Renewable Energy Monitoring with the PI System

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Nickolas Mayer

Agenda

OBJECTIVE

Discuss applications of the PI system currently used at Duke Energy Renewables for plant monitoring

OUTLINE

1. Introduction
2. PI System Applications
3. Real Time Monitoring
4. Performance Reporting
5. Wind Power Forecasting
6. Solar Business Strategy
7. Future Developments

About Duke Energy Renewables

Background

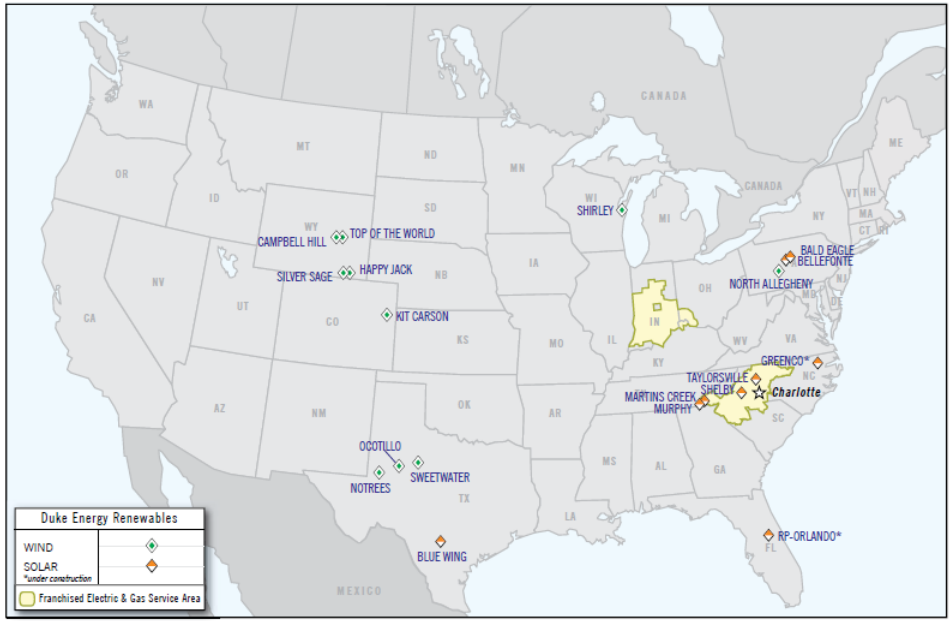
- Duke Energy Renewables is committed to becoming a leader in developing innovative wind and solar energy solutions for customers throughout the United States.
- Long-term power purchase agreements with regional utilities, electric cooperatives and municipalities enable customers to lock in competitive prices for renewable power.

Growth Timeline

- 2007: entered renewables industry with acquisition of 1000 MW in wind asset development from Tierra Energy
- 2007 - 2011: has invested $2.5B into growing fleet of commercial renewable assets
- 2012: completion of construction will add 770 MW from 5 new wind farms
- 2013: renewable portfolio will power 500,000+ homes

Duke Energy Renewables

Duke Energy Renewables Generation Facilities

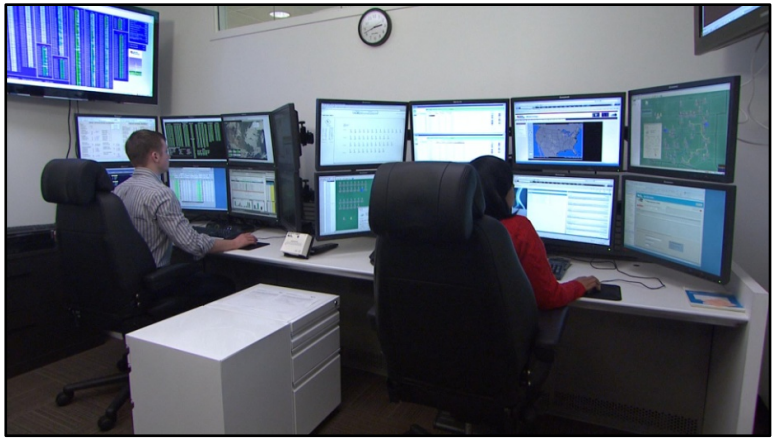


Renewable Energy Monitoring Center

R.E.M.C.

- Mission: To serve as the centralized hub for wind and solar renewable plant operations, coordinating safe and efficient actions to achieve greater than 90% availability at each monitored wind farm, and greater than 90% availability at each solar plant.

- The R.E.M.C. helps to maximize profits for both Duke Energy and its contracted site owners by providing world class 24/7 monitoring services through professional communications, consistent processes, reliable reporting, ethical conduct, and dedication to safety.



