate

Jobs

Equipment Library

User Management

Import Load Profile

Color Index Color Symbol Color Value Alert Settings

Alert Configuration

Alert Notification: ☐ E-mail
☒ SMS
☒ Dashboard

Effective Date: 01/12/2022 01/19/2022

Max Number of Alerts: 20

Alert Polling: Hourly
Interval: 00:00AM PT - 08:00 PM PT

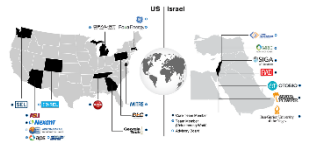
Alert Criteria

Measurement Object: Breaker Phase: Details

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11

Commercialization - Software Deployment

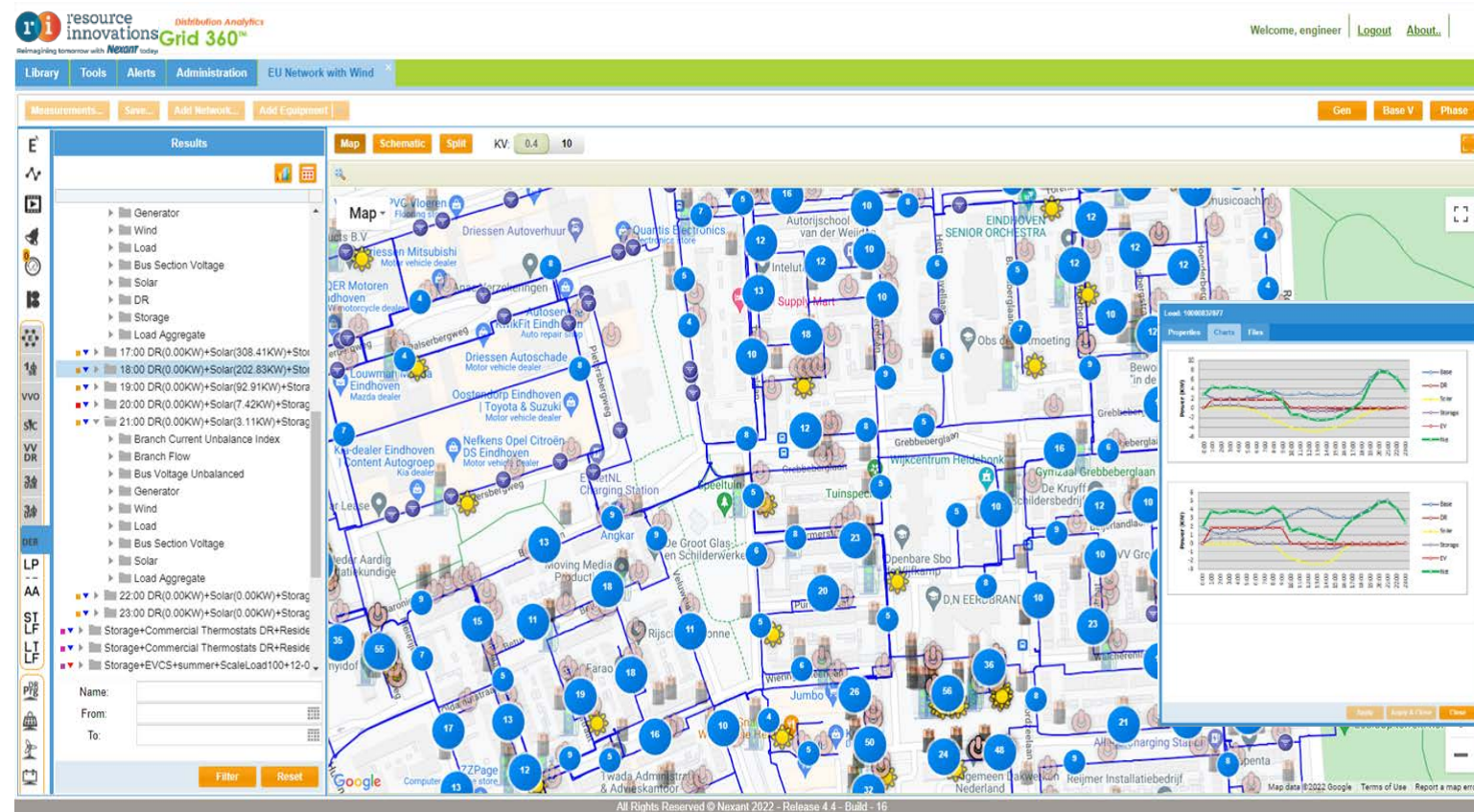


Primary Markets:

