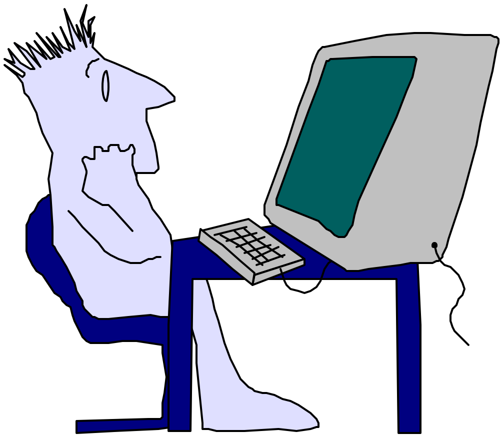

OPERATOR INTERFACE SUGGESTIONS

TO HELP YOU MEET THE NERC CONTROL PERFORMANCE STANDARDS

(CPS)

DRAFT

OPERATOR INTERFACE SUGGESTIONS

DRAFT

Table of Contents

I. INTRODUCTION

A. Caveat

This document is not intended to mandate the displays used by control area operators. It is offered as a forum to share ideas to help meet the new NERC Control Performance Standards (CPS). Forward comments and suggestions to the authors. This feedback will be made available to others via the NERC Control Criteria Task Force (CCTF) Forum and the NERC web page.

Send comments, questions or suggestions to:

Charles Sanders
501/543-5448
csanders@entergy.com

Terry Bilke
414/544-7119
so3876@wepco.com

Other Performance Subcommittee members noted in this paper:

Alan R. Oneal
MidAmerican Energy Company
515/252-6449
aroneal@midamerican.com

Michael J. Potishnak
New England Power Pool
413/535-4308
mpotishnak@nepool.com

B. Benefits of Early data collection

Although CPS performance does not have to be reported until February of 1998, it's in your interest to collect and report data as soon as possible. Eventually, CPS compliance will be based on a 12-month rolling average. Those who wait until next year will have only one month's performance in their report. If they have one bad month, they will pay a price until their rolling average recovers.

If you collect data and start calculating CPS now, you can pick the point where you start reporting via CPS. Companies that have made the move to CPS have found it took up to 3 months to work the bugs out. It's important to start collecting data and calculating your CPS performance soon.

While it's LIKELY that good A1/A2 performers will be good CPS performers, there is no guarantee. Each control area should validate their performance beforehand.

C. IT'S NOT THAT DIFFICULT

All that's needed to meet the reporting requirements of CPS is to save 1 minute averages of ACE and frequency. An off-line CPS calculation tool is available from the NERC web site. The file (CPSCALC.XLS) can be downloaded from ftp://www.nerc.com/pub/sys/all_updl/prfrm/.

Companies have reported that they have been able to download and implement this tool within a day or two.

II. BACKGROUND

There are several documents available that provide information on CPS. The most useful are:

- NERC Policy 1-*Generation Control and Performance*.
- EPRI Report TR 107813.
- NERC *Frequently Asked Questions on CPS and DCS*.
- NERC *CPS Training Document*.
- NERC CPS Training Video (not yet released).

This paper is not intended to duplicate the information in the references above. However, a summary of CPS1 and CPS2 would help at this point.

A. CONTROL PERFORMANCE STANDARD (CPS) 1

- Major differences between CPS1 and A1:
  - ACE doesn't have to cross zero every 10 minutes.
  - Not penalized when ACE benefits system frequency.
  - More constrained when ACE adds to frequency deviations.
- Good A1 performers will LIKELY be good CPS1 performers.
- CPS1=(2-CF)*100%.

Where:

CF (Compliance Factor)= $(ACE_{1\ min\ ave} * \Delta F_{1\ min\ ave})/(-10B\epsilon^2)$

B = your frequency bias.

ΔF = difference from target frequency (must take time corrections into account).

ϵ = a system constant, presently 0.018 (eastern interconnection), 0.0228 (western interconnection) and 0.020 (ERCOT).

- Performance is expressed in % compliance.
- CPS1 for a period is the average of all 1-minute CPSs in that period.
- CPS 1 minimum standard is 100% (12 month rolling average).
- CPS reports are due 10th working day of each month.
- CPS data to include disturbance periods, also "unavailable data" periods should be noted.
- If deficient in CPS1 and/or CPS2 at year's end, you must obtain regulation resources.

B. CONTROL PERFORMANCE STANDARD (CPS) 2

- Standard designed to prevent large unscheduled power transfer.
- Data must be available for 5 minutes for period to be counted.
- Violation definition:

For each 10 minute period, $ACE_{Ave} < 1.65 * \epsilon_{10} \sqrt{(10B_{company}) * (10B_{interconnection})}$

Where:

ϵ_{10} = a system constant, presently 0.0057 (eastern interconnection) and 0.0073 (western interconnection and ERCOT).

$B_{company}$ = your frequency bias.

$10B_{interconnection}$ = bias of your interconnection, the official '98 numbers have yet to be released, but they are approximately -5692 Mw/.01Hz (eastern), -1825 Mw/.01Hz (western), and -920 Mw/.01Hz (ERCOT).

- CPS2 = [1 - (# violations/# available 10 minute periods)]* 100%
- Control Performance Standard 2 - 90% minimum.

- CPS2's L_{10} much larger than A2's L_d as long as frequency is near 60.

III. REAL-TIME OPERATOR INFORMATION

A. *Tabular Displays*

The traditional ACE chart is still an important tool in operating under CPS. Supporting tabular data on an EMS summary display will enhance the use of a chart. The most useful information would be CPS data and some type of alert for high risk and violation situations.

1. CPS Data

The operator would find the following information useful:

	CPS 1	CPS2
This Hour	127%	94%
Today	133%	91%
Minimum Target	125%	96%

The calculation for the present day and hour performance is straightforward. A target number would be valuable and requires a little explanation.

The standard for CPS is based on a 12-month rolling average. Assume it is presently the middle of June. The next CPS report will include performance beginning last July. Let's say a company sets a goal of achieving a minimum of 120% for CPS1 and 95% for CPS2. Eleven + months of data for the next report are known. It is fairly easy to come up with a calculation of the average daily performance needed between now and the end of the month to achieve the company goal. In the table above, the company is behind in its target and is shooting for a higher level of performance for the rest of the month.

