A NEW STANDARD IN METEOROLOGICAL MONITORING SYSTEMS INSTALLED AT THE PERRY NUCLEAR POWER PLANT

By

Jim Holian (SAIC) and Jamie Balstad (First Energy Corp)

May 2002

1.0 INTRODUCTION

The Perry Nuclear Power Plant (PNPP) is located on the southern shore of Lake Erie approximately 50 miles east of Cleveland, Ohio. Meteorological data have been collected from the 10- and 60-meter levels on a guyed tower onsite since the preconstruction era of the early 1970s. In the early 1980s, the meteorological monitoring system was upgraded to an elaborate system that included a Primary and Validity set of wind sensors as well as a Backup and corresponding Validity set of wind sensors at the 10-meter level. The 60-meter level contained only the Primary wind sensors and a corresponding Validity set of sensors. Sophisticated software would determine if the parameter measured was valid for each system by comparing it with its validity sensor. If the difference in the values exceeded predetermined criteria established as a statistical function for collocated sensors, the data were considered invalid.

The system with all of the software checks and balances was effective at catching sensors that were on the brink of failure and notifying the daily data reviewer through a system of flags that a potential problem exists. What the system could not do is tell the reviewer which sensor was failing, only that they do not match. When data did not match, the parameter for that given averaging period was coded as invalid. In addition, it had a high false alarm rate, particularly when minor tower interferences affected one sensor and not the other, or when the onset of precipitation caused a rapid change in wind or temperature. This resulted in countless hours each month of additional labor to manually edit the raw meteorological file and replace computer-generated invalid data with actual valid data from the digital printout or strip charts. Additionally, the system itself was very expensive to maintain, since there were six sets of sensors that must be calibrated and recertified every 6 months. Finally, as the age of the system increased, the frequency of downtime began to increase as well.

In 1999, PNPP decided to upgrade the meteorological monitoring system. This upgrade included removing some of the elaborate redundancy of the current system and replacing it with a more cost-effective system. The sophisticated software was replaced with simplified site-specific software that uses common meteorological principles and onsite climatology to determine the validity of a given parameter.

2.0 MONITORING EQUIPMENT CHANGES

The first change to the system was done on paper and may be the most important. The Primary and Backup Systems were renamed Systems A and B. This change eliminates the panic that ensues in the Control Room whenever they are notified that a Primary System is not working and the Backup System is now online. There is always that feeling that the Backup System is just not as good as the Primary System, when indeed the systems are identical!

Physically, the monitoring system was upgraded to include two basically independent meteorological monitoring systems (A and B). Systems “A and B” contain wind speed, wind direction and delta temperature data for 10- and 60- meter elevations. System A contains additional dew point, precipitation and station pressure data. A new equipment shelter was installed near the tower. System processor outputs were connected to the Plant Integrated Computer System data acquisition system via a fiber optic link. Data is also available from each system’s data logger via a remote dial-up modem. These modem links can be used by the Control Room, emergency response facilities, and key offsite personnel to access the digital data if the fiber optic link fails, or if the onsite Plant computer goes down. In addition, strip chart recorders were eliminated from both the meteorological shelter and Control Room. The Control Room now uses digital monitors.

Systems A and B provide multiple routes for communicating data to the plant computer for dispersion modeling and dose assessment as part of the CADAP software program. From the meteorological shelter, data are sent to the plant computer for emergency support and are available on monitors in the Control Room. The information sent includes: (1) routine meteorology for emergency dose assessment calculations, and (2) the most recent, routine 15-minute meteorological data and hourly data. In addition, instantaneous meteorological data are available via remote dial up of the System A or B data logger. Finally, if all data lines are not available, data are stored and can be retrieved from the System A and B data loggers in the meteorological shelter.

For each parameter, the system develops hourly values that are derived from 15-minute values. The 15-minute values are developed from sub-second sampling. The system automatically performs electronic and status checks and continually monitors for reduced voltage (i.e., air flow) in the temperature aspirators. The system also recognizes manually initiated bypass codes, which may be used during maintenance or calibrations.