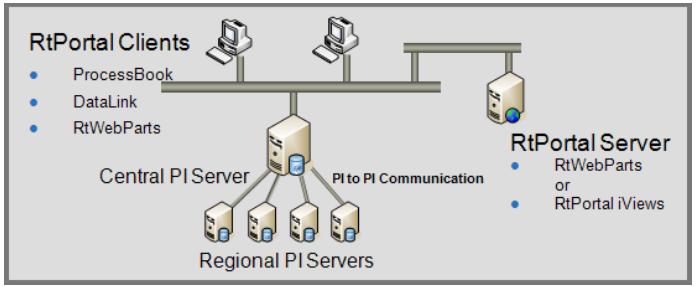
MONITORED FLEET TODAY

- 1,200 MW wind power generation
- 58.8 MW solar power generation

PI System Applications

OSIsoft Products Used

- PI Notifications
- PI DataLink
- PI ProcessBook
- PI Coresight
- PI Asset Framework (AF)
- Enterprise Agreement



PI System Benefits

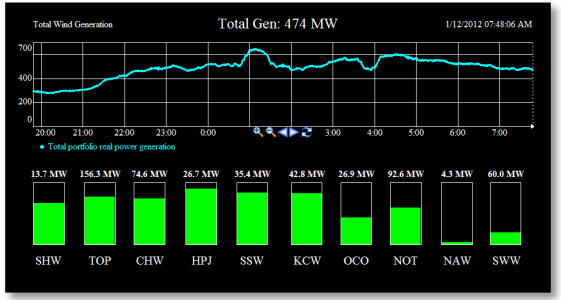
- Visual uniformity
- Unmodified records of site data
- Clear visual alerts for operators
- Custom built in-house displays
- Ad-hoc real time troubleshooting
- Remote detection of issues at unmanned sites
- Faster, more knowledgeable decisions
- Efficient reporting process

Real Time Monitoring: PI ProcessBook

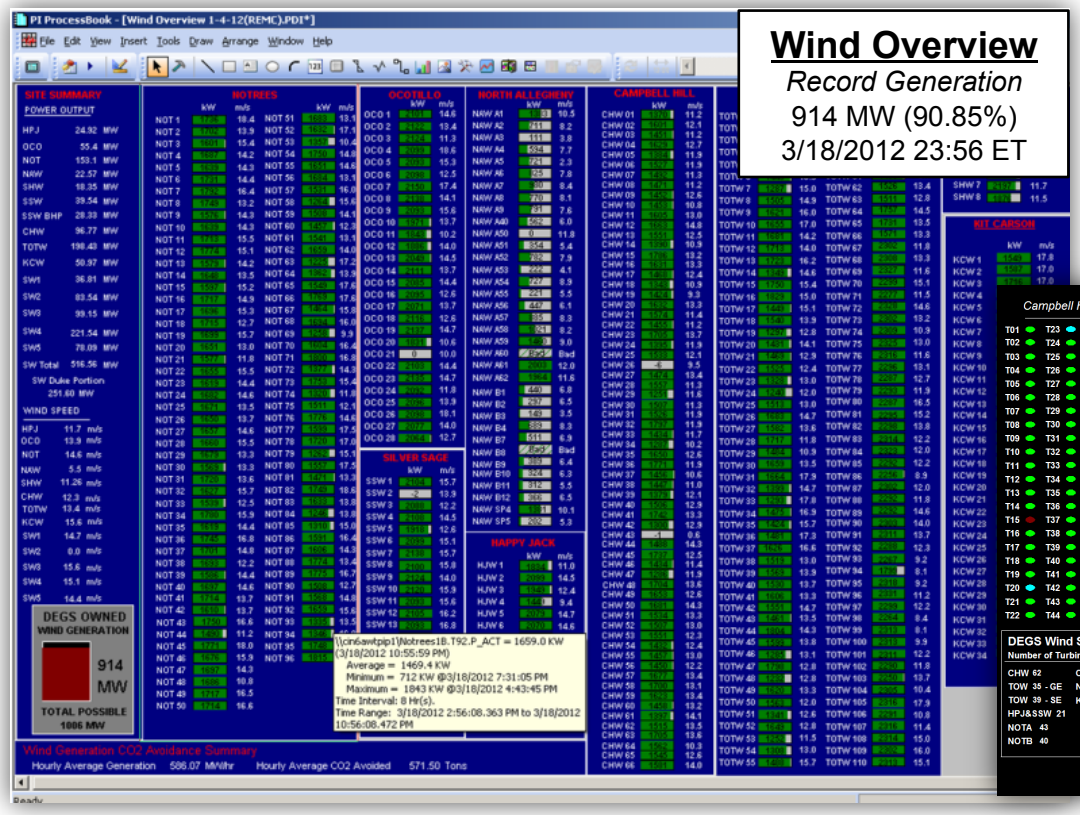
Primary monitoring scheme for wind & solar operations

Key monitoring functions

- Faulted turbine alerts
- Generation trends
- Substation issues
- Underperformance detection
- Weather patterns
- Inverter faults and alarms
- Solar site startup verification