2. Operator Alert

In addition to the tabular information, it would be wise to alert the operator when the risk of performing badly is high or if the CPS performance is presently poor.

The L_{10} limit on the positive side of ACE is constrained by nearly 2/3 when average frequency goes to 60.01 Hz. The + side of the ACE chart is almost entirely constrained at 60.025 Hz. The other side of the chart is similarly constrained when frequency is low.

A "yellow flag" on the EMS summary page when average frequency deviation (1-2 minutes) goes to +/- 0.01 Hz or when ACE goes beyond L_{10} could be useful. A red flag when average frequency deviation approaches +/- 0.02, particularly when frequency is "in phase" with ACE would tell the operator that VERY bad CPC is possible.

B. *Graphical Displays*

1. Traditional ACE Chart (with one change)

Figure 1 is a traditional ACE chart with two pen scales. The value of this chart has not diminished. However, there is one change to assist the operator. The scale of the chart includes the L_{10} limit.

Operators need to remember that this is a 10-minute limit. ACE can go beyond this without incurring a CPS2 violation. The average, however, must be below this band. On the other hand, if frequency deviates from 60Hz, the limit on the associated side of the chart becomes constrained. Additional information would therefore help the operator. This is shown in subsequent charts.

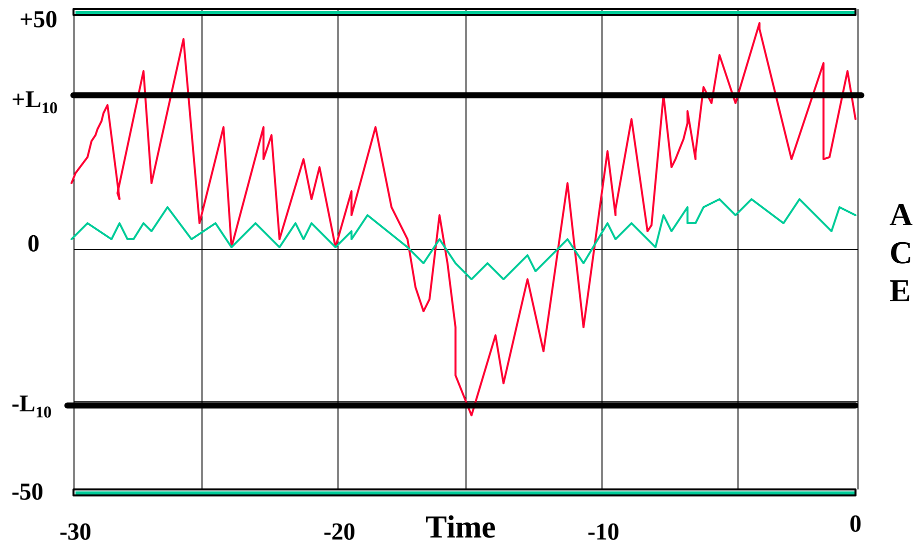

Figure 1 ACE Chart with L(10) Limits

2. ACE with Alert Bands

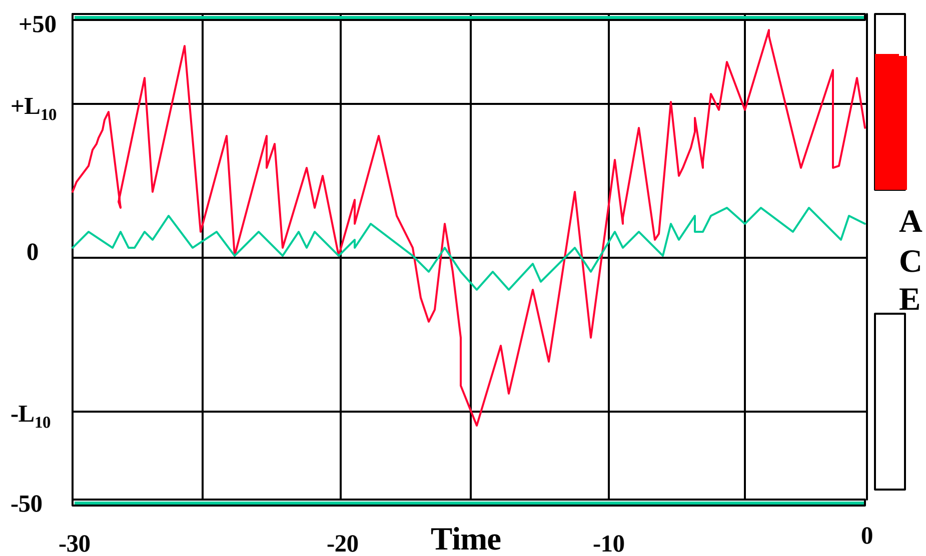

Figure 2 ACE Chart with Colored Alert

It would help to alert the operator when the one minute average frequency deviates significantly from zero. Figure 2 shows a chart with a "warning light" that activates when the short-term average frequency is either too high or low. In this example, recent frequency has been above 60.01 Hz. If the recent average frequency were below 59.99 Hz the box on the negative side of the ACE chart would turn yellow. The associated box could turn red if average scheduled frequency went beyond +/- 0.02 Hz . This would alert the operator that once side of the ACE chart is almost entirely “off limits”. A dynamically changing alert band would be an extra enhancement.

3. ACE with Dynamic Limits

Figure 3 is an example of a chart that displays dynamic limits through time. In this case, frequency has gone high over the last few minutes. The extreme positive side of the ACE chart should be avoided. Conversely, frequency was low from about 8-22 minutes ago. The negative side of the chart was therefore constrained.

Some people have suggested using algorithms to predict frequency in order to project ACE limits into the future. The theorists say that this will not work because as CPS is implemented, frequency will become tighter yet more random. The bottom line is that a complex frequency forecaster might be of limited value.

We can, however, use a knowledge of the variation of frequency to our benefit. The “Control Strategies” section of this paper notes that the 1 minute frequency averages show positive *autocorrelation* out several minutes. This means the average frequency a few minutes from now will be something like the recent past. The idea is to use AGC to prod the generating units. The operator should intervene (beyond what they do today) only if frequency deviation or ACE becomes extreme.