Before the 15-minute value for a given parameter is accepted by the system computer to store or transmit, a real-time reasonability check is performed. For wind speed and direction, the System A parameter is compared to the corresponding System B parameter. If the difference exceeds reasonable predetermined criteria established for the Perry Plant Site (Table 1), the parameter is compared with the A and B System values at the other level (10 or 60 meters). The value chosen for the initial parameter will be the one closest to the other two values. A number flag is then initiated for each parameter, notifying the reviewer that the two systems did not initially agree and that a judgment was made depending upon other similar values. For temperature and delta-t, if the difference between Systems A and B exceed predetermined criteria, the value closest to the previous 15-minute value is accepted and flagged accordingly. For the single sensor parameters such as dew point and precipitation, reasonability checks include comparisons between previously accepted values and climatological extremes.

3.0 SITE-SPECIFIC SOFTWARE

There are many varieties of commercially available software that will compare meteorological data and send electronic messages or flags that key the end user into the quality of the data. However, most of these software packages do not have the capability to include regional or seasonal variations in weather or include onsite climatology in the decision-making process. As a result, new software was developed that uses algorithms based on the logical methods followed by experienced meteorologists to determine the validity of meteorological data. Some of the key elements of the software logic include:

- Detecting the presence of wind direction shear between tower levels
- Identifying differences in the data attributable to tower interference
- Recognizing light and variable winds
- Identifying wind speed cup/threshold problems before they become obvious
- Recognizing differences in delta-t attributable to sunrise/sunset
- Identifying aspirator trips/fluctuations
- Identifying problems associated with temperature, dew point, precipitation interactions
- Ability to turn off any sensor for maintenance/calibration

The new validity software is designed to assist the data reviewer in determining whether the data are good, questionable, or likely to be bad. This software is not designed to eliminate the need for data review by someone familiar with some concepts of meteorology and the particulars of the PNPP site. Unlike the previous system software, which eliminated any data which failed the comparability statistics resulting in hours of manual labor to re-enter perfectly good data, this software allows data to pass through at all times, but notifies the reviewer through a system of flags that it requires closer scrutiny. More times than not, data which are flagged as questionable are good data, but vary somewhat due to variations in meteorological conditions over a short period of time, even in collocated systems. Only when the software indicates questionable data for the same parameter for multiple hours should the reviewer become concerned that a system problem may be occurring or about to occur.