Real Time Monitoring: PI ProcessBook



Wind Overview

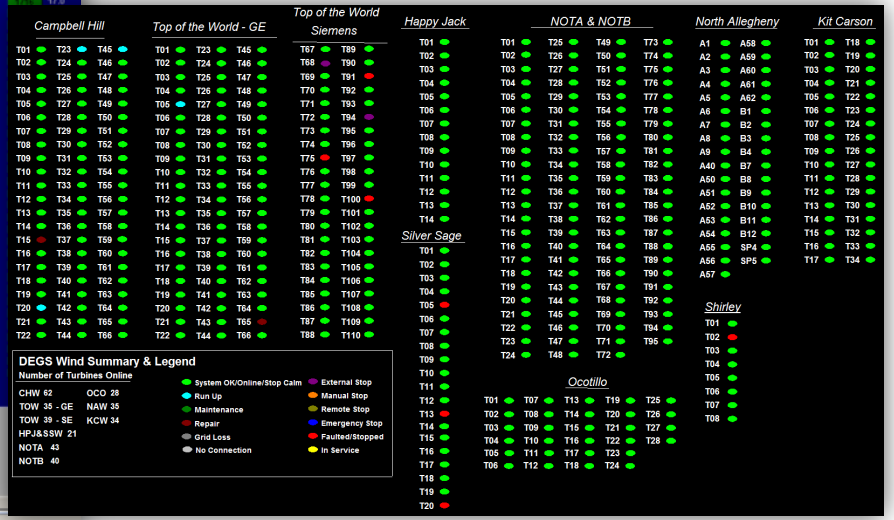
Record Generation

914 MW (90.85%)

3/18/2012 23:56 ET

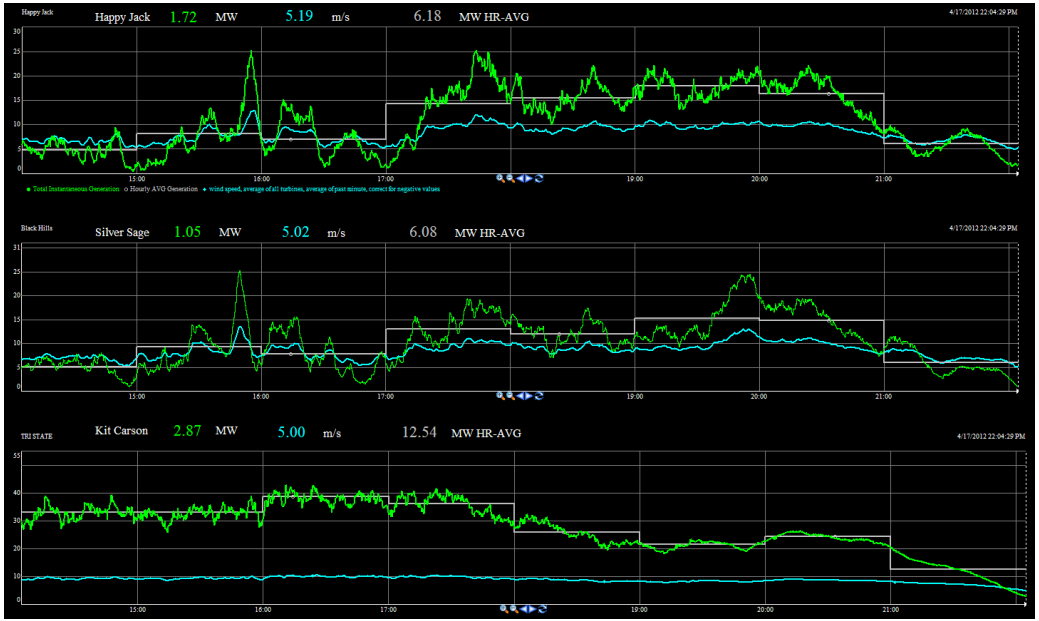
Turbine Alarms Screen

Duke Energy Fleet

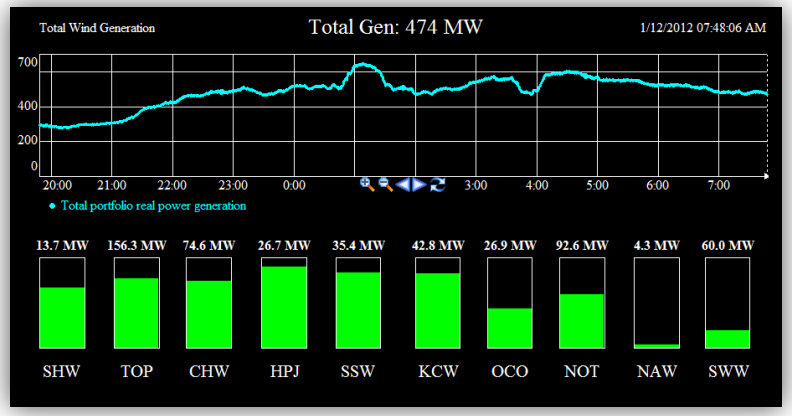


Real Time Monitoring: PI ProcessBook

Nomination Power Trends



Wind Fleet Production



Wind Turbine Performance Monitoring

Daily generator performance is tracked through energy yield calculations and power curve assessment to quickly correct issues and optimize turbine performance.

Duke Energy Renewables

Happy Jack Daily Site Report

12/19/2011

MORNING STATUS

On Line	14
Faulted/Stopped	0
Service Mode	0
Curtailment	0
No Comm./Off Line	0

UPDATE | Clear Comments | SAVE & SEND | RESIZE REPORT

SITE PERFORMANCE

Morning availability	100%
Morning windspeed	8.95 m/s
Morning MW Output	11.41 MW
MTD Budget Met	31.2%
Month Passed	58.1%