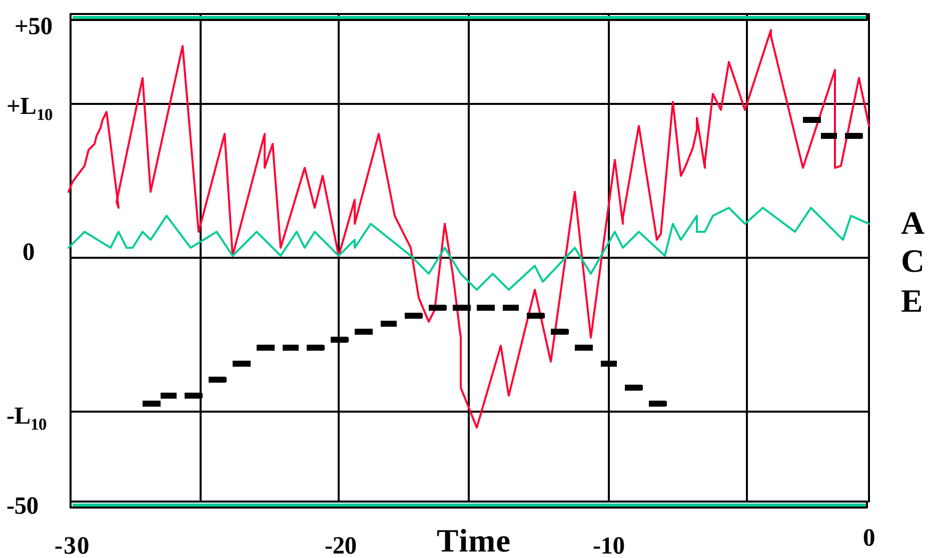

Figure 3 ACE Chart with Dynamic Limits

Figure 4 has the same ACE and frequency information as the chart above, but uses colors to highlight the “danger areas”. Yellow indicates relatively high/low frequency, while red indicates very high/low frequency.

Another variation of this chart would be to look at the combination of ACE and frequency. If ACE and frequency are both excessive in the same direction, the area of the chart could be highlighted red. If either ACE or frequency are high/low that part of the ACE chart could be highlighted yellow.

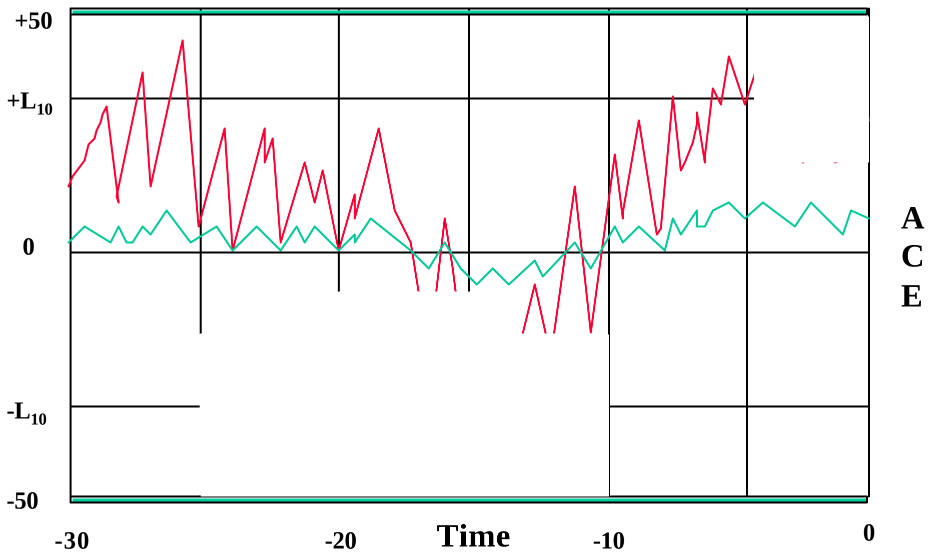

Figure 4 ACE Chart with Colored Warning

Figures 5 shows an industrial engineering tool called a Statistical Process Control (SPC) chart. These charts track a process over time and highlight situations that are statistically rare. In other words, they flag points where the process goes “out of control”. An operator should not intervene in a process unless it has gone out of control.

The Upper Control Limit (UCL) and Lower Control Limit (LCL) show the bounds where a process can normally range. The UCL and LCL are calculated at 3 standard deviations from the average observation. Anything beyond these limits are “rare” events that imply the process is out of control. If a process passes beyond these limits, action should be taken to restore control. Information should also be collected. This information gives clues on how to improve the process in the future.

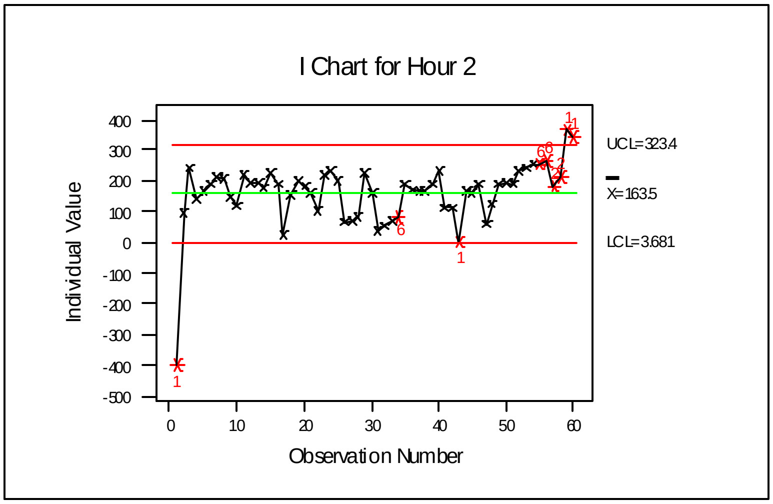

Figure 5 SPC Chart of CPS1

Figure 5 is an actual SPC “Individuals” chart for CPS1 for hour ending 0200 for an eastern interconnection company on January 27. The process went significantly out of control at the beginning of the hour. This is likely due to a schedule change that caused ACE to go excessive (with respect to frequency). If this were the only out of control situation for the hour and CPS performance was substandard, the schedule change was too great for the company's regulating resources. This tells the operator how large a schedule change to allow with similar regulation.