1. Energy Management Systems (EMS)
2. Distribution Management Systems (DMS)
3. Supervisory Control and Data Acquisition (SCADA)
4. Programmable Logic Controller (PLC)
5. Industrial Control Systems (ICS)/Cyber-Physical Systems (CPS)
6. IoT devices

Integration/add on of new technology without need for wholesale replacement of systems/devices

Licensing mechanism is preferred



Malware Threat Mitigation

False Data Injection

Multilayer Anomaly Detection

AI based Intrusion Detection

Self-healing and Auto-Remediation

State Estimation

Topology Processor

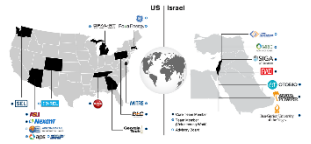
Forecasting

Optimal Power Flow

Contingency Analysis

Fault Analysis

Commercialization - Industry Advisory Board

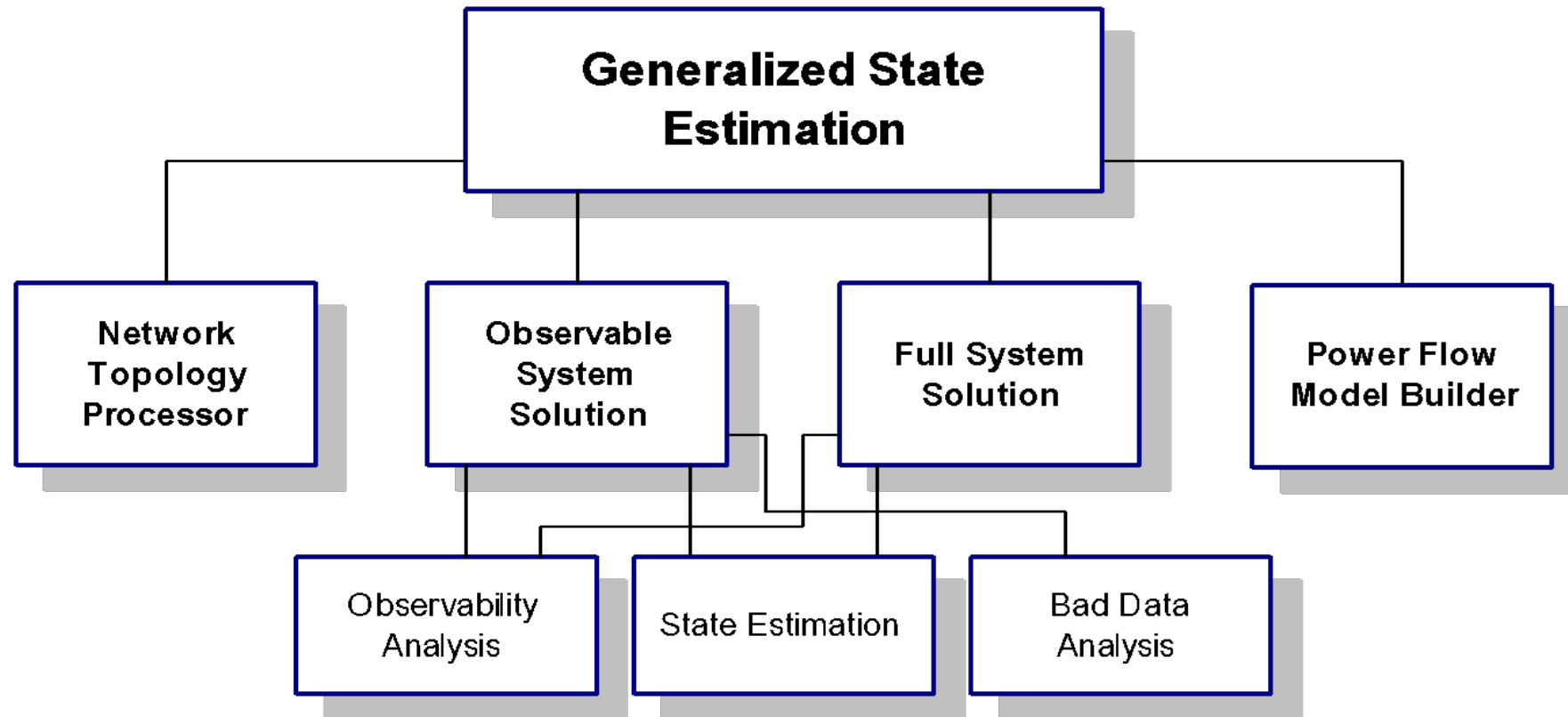
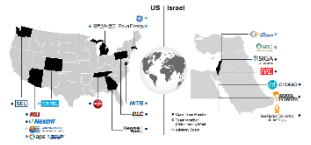