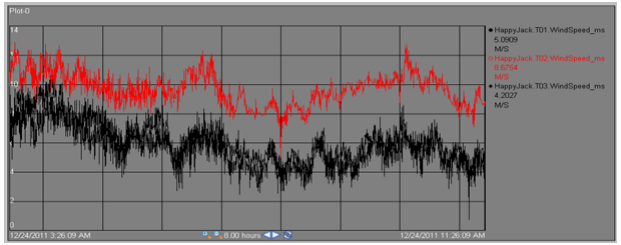
WTG	Turbine Status	Codes/Faults/Comments	Availability Yesterday	Ave m/s Yesterday	Actual MWh Yesterday	Exp MWh Yesterday	Energy Yield (Past 7 Days)
T01	On Line		100%	9.1	26.3	25.4	101.3%
T02	On Line		100%	9.3	24.9	26.5	71.3%
T03	On Line		100%	8.5	23.6	22.6	102.2%
T04	On Line		100%	8.5	23.9	22.1	108.4%
T05	On Line		100%	7.9	21.3	19.5	107.6%
T06	On Line		100%	8.4	22.4	21.6	103.0%
T07	On Line		100%	8.0	21.4	19.7	105.8%
T08	On Line		100%	9.0	24.5	24.6	102.5%
T09	On Line		100%	8.6	23.8	23.0	100.3%
T10	On Line		100%	8.6	24.5	22.9	109.2%
T11	On Line		100%	9.0	25.2	25.2	99.7%
T12	On Line		100%	8.8	25.7	24.0	104.4%
T13	On Line		100%	9.0	25.9	24.9	103.0%
T14	On Line		100%	9.2	26.5	25.9	102.3%

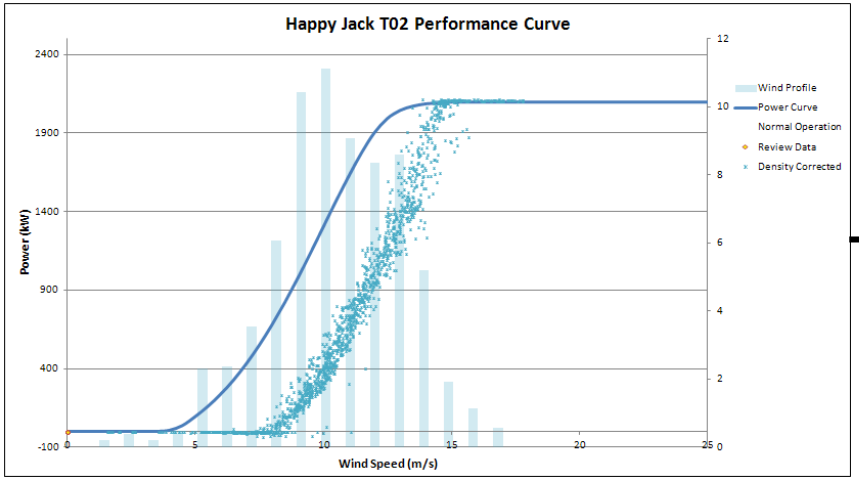
Wind Turbine Performance Monitoring

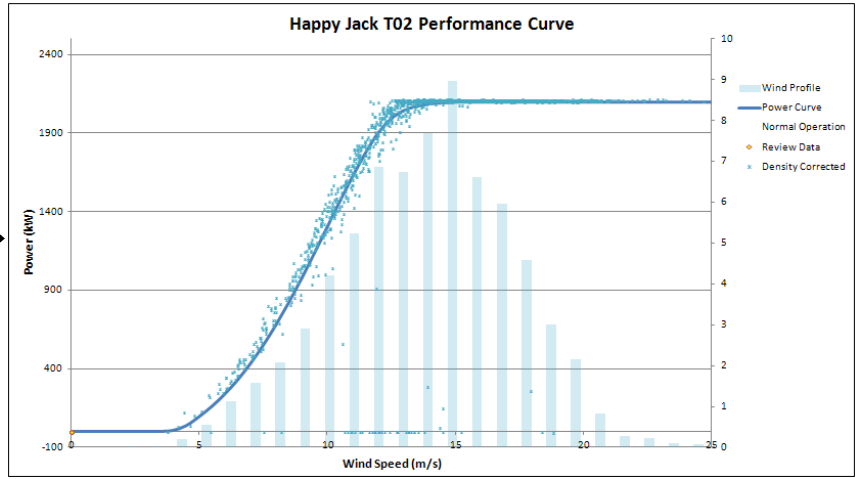
Example of Success

1. REMC operators noticed increasingly low EY on HPJ-T02 after generating daily reports
2. Investigated root cause through power curve assessment & ad-hoc wind speed trends
3. Notified site manager of possible faulty anemometer
4. Anemometer replaced, turbine performance improved

WINDSPEED TRENDS: T01,T03 (black), T02 (red)