SPC charts are easily applied to the data available under CPS. They can be used for both real time operation and also historically for process improvement. These charts are further discussed in the Appendix. In addition, the references listed in this paper (or any good Quality Control/Quality Management text) can provide more information.

IV. HISTORICAL/REPORTING INFORMATION

A. Tabular Displays

Monthly and yearly data (beyond summary values) need not be continuously displayed to the operator. The data should be available for analysis and reporting. The simplest way to save monthly CPS data is to store it in a matrix. A table 24 hours (25 for Daylight savings time) **X** 31 days would work. An hourly summary column would provide the information needed for reporting.

It is worthwhile to include a mechanism to identify outliers in the data. These extreme values can pinpoint data and control problems. The "stars" shown in Figure 6 represent CPS values that have been flagged. A two color approach (yellow for 2 standard deviations from the mean, red for 3) would tell management and analysts where to dig deeper. This "flagging" technique will only work effectively for CPS1. CPS2 only varies from 0-6 in a given hour.

Data tables are needed for both CPS1 and CPS2. The number of hourly data samples and unavailable periods should also be kept.

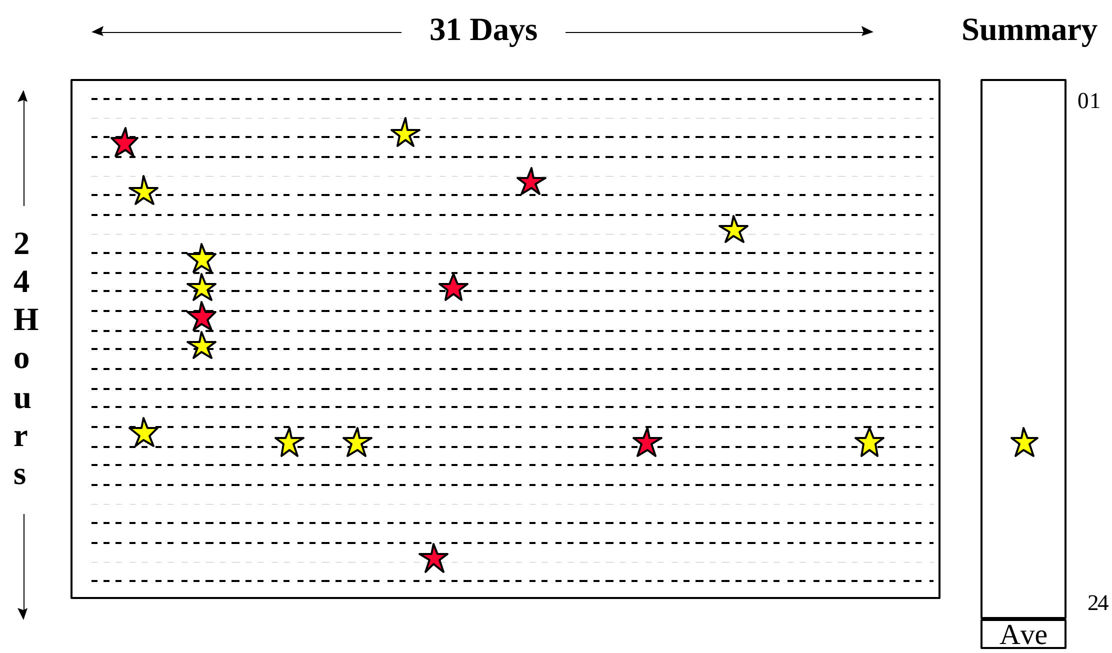

Figure 6 Monthly Data Matrix

B. Graphical Displays

The Statistical Process Control charts mentioned earlier are very applicable to representing and tracking hourly, weekly and monthly performance. The longer the unit of time monitored (daily vs. hourly), the "higher level" of the analysis. It moves away from the operator towards things more far reaching. These charts are explained further in the Appendix.

C. Required Reports

The NERC *"Control Performance Training Document"* contains the monthly report, CPC Form 1. Each month, an hourly summary of the following data points is required:

1. CPS1 compliance factor.
2. CPS2 violations.
3. # of CPS1 samples.
4. # of CPS2 unavailable periods.

V. CONTROL STRATEGIES

A. HOW SHOULD WE OPERATE UNDER THE CPS?

Utilities have the option of maximizing economy, maximizing CPS or operating somewhere in between. Stressing economics likely means a utility will take a longer-term view on controlling CPS. They will accept a few bad periods in exchange for the expected savings. Finally, some companies may choose to operate via A1/A2 and report CPS performance. No matter what strategy chosen, everyone ultimately has to meet the minimum standard The options are discussed below.

B. Continue A1/A2 and Report CPS

From an EMS support perspective, continuing to operate via A1/A2 requires little change and incurs little cost. All that's needed is to save one minute averages of ACE and frequency. This data can be entered into the "off-line" tool available on the NERC web page.

Note: Although it is likely that good A1/A2 performers will do well under CPS, there is no guarantee. Testing should be done before CPS is enforced to validate their performance.

C. Modify AGC to Provide the Operator Control Options

The next few subsections discuss different operating strategies that are available if a fairly simple change is made to AGC.

1. Minimize Production Costs by Minimizing Control Action

CPS1 and 2 are less constraining than the old CPC standards as long as frequency is near 60 Hz. As frequency goes high or low, ACE that contributes to the high/low frequency significantly reduces CPS performance.

Most companies would like to take advantage of the benefits of not pulsing units when it's not required (a more optimal dispatch and better unit heat rate). ACE doesn't have to cross zero every ten minutes when frequency is near 60. In fact, CPS1 is better if we don't cross zero when we're helping frequency back to 60 Hz.

Traditional EMS controls tried to force ACE across zero every 3-7 minutes. This was to prevent incurring an A1 violation. There is no longer a requirement to cross zero. ACE must stay within a certain range.