Table 1. PNPP Site-Specific Evaluation Criteria

Description	Value	Eng. Units
MAX WIND SPEED DIFFERENCE BETWEEN SYSTEMS A/B	3	MPH
MAX WIND SPEED DIFFERENCE 10-60 METER	10	MPH
MIN WD WHERE TOWER IMPACTING WIND SPEED - A	75	DEGREES
MAX WD WHERE TOWER IMPACTING WIND SPEED - A	100	DEGREES
MIN WD WHERE TOWER IMPACTING WIND SPEED - B	100	DEGREES
MAX WD WHERE TOWER IMPACTING WIND SPEED - B	115	DEGREES
WD WHERE TOWER IMPACTING BOTH A/B WIND SPEEDS	100	DEGREES
MAXIMUM ALLOWABLE WIND SPEED	98	MPH
MINIMUM ALLOWABLE WIND SPEED	-0.1	MPH
MIN WIND SPEED FOR WD VALIDATION	3	MPH
MAX WIND DIRECTION DIFFERENCE A/B	15	DEGREES
MAX WIND DIRECTION DIFFERENCE 10-60 M	30	DEGREES
MIN WD WHERE TOWER IMPACTING DIRECTION - A	60	DEGREES
MAX WD WHERE TOWER IMPACTING DIRECTION - A	80	DEGREES
MIN WD WHERE TOWER IMPACTING DIRECTION - B	80	DEGREES
MAX WD WHERE TOWER IMPACTING DIRECTION- B	110	DEGREES
WD WHERE TOWER IMPACTING BOTH A/B DIRECTIONS	80	DEGREES
MAXIMUM ALLOWABLE WIND DIRECTION	361	DEGREES
MINIMUM ALLOWABLE WIND DIRECTION	-0.1	DEGREES
MAX SIGMA THETA DIFFERENCE A/B	10	DEGREES
MAX DIFFERENCE IN DELTA T A/B	1	°F
BOTH 10/60 METER ASPIRATORS OK	4.6	VOLTS
60-METER ASPIRATOR HAS FAILED	4.2	VOLTS
10-METER ASPIRATOR HAS FAILED	3.8	VOLTS
BOTH 10/60 METER ASPIRATORS FAILED	3.45	VOLTS
MAX AMBIENT TEMP DIFFERENCE A/B	1.2	°F
MAXIMUM ALLOWABLE AMBIENT TEMPERATURE	110	°F
MINIMUM ALLOWABLE AMBIENT TEMPERATURE	-30	°F
MAXIMUM ALLOWABLE DEWPOINT TEMPERATURE	82	°F
MINIMUM ALLOWABLE DEWPOINT TEMPERATURE	-30	°F
MAX DEW POINT EXCEEDING AMBIENT TEMPERATURE	1.8	°F
MAX DIFFERENCE CURRENT/PREVIOUS 15-MIN RAIN	0.99	INCHES
MAX TEMPERATURE-DEWPOINT SPREAD DURING RAIN	10	DEGREES
MINIMUM ALLOWABLE PRECIPITATION	-0.1	INCHES
MAX ALLOWABLE 15-MINUTE PRECIPITATION	1	INCHES
MAX ALLOWABLE STATION PRESSURE	30.75	IN/HG
MIN ALLOWABLE STATION PRESSURE	27.75	IN/HG
MAX 15-MINUTE PRESSURE CHANGE	0.2	IN/HG
MAXIMUM ALLOWABLE DELTA TEMPERATURE	15.0	DEGREES
MINIMUM ALLOWABLE DELTA TEMPERATURE	-6.0	DEGREES
DEWPOINT ASPIRATOR HAS FAILED	3.25	VOLTS
DEW POINT & 60 METER ASPIRATOR FAILED	2.95	VOLTS
DEW POINT & 10 METER ASPIRATOR FAILED	2.75	VOLTS
ALL ASPIRATORS FAILED	2.58	VOLTS

The software uses a tiered approach in determining if a measured parameter for a given time period is reasonable. Table 2 includes an example of the wind direction algorithm written into the PNPP real time data evaluation program. Parameters which have a sensor for both the A and B system, i.e., wind speed and wind direction at both levels, perform normal validation by comparing data between identical sensors at the same level. When this comparison exceeds the site predetermined criteria, a secondary validation is performed by comparing with data at the other level, choosing the value that closely follows the data at that level. Delta-t and ambient temperature, which have duplicate systems, compare values between each other as normal validation, and then use previous reported data to determine if trend criteria are exceeded for secondary validation. Single sensor parameters, such as dew point and barometric pressure, use previous reported data to determine if data trends are exceeded as normal validation, and use Perry Plant site climatological extremes for secondary validation. In cases where the software validation determines predetermined criteria have been exceeded, but these differences are the result of either tower interferences or other normal meteorological phenomenon, the System A parameter is chosen and the value flagged accordingly. Examples of these include tower interference for wind direction through the tower before impacting the sensors, natural wind shear between levels, or rapid temperature changes around sunrise and sunset. No validation is performed on temperature or delta-t if the software determines one or more aspirators has failed. Finally, no validation is performed if either the System A or B parameter has been manually turned off for maintenance or calibration.

The software validity flags are numbered from 0 to 9, depending upon the type and results of the validation performed. Specific flags are outlined in Table 3. In general, flags 0,1,2, and 3 indicate good data; 4 indicates only System A data were passed because outside factors influenced the validation and the data should be reviewed, but is likely good; 5 and 6 indicate no validation was done and the parameter passed through should be checked for consistency; 7 and 8 indicate the software detected a potential problem and the data passed through needs to be checked closely to determine manually if it is consistent; and 9 indicates no data were received from the data logger or the sensor was turned off.

Table 4 lists the current PNPP meteorological parameters, the associated validity indicators, locations, and missing indicators. Table 5 is an example PNPP hourly data listing beginning October 4, 2000, at 1500 and ending on October 5, 2000, at 0700. Note that, in several instances, the software selected System A or B (0 or 1 validity indicator) for wind speed and direction as a result of light winds and tower interference, and in some instances had to perform additional validation checks (validity indicator 2) before selecting the valid value. Also note that twice the wind speeds fell below 3 mph and were determined to be too light to perform validation checks (validity indicator 4). However, all of the data were considered valid by the system. This example is typical of the system operation at PNPP.