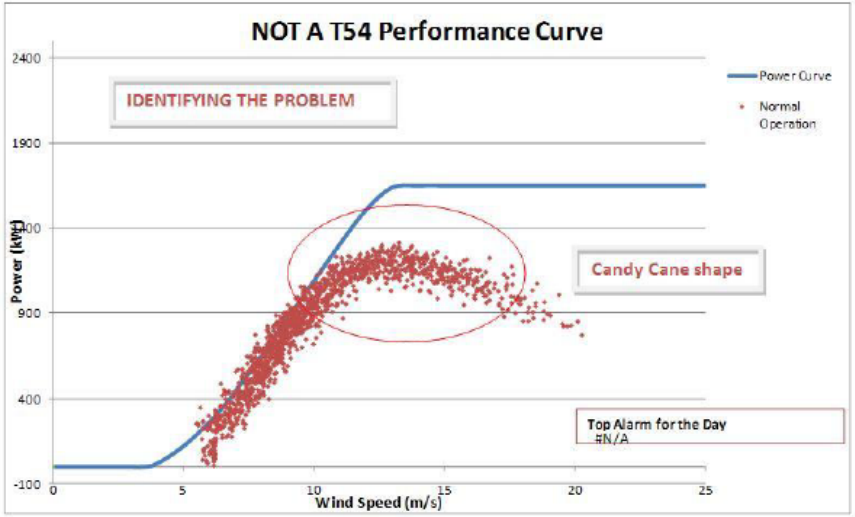
Wind Turbine Performance Monitoring

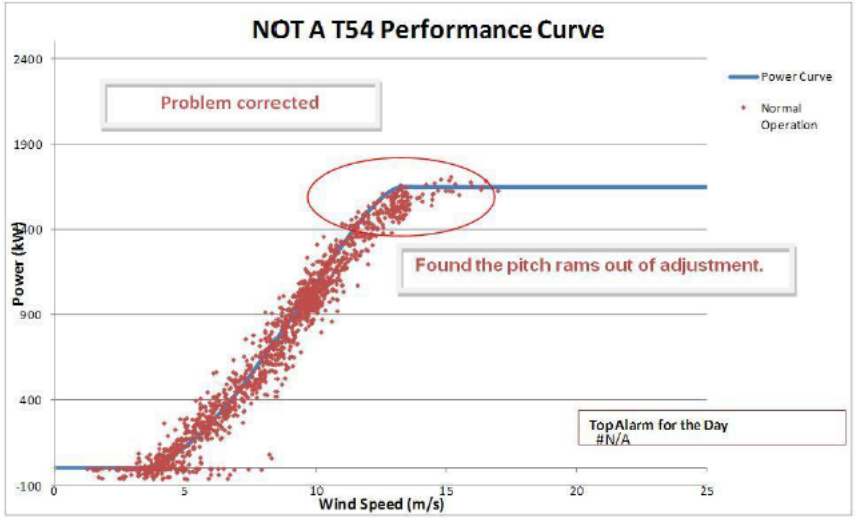
PROBLEM:

1. “Candy cane” performance curve detected at Notrees T54
2. Issue identified as pitch rams out of alignment

SOLUTION:

Pitch rams adjusted by technicians
Estimated annual revenue increase: $54,000



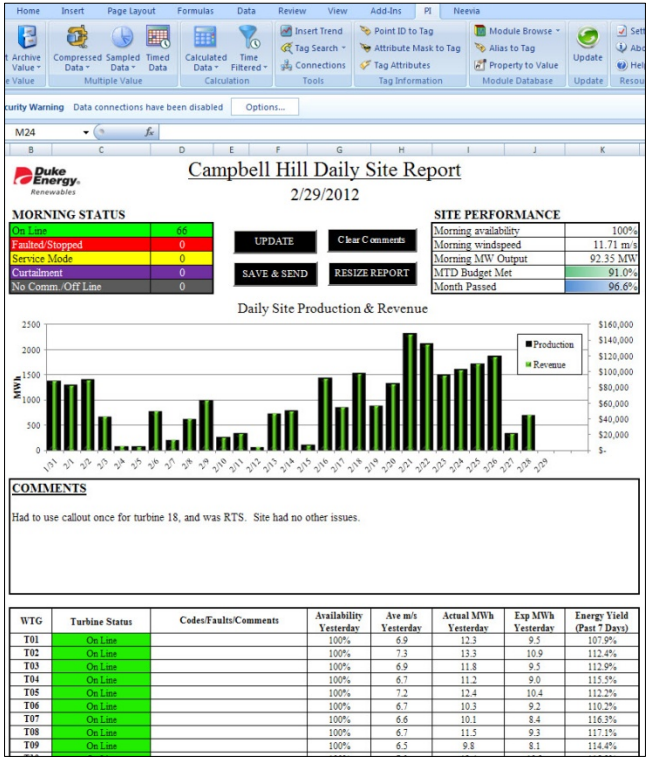


Plant Performance Reporting

PI DataLink

- Allows import of plant data into spreadsheets
- Primary tool for performance analysis
- Daily / Weekly / Monthly reporting
- Comprehensive assessment of fleet-wide data
- Standardized reports generated efficiently by operations team
- Effective communications to site staff
- Issue identification & tracking

Site Name	Site Size	Production (MWh)*		Energy Yield		Availability		Capacity Factor		Weekly Revenue Data*		
	DC kW	Week	Target	Week	MTD	Week	MTD	MTD	Month Target	Actual	Budget	% Met
TX Solar 1 (Bluewing)	16,623	590.8	506	94%	96%	100%	100%	18%	21%	$94,816	$81,153	117%
Solar Star NC 1 (Shelby)	1,018	30.9	32	102%	102%	100%	99%	22%	20%	$5,031	$5,280	95%
Taylorsville	1,150	32.4	34	97%	97%	100%	100%	22%	20%	$4,900	$5,180	95%
Martins Creek	999	25.1	24	107%	105%	100%	100%	19%	17%	$5,151	$4,973	104%
OUC Stanton	5,915	221.8	189	99%	99%	100%	100%	25%	22%	$43,032	$36,575	118%
Solar Star NC II (Murfreesboro)												
Murphy's Farm (Culberson)	998	29.3	27	108%	102%	100%	100%	21%	19%	$4,134	$3,865	107%
Murphy Point (Wingate)	998	30.2	27	101%	100%	100%	99%	21%	19%	$4,261	$3,865	110%
NC Renew Properties (Holiness)	997	27.6	27	99%	101%	99%	100%	20%	19%	$3,897	$3,865	101%
Ajo												
Bagdad												
Avg/Total	28,698	988.2	867	97%	98%	100%	100%	20%	21%	$165,221	$144,757	114%