Michael Potishnak of NEPOOL wrote a paper (see the References section) on how to make a fairly simple change to the ACE crossing logic that could do what is suggested. He recommends “tricking” AGC to think ACE has recently crossed zero as long as CPS is not being violated. This relaxes control, limits the amount of unit pulsing and lets the “economic” logic of AGC dominate.

2. Maximize CPS

A short study was done on how frequency varies to gives clues on how to modify AGC. There is autocorrelation in the 1-minute averages of interconnection frequency out to around 15-20 minutes. This is another way of saying the average frequency in a few minutes will be pretty close to what it has been for the last few minutes. Note: This relationship may not be as strong once all companies are operating under CPS.

CPS1 performance gets bad when ACE and frequency are both high or low. CPS1 performance gets VERY bad when they are in the same direction and frequency deviates from 60 by +/- 0.015 Hz. This leads to a suggestion in how to apply the EMS code described in Mike Potishnak’s paper.

There should perhaps be three levels of control:
Relaxed-Reduce the requirement to cross zero when frequency is near 60 Hz.
Normal-Similar to today’s control of crossing zero every few minutes.
Tight-Stay as close to “zero” as possible (cross “zero” more often).

The operator should be able to toggle the preferred level. A good CPS performing company might keep it in “relaxed”. Those in danger of not meeting the standard could pick tighter control. From here, AGC could take over.

There was a discussion in the “Displays” section of this paper on the calculation and display of a “CPS target” based on how a company has performed over the last 11 months. This target could be used in the EMS logic to set the control mode automatically. The greater the danger in not meeting the CPS target, the tighter the control. The operator still should have some means to override it.

If frequency deviates moderately from 60 Hz (an analyst-enterable amount, say +/- .015 Hz), control should temporarily move out of “Relaxed” if that’s where it is. In addition, the “zero” target that AGC is trying to cross should move to the other side of the ACE chart. In other words, if frequency (the average for the past minute or so) is high, ACE should try to cross not zero, but some negative number. This number should be analyst-enterable, perhaps something around 1/3 of L_{10}. Let’s call this a “zero cross offset”.

If frequency deviates even more (an analyst-enterable # around +/- 0.025 hz), not only should there be a “zero cross offset”, but control should step up to “Tight Control” in order to keep ACE on the side of the chart that helps frequency. Once frequency drops back to normal, control can drop back to the operator preferred level.

Some people might be afraid that controls as suggested wouldn’t work because they fear frequency swings from high to low too often. Analysis done on one-minute average frequency on the interconnections show it goes high or low (> +/- 0.01 Hz) around 10% of the time.

There appears to be little danger in applying an AGC offset as discussed. Even though frequency goes high and low, it does not always cycle between high and low. A quick analysis of data showed average time between “flip-flops” was 10-15 minutes. This would give AGC time to recover.

3. Inadvertent Management

The idea of controlling to a "zero offset" could be applied to inadvertent energy management. For example, if a company has delivered an undesirable amount of inadvertent, the operator could toggle a "reduce inadvertent" field. AGC should then control to a small negative value of ACE. This mode should, however, be automatically disabled whenever average frequency deviation (negative in this example) would cause bad CPS. It should restore inadvertent recovery when frequency is near 60 Hz (or positive in this example).

There is one word of caution on inadvertent management. The NERC Performance Subcommittee is looking at ways of separating good inadvertent (that supporting frequency) vs. bad inadvertent (that causes frequency deviation). There may eventually be penalties paid for bad inadvertent. More coordination on inadvertent management and frequency might be needed.

4. Summary-Don't Over-Control

The one-minute CPS1 periods don't lend themselves to operator control by period. The time frame is too short. An adjustment now may counter what's needed next period. Experience will tell once utilities convert to the new standard, but the best policy will likely be to establish an operating strategy and shoot for good long-term performance. Let AGC do most of the control. Don't operate minute-to-minute.

CPS2 is measured over 10-minute blocks. Because this is within the timeframe an operator can respond, it is less susceptible to over-control. The operator can manage CPS2 directly.

VI. REFERENCES

NERC Policy 1-*Generation Control and Performance**
EPRI Report TR 107813
NERC *Frequently Asked Questions on CPS and DCS* *
NERC *CPS Training Document**
NERC CPS Training Video (not yet released) *
Off-Line CPS Calculator (CPSCALC.XLS found at ftp://www.nerc.com/pub/sys/all_updl/prfrm/)
"Devil's Advocate Design of an Operator Interface" by Mike Potishnak
"Statistical Quality Control" by Eugene Grant & Richard Leavenworth -McGraw-Hill #
"Statistical Quality Design and Control" by Richard DeVor et.al.-Macmillan #

* Available on the NERC web site (http://www.nerc.com/~oc/perform.html).

The American Society of Quality Control home page at http://www.asqc.org/ has a large selection of references on control charts and process improvement. You can search on subjects such as Statistical Process Control or Control Charts.

VII. APPENDIX-STATISTICAL PROCESS CONTROL (SPC) CHARTS

A. BACKGROUND

This appendix describes the potential value of using Statistical Process Control (SPC) charts for Control Performance Standard (CPS) improvement and also real time operations

SPC charts have proven themselves in industrial processes similar to power system control. The charts monitor a process over time and track its state. The charts can tell if things are normal. They also "flag" changes that have assignable causes.

If we know when a change (either for better or worse) occurs, it is much easier to find the underlying cause. A change for the worse can be corrected. An improvement can be repeated and ideally made permanent.

1. Process Variation

A simple example can be used to explain process variation. Consider a rifleman firing at a target. Any shot missing the bulls-eye can be considered an error. The dispersion pattern of the bullets is caused by several factors. Some of the contributors would be:

- trigger squeeze.
- breathing techniques.
- wind.
- sight adjustment.
- quality of the ammunition and rifle.
- eyesight and steadiness of the marksman.
- training.

The apparent random variability of the shot pattern is due to the combined effects of the factors above. Quality control experts call this "common cause variation". The greater the number of contributors, the greater the variation. The sum of all these lowers the marksman's performance. The implication of the discussion is that elimination or reduction of individual contributors will improve performance. Identifying and working on the largest problems will pay the most dividends.