4.0 SYSTEM PERFORMANCE

Since the upgraded meteorological monitoring system became fully operational in October 1999, data recovery for the key parameters, (i.e., wind speed and direction, temperature, and delta-t) have all exceeded 95 percent at both the 10- and 60-meter levels, with many months of 100 percent data recovery. In addition, because the system automatically replaces questionable data with data that has passed the software validity checks, the manual labor required to validate the meteorological data has been reduced substantially. Prior to October 1999, questionable data needed to be carefully reviewed and manually replaced with backup data, either from the digital data or strip chart recorders. Now, invalid data, either due to a problem, maintenance, or calibration, are automatically taken out of the validated data set by the software program. Much time and effort was expended in the past just to get the data recovery up to the minimum 90 percent. PNPP estimates that more than 200 labor hours were saved in 2001 alone, just in reduced manual data replacement.

Table 2. Example Wind Speed Algorithm

- For both levels
  - If neither wind speed reading is obtained from front-end processor
    - set valid value to the bad wind speed value and set flag to 9
  - If both wind speeds were “off” or “out of range”
    - set valid value to the bad wind speed value and set flag to 9
  - If one wind speed was “off” or “out of range”
    - set valid value to good measurement and set flag to
      - 5 if using Train A or 6 if using Train B
  - If both wind speeds are a “stuck” value for last 12 15-minute periods
    - set valid value to the bad wind speed value and set flag to 8
  - If only one current wind speed is a “stuck” value for last 12 15-minute periods
    - set valid value to the other train and set flag to 7
  - If flag is less than 5
    - If the difference in wind speeds is ≤ allowable and not blowing through the tower
      - set valid value to Train A wind speed and set flag to 0.
    - If the difference in wind speeds at level is ≤ allowable and blowing through the tower
      - If both wind directions are blowing through the tower
        - set valid value to Train A wind speed and flag to 4
      - If one wind direction is through the tower
        - set valid value to system sensor not in tower and set flag to 1 or 2 depending on which system sensor was used
    - If the difference in wind speeds at level is greater than allowable
      - If both wind directions are blowing through the tower
        - set valid value to Train A wind speed and flag to 4
      - If one wind direction is through the tower
        - set valid value to system sensor not in tower and set flag to 1 or 2 depending on which system sensor was used
      - If the wind direction is not through the tower
        - If both sensors are “good” on the other level (flags are less than 5)
          - Calculate the difference in values at other level
          - Calculate the difference in values between levels.
          - If the difference at other level is ≤ allowable, and the difference between one or both levels is ≤ allowable
            - Compare each wind speed to the wind speed at other level. Select either Train A or Train B wind speed that is closer to the values at the other level. Set the flag to:
              - 1 if Train A selected or 2 if Train B selected.
          - If the difference at other level is > allowable or the difference between both levels is > allowable
            - set valid value to Train A and flag to 4
        - If only one sensor is “good” on the other level (one sensor on other level is 5 or 6)
          - Calculate the between level difference based on “good” sensor.
          - If the difference between levels is ≤ allowable
            - Compare each wind speed to the only good wind speed at other level. Select either Train A or Train B wind speed that is closer to the value at the other level. Set the flag to:
              - 1 if Train A selected or 2 if Train B selected.
          - If the difference between levels is > allowable
            - set valid value to Train A and set flag to 4
        - If neither sensor on other level is “good” set valid value to Train A and flag to 8.