WTG	Turbine Status	Codes/Faults/Comments	Availability Yesterday	Ave m/s Yesterday	Actual MWh Yesterday	Exp MWh Yesterday	Energy Yield (Past 7 Days)
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T03	On Line		100%	6.9	11.8	9.5	112.9%
T04	On Line		100%	6.7	11.2	9.0	115.5%
T05	On Line		100%	7.2	12.4	10.4	112.2%
T06	On Line		100%	6.7	10.3	9.2	110.2%
T07	On Line		100%	6.6	10.1	8.4	116.3%
T08	On Line		100%	6.7	11.5	9.3	117.1%
T09	On Line		100%	6.5	9.8	8.1	114.4%

Wind Power Forecasting

Forecast Model Improvements

- PI system aided improvements in wind forecast model
- Forecast model obtains real time MET data from PI system
- 1/20/2012: Tag created for 1-min avg m/s of all wind farm WTG nacelles. Integrated into forecast model
- Improved wind forecast projection in both DA & RT

	Dec 19 - Jan 20	Jan 20 - Feb 20	
	Deviation from DA	**Deviation from DA**	**% Improvement**
Max	48.65	49.11	-1%
Avg	10.17	7.82	23%

	Dec 19 - Jan 20	Jan 20 - Feb 20	
	Deviation from RT	**Deviation from RT**	**% Improvement**
Max	48.65	22.67	53%
Avg	5.24	3.25	38%

Table 1: Forecast improvement: day ahead (DA), real time (RT)

Online Forecasting Tool

- Streams real-time PI data from MET stations
- Calculates site power based on RT availability and power curve equation
- Provides operator interface for accurate power forecast nominations

Campbell Hill - Wind Forecast

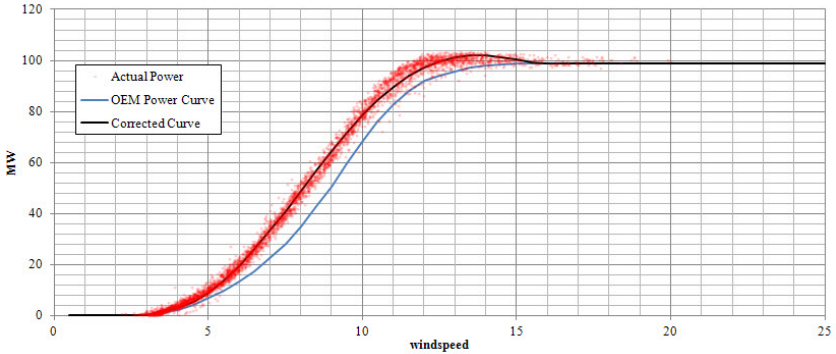
HOUR ENDING	DA EXPECTED GENERATION [PER TURBINE]	DA WIND FORECAST [M/S]	DA TURBINES AVAIL	DA FORECAST [MW]	RT EXPECTED GENERATION [PER TURBINE]	RT WIND FORECAST [M/S]	RT TURBINES AVAIL	RT FORECAST [MW]	DEVIATION FROM DA [MW]	ACTUAL WIND	ACTUAL MW	DEVIATION FROM RT [MW]	USER
04/06/2012 01:00	0.29	6.7	66	20	0.39	7.3	66	26	-8.87	6.98	28.87	-2.87	bedmonson
04/06/2012 02:00	0.29	6.7	66	20	0.15	5.5	66	10	6.05	5.61	13.95	-3.95	bedmonson
04/06/2012 03:00	0.29	6.7	66	20	0.23	6.2	66	16	1.71	6.27	18.29	-2.29	bedmonson
04/06/2012 04:00	0.29	6.7	66	20	0.36	7.1	66	24	-4.73	6.69	24.73	-0.73	bdavis
04/06/2012 05:00	0.25	6.4	66	17	0.29	6.7	66	20	-6.77	6.63	23.77	-3.77	nmayer
04/06/2012 06:00	0.27	6.5	66	18	0.07	4.6	66	5	7.59	5.15	10.41	-5.41	nmayer
04/06/2012 07:00	0.29	6.7	66	20	0.02	3.7	66	2	18	3.63	2	0	nmayer
04/06/2012 08:00	0.31	6.8	66	21	0.06	4.4	66	4	16.82	4.08	4.18	-0.18	nmayer

Wind Power Forecasting

(+) Bias = low forecast values
(–) Bias = high forecast values

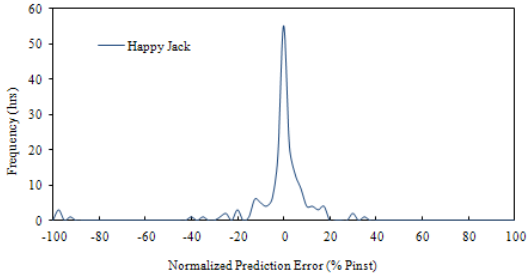
Power Curve Assessment

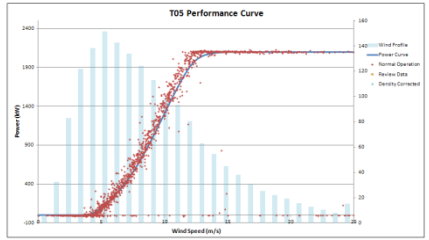
- Turbines performing below/above rated power curves
- Caused errors in forecasted power nominations
- Developed aggregate site power curve based on historical site data from PI server
- Characterize actual observed plant performance based on historic data archive