2. Over-Control Example

Over-control would occur when the marksman would fire one shot, guess at what caused it to be off-target, and then make a change (position, sight adjustment, ammunition, etc.). The marksman would again fire only one shot, make some change and repeat the process. After 5 or 6 repetitions of this method, the bullets would no longer be hitting the paper. This is over-control.

The expert marksman will fire three or more rounds under the same conditions. S/he will observe the pattern (range in SPC terms) and make an adjustment based on the center of mass (average) of the bullet pattern. After 2-3 iterations, the marksman's pattern will be centered on the bulls-eye. As more improvements are made, the spread will decrease.

Note that as both the average and the spread (range) of the pattern improves, the marksman's score also improves. Once the pattern is centered, the score can only be improved by decreasing the spread. This normally takes resources (better rifle, ammunition, etc.) that normally takes management involvement.

3. Two Types of Variation

Quality specialists have identified two causes of variation or defects. They are called common cause and special cause. The source and remedies for each are different.

a) Common Cause Variation

Common cause variation or defects are caused by what can be thought of as a "sea of variables" that surround the process. They come together at times to produce a random, yet predictable variation.

It is generally accepted that common cause errors are "management controllable". In other words, management has the tools and resources needed to reduce and prevent these defects. They provide the direction and guidance to fix the problems.

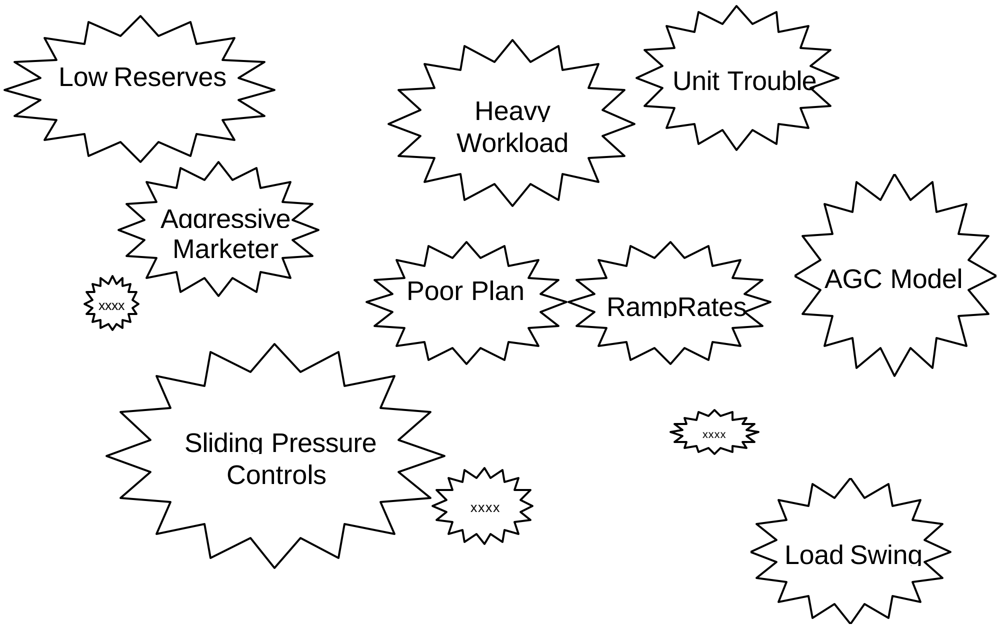

Figure 7 Sea of Variables

b) Special Cause Variation

Special cause defects occur when there is a significant change in the working environment or process. This is signaled by a measurable shift (either up or down) in the process. The people closest to the work can usually find and correct a special cause event.

Error Type	Sam	Fred	Bill	Sally	Kelly
A	1	2	1	0	0
B	0	3	1	0	0
C	2	4	2	2	0
D	1	3	0	1	0

Figure 8 Error Cause Example

A simple example can be used to clarify the common cause/special cause discussion. Figure 8 shows data a manager collected on her five employees (all do word processing). She identified four error types (A-D) and tabulated the number of mistakes each worker made.

One of the principles of process improvement is “management by fact”. Data is used to identify problems and point to possible solutions. A first glance of the table above might lead to the impression that Kelly should be given a raise, while Fred should be counseled on his poor performance. The manager should be careful.

Kelley and Fred are both “special cause” situations. Their performance is different, but why? Since this a special cause situation, the workers would likely be able to come up with the underlying reasons. Possible explanations could be:

- Kelly does little work or was on vacation during the rating period.
- Kelly is the only one with a spell-checker.
- Kelly has a knack or special skill (use Kelly to train others).
- Fred missed the training on the new word processing program.
- Fred does twice as much work as the others.

There are other things that can be learned from the data with a closer look. Figure 9 compares the data from two directions. Fred and Kelly are identified with a # to denote their special cause status. A review of the number of occurrences of error type C shows it is a problem to nearly everyone. There is a “common cause” that contributes to the group’ s problems.

Error Type	Sam	Fred	Bill	Sally	Kelly	Total
A	1	2	1	0	0	4
B	0	3	1	0	0	4
C	2	4	2	2	0	10 *
D	1	3	0	1	0	5
Total	4	12 #	4	3	0 #	23

Figure 9 Common Cause/Special Cause Example

The manager should spend her time working on a solution to problem C. This will pay the most dividends. Workers do have the responsibility to call management's attention to problems and to offer potential solutions, but supervisors have the underlying charge of providing resources and direction in removing common cause variation. But whether the situation is common cause or special cause, solid facts are needed to make informed decisions. Figure 10 summarizes the general responsibilities for process variation and improvement.

TYPE	IDENTIFIED BY	CAUSED BY	WHO’S RESPONSIBLE
Common Cause	Normal Variation	“Sea of Variables”	Management
Special Cause	Step Change or Trend	Change in Process	Workers

Figure 10 Defect Cause Summary

4. Process Improvement

A deck of cards can be used to explain the quality control concept of process variation and improvement. Assume the deck of cards represents the current operating environment for a particular company. The deck reflects the workload, employee experience, ramp rates, AGC tuning, etc. of the utility. One card is drawn each hour. The number of CPS2 violations that occur in that particular hour vary as follows:

♣--0 violations.	**Face Card**--Add one violation.
♦ --1 violation.	**Ace**--Add two violations.