Table 3. Values and Description of Validity Flags

Validity Flag	Description
0	Normal data validation. Using System A
1	Secondary validation required, using System A. For dew point the freeze-point was converted to dew point or dew point slightly above the ambient temperature and has been set to the ambient temperature.
2	Secondary validation required, using System B
3	Used only for delta temp and temperature: one aspirator failed. Using the other system sensor.
4	Using System A Data. Validation exceed predetermined criteria because: Both System A and B wind directions were blowing through the tower. Secondary wind direction validation detected wind direction change with height greater than 30 degrees. Wind speed below light wind limit or wind speed less than predetermined criteria. Delta-t differences occurred during sunrise/sunset transition periods.
5	No Validation. Problem detected with System B sensor (turned "off" or problem with time/date stamp or reading data logger file) using System A
6	No Validation. Problem detected with System A sensor (turned "off" or problem with time/date stamp or reading data logger file) using System B
7	Ambient Temperature--Both aspirators off, results could be affected Delta Temperature--Both aspirators off. results could be affected . Dew-point temperature, possible "stuck" sensor (same reading for 5 readings) Precipitation--Difference between ambient temperature and dew point greater than 10 °F. Wind Speed--One sensors at same level are "stuck" (same reading for 13 readings) Pressure, possible "stuck" sensor (same reading for 5 readings).
8	Failed all validation checks. System A values passed if possible. Dew point exceeded ambient temperature by greater than allowable criteria. Dew point reset to ambient temperature. Wind Speed--Both sensors at same level are "stuck" (same reading for 13 readings)
9	No data obtained from either data logger or all similar sensors on same level turned "off"

Table 4. Hourly PNPP Meteorological Data Format

Parameter	Format	Columns	Missing Indicator	Units
Year (Last two digits)	I2.2	1 - 2	NA	-
Month (1 to 12)	I2.2	3 - 4	NA	-
Day (1 to 31)	I2.2	5 – 6	NA	-
Hour (1 to 24: 24 = Hourly update at midnight)	I2.2	7 – 8	NA	-
10 meter Wind Speed	F4.1	9 – 12	99.9	mph
10 meter Wind Direction	F4.0	13 – 16	999	degrees
10 meter Wind Direction Standard Deviation (σ_θ)	F5.1	17 – 21	999.9	degrees
60 meter Wind Speed	F4.1	22 – 25	99.9	mph
60 meter Wind Direction	F4.0	26 – 29	999	degrees
60 meter Wind Direction Standard Deviation (σ_θ)	F5.1	30 – 34	999.9	degrees
Delta Temperature (ΔT 60 – 10 meter)	F4.1	35 – 38	99.9	°F
10 meter Ambient Temperature	F5.1	39 – 43	999.9	°F
10 meter Dew point Temperature	F5.1	44 – 48	999.9	°F
Station Pressure	F5.2	49 – 53	99.99	in. Hg
Precipitation	F4.2	54 – 57	9.99	inches
Validity Indicators 10 m Wind Speed 10 m Wind Direction 10 m Wind Direction Standard Deviation (σ_θ) 60 m Wind Speed 60 m Wind Direction 60 m Wind Direction Standard Deviation (σ_θ) Delta Temperature (ΔT 60 – 10 meter) Ambient Temperature Dew point Temperature Station Pressure Precipitation	11(I1)	58 – 68	NA	-
Site ID (set to PV = Perry Validated)	A2	69 - 70	NA	-

