

Automated CVR Protocol No. 1

Primary Sector and End-Use:

Electric utility distribution feeders and substations feeding residential, commercial and industrial customers; large industrial or commercial customers that have the ability to implement automated conservation voltage regulation (CVR) within their facility.

Application Specifications:

This method applies to automatic CVR systems. These automated systems can be turned on and off on a daily basis, have the voltage set-points changed on a daily basis, have the ability to measure and record period average bus and end-of-line voltages, period kWh, period kVARh on a per feeder basis and measure and record period average temperature. The method is applicable where no previous energy usage information is available

The ideal application would be where the automatic CVR control components could also monitor and store the period data.

Method Description:

Primary Method

The primary method of verifying energy savings is to operate the system in such a way as to operate at different voltage levels on alternating days. The initial verification period would last one year. The verification would begin with 90 days or three months of one day at full voltage reduction, one day with voltage set at the controlled nominal midpoint above full reduction and one day of open loop (automated CVR off). During the next 9 months the automated CVR would be on continuously. Three out of these nine months would be selected based on season and other factors such as geographic weather patterns etc., to operate the system so that on alternate days the system is at full voltage reduction, and the next day at the controlled nominal midpoint.

Time series analysis procedures, robust statistical methods, and temperature compensation methods are then used to evaluate the total energy conservation by comparing energy use on similar days at different voltage levels. For instance, winter weekdays would be compared against winter weekdays, summer weekdays against summer weekdays, etc. Conservation voltage regulation factors (CVRf) then computed for each feeder the different seasons for weekdays and for weekends.

CVRfs are used to estimate total ongoing energy conservation. CVRfs are verified during similar periods in following periods by running alternating days with full end of line voltage reduction and 2 volts above full end of line voltage reduction for two to four week periods.

Program Savings

The program savings are estimated by using the following definition:

$$E_{\text{saved}} = E_{\text{used}} [(CVRf * Vr\%)/(1 - CVRf * Vr\%)]$$

In which:

E_{saved} = Energy Conserved for period in kWh, MWh or GWh

E_{used} = Measured Energy used for period in kWh, MWh or GWh

CVRf = Period conservation voltage reduction factor as computed using time series analysis and robust statistical methods with temperature compensation for specific seasons. CVRf will be different for weekday and weekend. (See estimation method below.)

V_r = Average period end of line voltage reduction

$V_r\%$ = Average period end of line voltage reduction in percent

V_{oc} = measured average end of line voltage with automated CVR non operational

V_{cvr} = measured average end of line voltage with automated CVR operational

$V_r = V_{oc} - V_{cvr}$

$V_r\% = V_r/V_{oc} * 100$

CVRf Estimation (applies to the performance evaluation period)

Integrated demand profiles, one each for the automated CVR system active and inactive, are estimated on a common ambient temperature basis using the UtiliData CVR Estimation Method (“Estimation of Automated CVR System Performance Using Observed Energy Demand Load Profiles”); the 24-hour sum of the difference between these profiles is the estimated conserved energy for the evaluation. The mean difference of the end of circuit voltages for the automated CVR system active and inactive is estimated. The CVRf is then determined from the ratio of these two quantities, and can be expressed on an absolute or per unit basis (the per unit basis is recommended).

Recognizing (1) the stochastic nature of the energy observations as discussed in the UtiliData CVR Estimation Method, (2) the requirement to evaluate the performance of candidate automated CVR systems using the smallest (least duration) set of energy observations, and (3) that the probability densities of the relevant observations clearly exhibit non-homogeneous variance and are also clearly not Gaussian processes, the required estimations should be carried out using robust statistical procedures. Specifically, the Minimum Covariance Determinant estimators should be applied, because (1) their breakdown point is high and (2) they do not require that the observations exhibit a symmetrical probability density.

Automated CVR Performance Forecasting

The UtiliData CVR Estimation Method referenced above, estimates CVR using the observations of the automated CVR system inactive state as a reference. In principle, forecasting for a given circuit then simply requires a base demand profile, a projected end of circuit voltage reduction, and the estimation results from the evaluation period.

Special Considerations:

Temperature

Correct temperature data is essential to the accurate use of this verification method. It is recommended that the automated CVR system records period temperatures at the substation. Because the substation is usually at the geographic center of the area served this temperature will usually suffice. However, if significant microclimates are known to exist, temperature monitoring and recording may also be required at the feeder end-of-line location, so that an average temperature for the feeder may be obtained.

Metering and Data

Data recording periods should be no greater than one hour, and can be as short as the system allows. Weather data should be collected on the same time period as the load data. Data collected is subject to audit.

Instrumentation

Voltage monitors should have linearity of better than ½% within the expected ranges of voltage and temperature drift should be less than ½% from -40 degrees C to 65 degrees C. Power monitors should be revenue grade accuracy but need not be revenue class.

Shop Calibration and Field Verification

Instruments and meters should be shop calibrated. Field verification and inspections are required to verify correct installation and correct readings.

Baseline

The baseline voltage levels are established by the historical regulator or LTC control settings. One or more years of historical regulator or LTC setting information should be made part of the verification data records.

Re-verification Triggers

Re-verification will be required when there is a +/- 10% shift in temperature adjusted total annual load, a +/-10% shift in temperature adjusted total load during heating regime hours, a +/-10% shift in temperature adjusted total load during cooling regime hours, or a permanent reconfiguring of the distribution system (not including re-conductoring, transformer replacement, capacitor banks, or other distribution system efficiency project).

If re-verification is triggered by a shift in the loads during heating or cooling regimes, the re-verification protocol will consist of one sixty day period during either the heating or cooling period. If re-verification is triggered by a shift in total annual load or a permanent re-configuration the re-verification protocol will consist of two sixty day periods, one in the heating period and one in the cooling period. During the re-verification periods the system will alternate daily, operating one day at full voltage reduction and the next day at the controlled nominal midpoint.

The new CVRfs determined by these re-verifications will be used in lieu of the original CVRfs.

Model

The current model used for the time series analysis includes compensation for temperature. There are a number of additional factors that affect energy use and could be added to the model. Addition of these factors will tend to improve the predictive accuracy and reduce “outlier” data points. Factors that may be considered for inclusion in the model in the future will include daylight and dark hours, solar intensity, day of week, humidity, etc.

Adding any or all of these to the model should not change the basic measurement and verification protocol.

Control Group:

No control group required because with on-off and variable voltage set point capability, the application group can act as its own control group during testing periods.

Recommended Models and Tools:

UtiliData Automated CVR Estimation Method Tools

MatLab® (©1994-2003 by the MathWorks, Inc.) tools are available from PCS UtiliData to use with this protocol.

References:

1. Rousseeuw, P J, Leroy AM, 'Robust Regression and Outlier Detection', Wiley 1987.
2. Rousseeuw, P J, 'Introduction to Positive Breakdown Methods', in Handbook of Statistics, Volume 15: Robust Inference, editors G S Maddala and C R Rao, Elsevier 1997.
3. "Estimation of Automated CVR System Performance using Observed Energy Demand Profiles", David Bell, March 15, 2004. (available at www.pcsutilidata.com)