♥--2 violations. **Deuce**--Add three violations.

♠--3 violations.

A quick calculation shows a standard deck contains 110 violations. The average number of violations that occur from a draw would be 2.1. This company could expect 50 violations/day. It is possible to get more or fewer violations with 24 hourly draws, but the average over many days with the same deck would be 50.

Quality specialists have shown that we are not forced to accept a particular level of performance. The idea behind process improvement is to continually find ways to better the job performance. Many small enhancements over time will keep increasing the process performance.

Going back to the deck of cards, a process improvement is the equivalent of pulling out one or two "bad" cards (♠,♥) and substituting better cards(♦ ,♣). Even if 5 or 6 improvements were made to the deck, it is still possible to draw 24 cards over a day and come up with 50 or more violations. However, over time, there would be fewer and fewer violations seen by following continuous improvements. You might have a few bad draws in a row, but the deck is improved. Performance will improve.

Quality specialist have developed charts that track a process over time and "raise a red flag" when a significant change has occurred. These SPC charts are described in most quality control texts. A detailed explanation is beyond the scope of this paper. It is enough to say that these charts can detect when such a condition arises.

B. STATISTICAL PROCESS CONTROL CHARTS

Control charts can track two types of variables (continuous and attributes). Continuous variables have a range of possible values. Voltage and CPS1 are examples of continuous variables. Attributes are yes-no, good-bad situations. A CPS2 period contains an attribute. There is either a violation or there is not. The type of control chart used is determined by the type of variable.

Control charts flag changes in average and range. The charts force investigation of problems. They also tell the operator when to keep their hands off (over-control). If operators could be notified on an out-of-control condition, data could be collected . Information such as load ramp rate, schedule changes, units on regulation, etc. would point to real problems and possible solutions . These "High Spot Reports" would provide valuable information on the state of the process. The major contributors to violations could be found and corrected.

SPC Charts are based on relatively simple calculations. This could be done directly by Energy Management Systems (EMS) or by statistical/QC software packages. Several software packages are available to construct these charts. "Minitab" is an example that was used in this paper.

SPC Charts have two primary purposes. First they tell the present health of the process. The process is in-control if variation is similar to what has occurred in the recorded past. In such cases, operator intervention is of little value.

The second use of an SPC chart is to tell when a process goes out of control. The chart signals a significant change. In most cases, the operator can find and correct the cause. Information gathered in these situations can give clues into how to make the process better.

The other reason for employing SPC charts is to track a process as potential improvements are made. Ideally, a company identifies the major contributors to poor performance. It applies some effort to the greatest problem. If the process improves (as demonstrated on the SPC chart) the company moves on to the next major contributor. The procedure is repeated theoretically forever.

1. CPS1 Charts

a) *"Individuals" Chart*

An SPC *Individuals* chart could be used for real-time operation and process improvement. If the CPS performance is OK and the process is "in control", the operator should not interfere. If the process goes out of control, intervention is needed and information should be collected. Figures 11, 12, 13, and 14 show the CPS1 performance for an Eastern Interconnection company for hours 1, 2, 3 and 15 through part of hour 17 respectively.

The Upper Control Limit (UCL) and Lower Control Limit (LCL) on the charts designate the range of normal operation (+/- 3 standard deviations from the mean). There is a less than 1% chance of the process being outside these limits by chance. There has to be a reason if the process goes beyond them.

There were several points in Figures 11-14 where the process was not in control. An individuals chart can do several tests for significant variation. Points flagged with a "1" on the chart show where there is an observation > 3 standard deviations from the mean. The other number points are basically flags showing long runs on one side of the mean. These are also significant.

Significant variation on the high side of the chart should be analyzed to identify why performance is better than the average. This can lend clues to process improvement if the contributors to the event can be sustained. Problems on the lower side of the chart should be identified to find problems that need to be rooted out.

CPS problems at the beginning of hours are quite likely due to large schedule changes. The SPC charts can ultimately lend clues to how large of ramps a control area can handle.

If a unit should trip, CPS1 performance might actually go extremely high. If frequency were initially >60, a unit trip would cause good CPS1 (but not CPS2) performance. If the unit were large enough to drag system frequency down, CPS1 performance would then go down the tubes. This may be what happened around 1600 on Figure 14.

If a company had significant control problems, they might start by only testing for the extreme "type 1" violations. Once they brought these into line, they could start including the more sensitive tests.