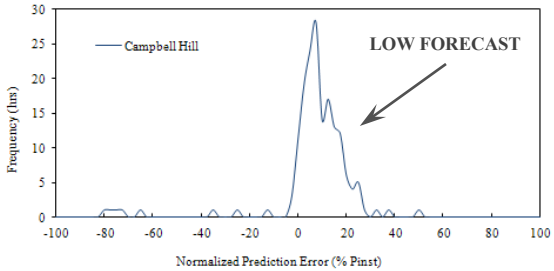


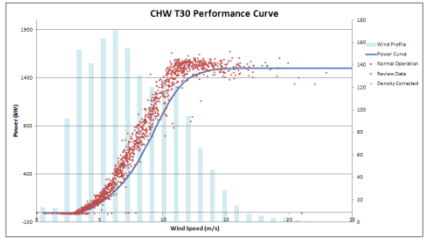
Model Bias Assessment

Forecast Bias = tendency of predicted values to be above or below actual measured values









Shaping Solar Business Strategy

Challenges

1. Rapid operational turnover of newly constructed sites
2. Multiple SCADA types & equipment manufacturers
3. Screen-space is valuable and limited
4. Sites are unmanned, reliable remote monitoring is critical

Solution

Standardize solar monitoring with the PI system

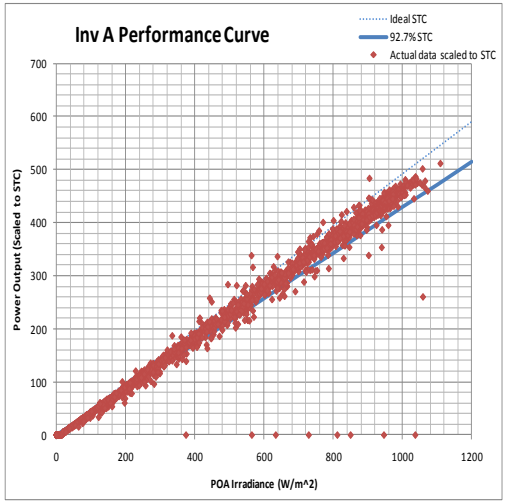
- Collect site data on solar specific PI server
- Create PI tags for operational variables
- Customize performance calculations & metrics
- Design standard monitoring visuals
- Develop alerts for inverter faults & underperformance

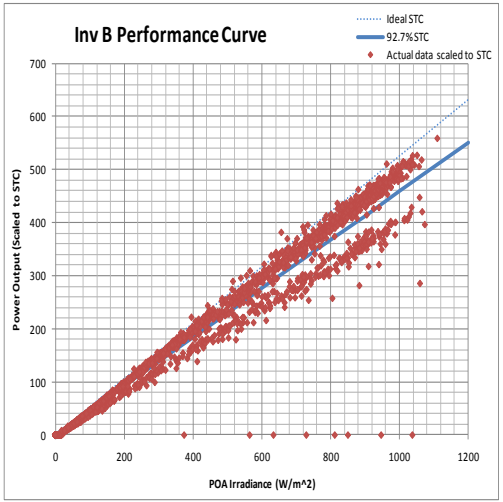
Continued on next slide

Shaping Solar Business Strategy

Issues detected at solar sites in PI system:

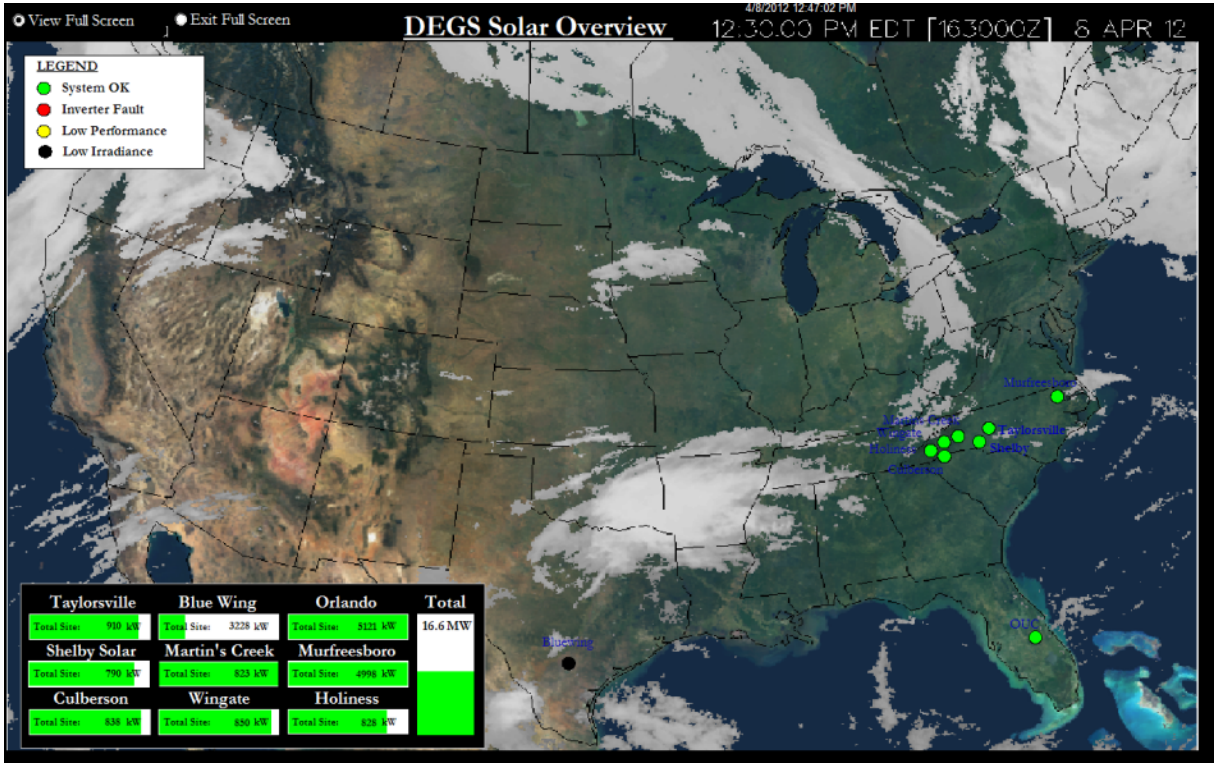
1. Blown fuses
2. Inverter grid faults
3. Communications failures
4. Storm damage to panels
5. Tracker motor errors