Form Industry Advisory Board

Board member organizations from previous collaboration of Resource Innovations with ASU: ComED, Entergy, Oncor, PSEG, Salt River Project, San Diego Gas & Electric Company, Southern California Edison, Southern Company, UK Power Networks

Future Industry Advisory Board will include Arava Power, Duquesne Light Company, Salt River Project, and Arizona Public Service plus many other utility companies

State Estimation - Overview



State Estimation - Example



Ask a roomful of people: “What time is it?”

“Around noon”

“12:01”

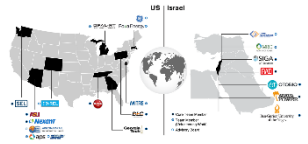
“12:00:01”

“12:00”

“12:00:02”

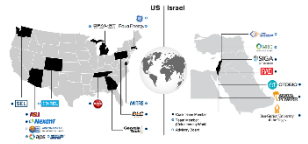
“12:03”

State Estimation - Generalized Bad Data Analysis



- **Recognizes the interaction between status & analog measurement errors**
 - Avoids camouflaging of topology errors as multiple analog measurement errors – does not assume correct topology
- **Performs estimation using a mixed model**
 - Parts of the network are represented at a physical level using explicit bus-section/switching-device modeling
- **Estimates analog states & breaker statuses simultaneously**
 - Supports largest weighted & normalized residual methods – an efficiency / accuracy tradeoff
- **Measurement redundancy is of paramount importance**

State Estimation - Measurement Error Identification



SCADA Checks

- Rejection of bad data by source SCADA system

Gross Error Checks

- Rejection of data outside limits

Plausibility Checks

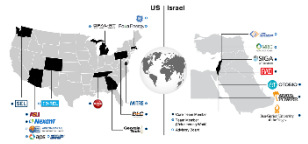
- Rejection of suspect data based on known data

Bad Data Analysis

- Weighted Residual Test and Normalized Residual Test (default)

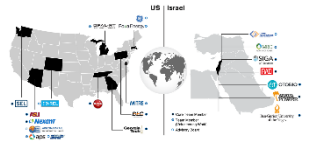
Final Solution

State Estimation - Bad Data Analysis Special Features

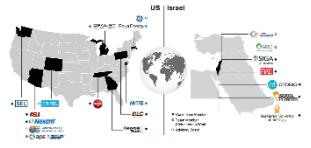


- **Detection & identification**
 - Weighted residuals
 - Normalized residuals
- **State estimation solution during bad data analysis**
 - Linear (non-iterative)
 - Non-linear (iterative)
- **Cycling with state estimation solution after bad data analysis**
- **Automatic & multi-level Bad Data Analysis (Screening Pockets and Zoomed Windows)**
 - Screening – Performs rigorous analysis on identified “bad data pockets”
 - Zooming – Remodels pockets for Bad Data Analysis at bus-section/switching-device level and “zooms in” if topology errors are suspected
 - Handles any expansion, contraction, creation & merging of electrical & observable islands
 - Provides effective pinpointing of bad data locations

State Estimation - Localized Modeling Special Features



- **Switch & bus injection pseudo-measurements are subject to bad data analysis**
 - Pseudo-measurements are used to augment available realtime measurements
 - Pseudo-measurements are typically calculated using short-term load forecasts or historical data
- **Gross errors do not propagate extensively**
- **Searching for bad data in the locality of the problem is efficient, particularly for large networks**
- **Local bad data analysis involves “windowing” and “pocketing”**
 - Pockets and windows can change, overlap or merge on the fly



Thank You!

Questions?