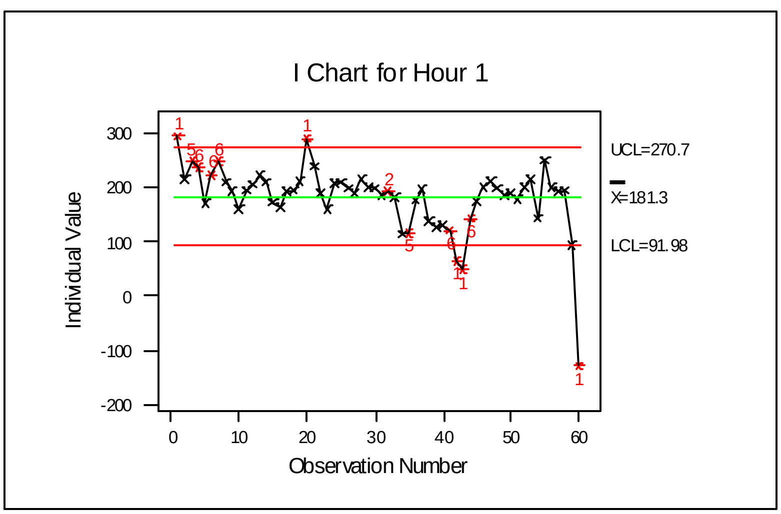

Figure 11 CPS1 Performance-Hour 1

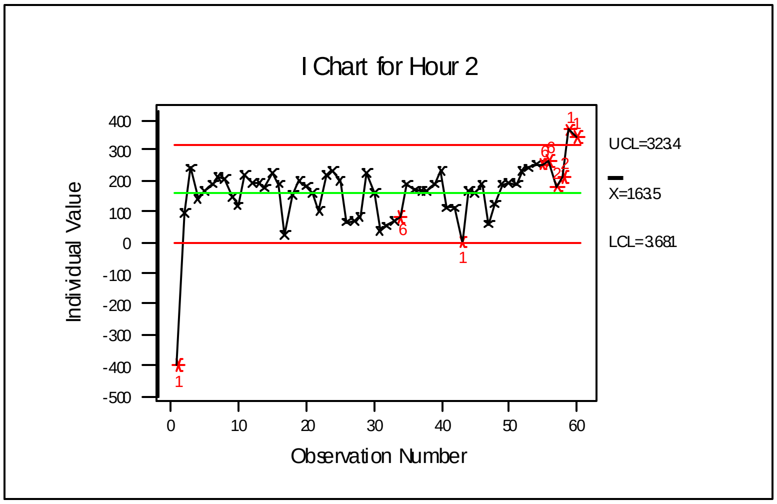

Figure 12 CPS1 Performance-Hour 2

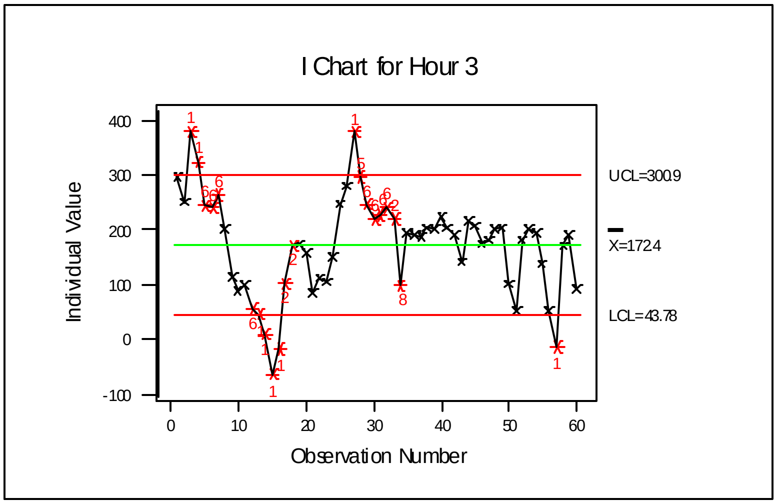

Figure 13 CPS1 Performance-Hour 3

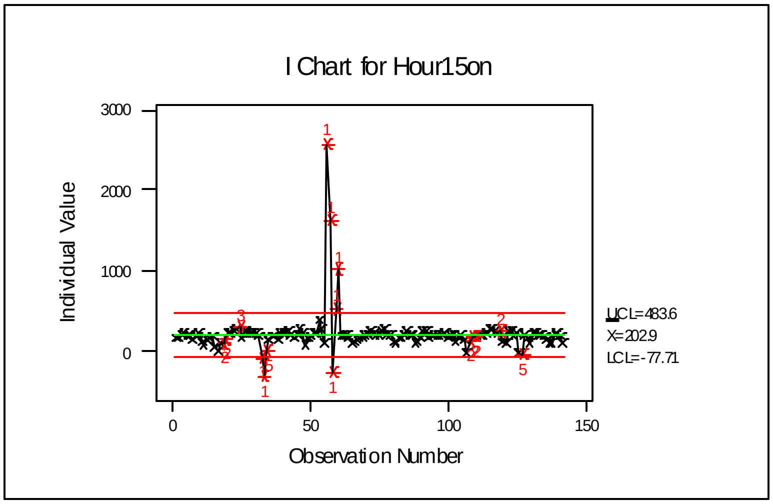

Figure 14 CPS1 Performance-Hours 15/16+

b) X-Bar and R Charts

Another SPC option is to group several minutes together into subsets and look at larger blocks of time. This would also allow the use of a more powerful SPC tool, X-bar and R charts. These two charts are used in tandem. The X-bar (average) chart is much like the individuals chart. The added R (range) chart plots the "spread" of the samples taken.

An X-bar R chart combination tells whether a process' mean, dispersion or both have changed. This information can point to the underlying cause of the problem. Quality control references[1] give suggestions on what is occurring based on the X and R patterns observed.

Figure 15 looks at an X-bar R chart set for groups of 10-one minute CPS1 values for the same company for January 27. There are fewer "out of control" situations. These, however, are the most significant. They would be the first ones that should be investigated.

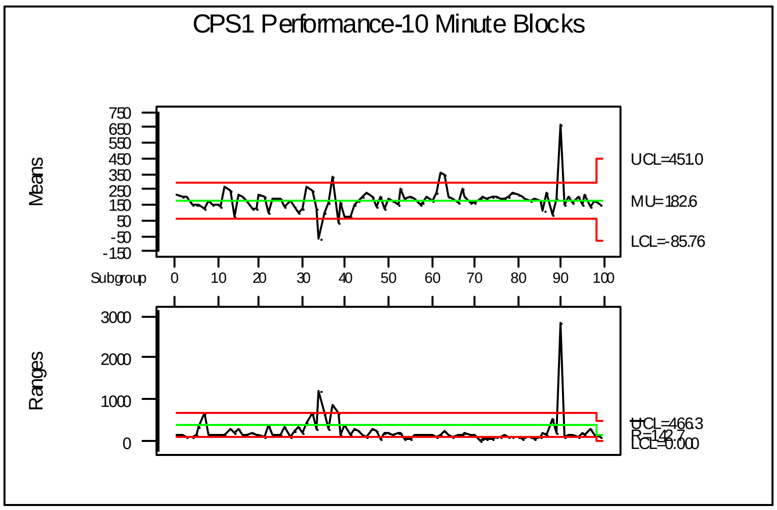

Figure 15 X-Bar and R Charts for January 27

2. CPS2 Chart

Although it is possible to track CPS2 via control charts, it probably isn't needed. CPS 1 data seems the most appropriate measure to track via SPC for real time and short term applications. CPS2 can only vary between 0-6 for each hour. Macro-analysis (daily, weekly) is possible for CPS2, but it is likely redundant. Seeing a large ACE value for an extended period causes a CPS2 violation, it will be picked up by tracking CPS1.

[1] Grant & Leavenworth, "Statistical Quality Control" pp. 100-103