Detect Issues → Save $$

Solar Monitoring System

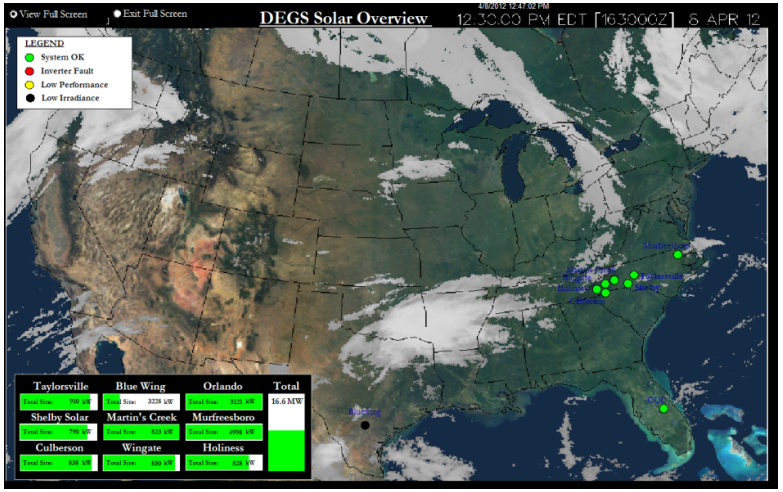


Solar Monitoring System

"This [solar monitoring program] delivered a highly functional monitoring center interface and saved us the expense of having to use 3rd party programmers."

Greg Wolf
President DE Renewables

Duke Energy Renewables



Business Challenge

- Need an in-house monitoring scheme for the rapidly growing solar fleet that is uniform, dynamic, and effective.

Solution

✓ Developed solar overview map which integrates real-time site performance data with current weather patterns in PI

Results & Benefits

- ❑ Provides operators with solar site status at a quick glance
- ❑ Precedent for future developments in fleet monitoring

Future Developments

PI Notifications

- Provide email alerts to REMC operators during emergency events
  - Equipment communications issues (functional)
  - Substation outages (in development)
  - Solar inverter faults (in development)
- Bring alarms to operator
- Maintain strict tolerance on critical alarms response

Substation Monitoring

- Create, view, manage alarms
- Acknowledgements & escalations
- Email, IM, and desktop alerts
- View active and archived alarms

Contact Information

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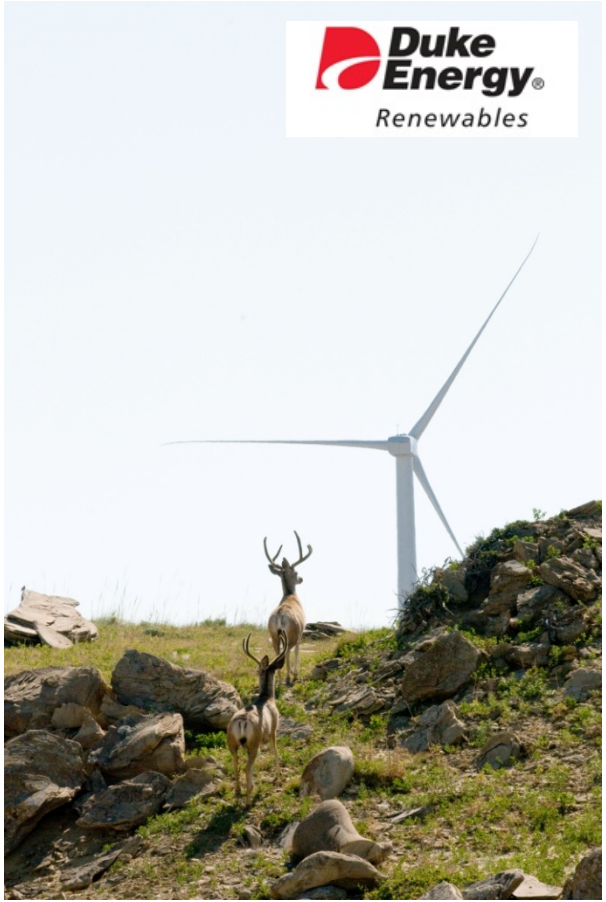

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