Table 5. Example PNPP Hourly Meteorological Data Output

	10-Meter			60-Meter									
YrMoDaHr	Ws	Wd	Sig	Ws	Wd	Sig	Dt	Ta	Td	Sp	Prec	Validity Ind.	Site
00100415	3.8	349.	22.8	4.4	352.	21.1	-1.0	59.6	55.1	29.32	0.00	00010000010	PV
00100416	3.9	14.	32.9	6.2	18.	22.8	-0.8	59.0	54.8	29.33	0.00	00010000000	PV
00100417	6.0	347.	17.3	9.0	356.	12.9	-0.8	58.3	53.9	29.34	0.00	00010000000	PV
00100418	3.8	12.	35.9	6.1	18.	16.5	-0.8	59.0	53.8	29.35	0.00	00010000000	PV
00100419	4.2	52.	14.1	6.7	45.	10.7	-0.6	58.8	53.4	29.35	0.00	00010000000	PV
00100420	3.0	72.	9.6	0.6	71.	3.6	0.9	56.7	52.8	29.34	0.00	02022000000	PV
00100421	2.3	74.	10.9	0.6	74.	4.2	1.4	56.1	52.7	29.35	0.00	02022000000	PV
00100422	1.4	117.	37.8	0.6	97.	3.6	1.6	55.5	52.7	29.36	0.00	00021000000	PV
00100423	2.6	109.	24.2	0.9	117.	4.6	2.0	54.7	52.7	29.36	0.00	11020000000	PV
00100424	1.8	95.	20.3	0.9	119.	2.2	1.9	54.5	52.5	29.36	0.00	21024000000	PV
00100501	2.3	110.	17.5	1.0	125.	4.0	1.8	54.3	52.6	29.37	0.00	11020000000	PV
00100502	4.0	139.	14.2	0.8	146.	4.1	0.5	55.6	52.9	29.38	0.00	00020000000	PV
00100503	2.5	92.	12.4	0.9	122.	3.4	1.0	55.0	52.4	29.37	0.00	21024000000	PV
00100504	2.4	76.	23.1	8.3	101.	5.6	1.2	54.3	52.0	29.36	0.00	22011000000	PV
00100505	4.1	107.	16.5	9.7	106.	6.8	0.3	54.7	51.8	29.34	0.01	11011000000	PV
00100506	5.0	112.	14.0	1.5	114.	6.8	-0.1	54.4	51.9	29.33	0.00	10020000000	PV
00100507	4.5	78.	14.6	2.1	89.	7.7	-0.2	54.1	52.0	29.34	0.02	22021000000	PV

Key:

Yr = Year	Dt = Delta-t
Mo = Month	Ta = Ambient Temperature
Da = Day	Td = Dew Point
Hr = Hour	Sp = Station Pressure
Ws = Wind Speed	Prec = Precipitation
Wd = Wind Direction	Ind = Indicator
Sig = Sigma Theta	PV = Perry Validated

Instruments and Calibration (I&C) personnel at PNPP have also benefited from the upgraded monitoring system. The number of sensor/equipment failures has decreased substantially since October 1999. For instance, there were an average of 28 work order requests each year for non-routine maintenance or calibration of the meteorological system prior to the upgrade. Since then, that number has dropped to around 12 requests, a decrease of nearly 60 percent. In addition, operating and maintaining the labor-intensive chart recorders in both the meteorological shelter and Control Room has been eliminated, saving thousands of dollars annually in chart paper and labor hours. The number of sensors to be calibrated and recertified has dropped by one-third, saving recertification costs and labor hours there as well.

Finally, the overall time to perform the weekly system checks and semiannual calibrations has been reduced because the system is more user friendly and the number of monitoring channels is less. As a result of the meteorological system upgrade, PNPP conservatively estimates that the annual savings in equipment, labor, and supplies exceeds $60,000.

5.0 SUMMARY

The meteorological monitoring system at PNPP was originally installed in the early 1970's, upgraded in the early 1980's, and became increasingly more expensive to maintain in the mid 1990s. In addition, the original data validation software was extremely outdated. As a result, First Energy Corp and PNPP elected to upgrade their current monitoring system to a more cost-effective and user-friendly system. This new system replaced the complex series of primary and validity sensors and backup and validity sensors with two nearly independent systems. Systems "A and B" contain wind speed, wind direction and delta temperature data for 10- and 60- meter elevations. System A contains additional dew point, precipitation and station pressure data. A new equipment shelter was installed near the tower. System processor outputs are connected to the Plant Intergated Computer System data acquisition system via a fiber optic link. Data is also available from each system's data logger via a remote dial-up modem. State-of-the-art software was developed, which compares data between the two redundant systems with predetermined values based on regional meteorology and onsite climatology, and makes decisions on the quality of the data. The software generates one meteorological data set which is the "best of" the two independent systems after eliminating spurious data from either system which could influence one system or the other, such as tower interference, aspirator motor failures, etc. The new software always allows data to pass through, leaving the ultimate decision to eliminate data up to the reviewer and saving hundreds of labor hours annually in manually re-entering data. PNPP has realized additional cost savings with the reduction of the number of sensor recertifications and the reduced costs associated with maintenance and calibrations. PNPP has estimated that the upgraded monitoring system has nearly paid for itself since it became fully operational in October 1999.