

Communication Reliability Improvements through Measurement and Verification of Demand Response Programs

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Abstract

Measurement and Verification (M&V) processes and tools are the means for assessing the effectiveness of demand response programs. These processes and tools are continually adapted to extract greater information from M&V data. M&V analysis for demand response programs involves much more than simply analyzing load profile data. Load profile data analysis does yield insight into the load usage in the sample however it is also important to understand the communication networks used to communicate to devices in the field. In order to make accurate estimates of curtailed load, we must also be able to estimate the reliability of the curtailment message reception. This paper details the analyses and methods used to improve the communication of demand response or curtailment signals in order to maximize load reduction results. This paper focuses on four areas of analysis used to improve communication reliability and therefore load reduction results. First, communication studies include tests of the paging system over time to look for intermittent communications, hardware malfunctions or other anomalous data. Geographic analysis uses maps to determine if there are any geographic dependencies in the communication system. External antenna deployment studies seek to improve communication in intermittent areas while maintaining a balance between the M&V sample and the population at large. Finally, paging simulations and tower to site profile analyses aid in planning new projects and taking a detailed look at poor communicating sites. In coordination, these methodologies have improved year to year reception performance by as much as 10%.

Introduction

Demand response programs may utilize a variety of communication channels. Paging networks, cellular networks, home phone lines, or meter readers may be used obtain load data from meters in the field. Here we will focus of the use of paging networks to communicate curtailment messages to devices installed at residential or small commercial sites. The communication analyses presented here will be most beneficial for such a communication infrastructure since paging reception rates may be hard to predict. Most load curtailment or real time pricing programs use paging systems to send a message to thermostats or digital control units to control load usage or send the user a notification. The success or level of load reduction achieved by these programs is highly dependent on the reception reliability to enrolled participants. Paging reception may be dependent on a number of different factors. These include distance to paging tower(s), local geography, or environmental conditions. In a residential or small commercial program with one-way communications, a randomly selected sample is often used to measure load savings from the demand response program. Meters are placed on these sampled sites and the results are aggregated to represent the full program. These sampled sites will also provide an idea of how reliable paging reception is across the full program. Detailed analysis of the paging reception at these sites can provide key pieces of information for improving the operation, efficiency, and load reduction amounts of demand response programs.

In order to understand the reception reliability of such a demand response paging system, a number of important analyses can be conducted. These analyses include the use of daily monitoring tests, installation verification and quality control, external antenna studies, paging simulation, and

tower to site profile analyses. This paper details how each of these plays a key role in improving the demand response system reliability.

The analyses described in this paper use advanced mapping and topographical software packages to understand geographic effects on communication reliability. Additional data is gathered through specific paging studies. These studies involve testing message reception by time of day, using different paging transmitters, and through quality control checks of hardware equipment.

The detailed study of communication data in a demand response system is critical to providing accurate load reduction results. Furthermore, it is necessary to determine weaknesses in the system's communication reliability. Pinpointing any communication problems allows for a targeted improvement on the system as a whole. These targeted improvements lead directly to higher load reductions at the time of curtailment.

Communication Studies

Demand Response programs play a key role in delivering emergency capacity and also are used for economic dispatch. Figure 1 shows the load profile in New England on August 2, 2006 where demand response programs played a key role in flattening out the peak. Residential air conditioning curtailment programs alone supplied 60 Megawatts of capacity reduction during this peak period. Communication reliability plays a key role in planning and operating such a program. For example, if the intention was to provide 60 MW of installed demand response capacity but there was only 85% communication reliability, over 70 MW of installed capacity would need to be available. Therefore, efforts to improve communication reliability can directly lead to cost savings regarding marketing, equipment, and installations. Generally we would expect a demand response program to have at least a 70% reception rate to be cost effective. Any reception rate less than that would likely lead to using an alternative communication methodology or simply not having such a program in that area.

Testing communication reliability at sites before enrollment can be done to some extent using a spectrum analyzer. This device will show paging strength before installing the necessary equipment. Unfortunately, this method of testing is not foolproof. Many sites may have intermittent communications. Additionally, when customers are initially recruited into a demand response program, it is not known how reliable communications will be at their location.

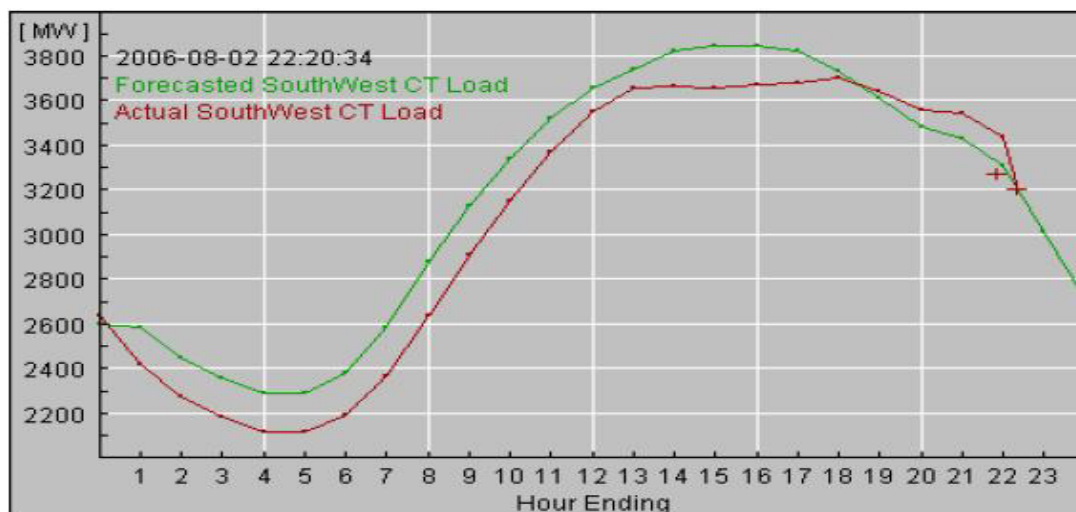


Figure 1
Southwest Connecticut Load Usage, August 2, 2006

Once a participating population has the curtailment devices installed and the M&V sampled sites are selected, proper data collection is the key toward program improvement. For a demand response program where digital control units are used, daily nicking tests are important for collecting communication reliability data. These tests involve sending a signal to the digital control unit and receiving verification back from a gateway device which confirms the signal's receipt. By conducting this test daily a number of important pieces of information can be collected. First, we will be able to determine the reception percentage on a day to day basis. Second, by looking at the data over time, we can detect M&V hardware malfunctions, paging tower problems, or geographic regions with intermittent reception. The cost of running daily tests is generally small since the additional paging is relatively small compared to the size of most paging plans. However, there must be staff available to initiate the tests and analyze data. The gains in program improvement however may be significant. For example, the detection of a temporarily inoperable paging tower may effect a large percentage of enrolled participants and therefore a large percentage of potential load savings. Early detection can lead to the problem resolution before an emergency event needs to be called (Hess, 1997).

Geographic Analysis

Figure 2 shows an example of a map with M&V locations plotted. In this case, the blue sites represent a comparison group while the yellow sites represent a curtailed group. The dots in each square indicate the number of pages received from the last paging test. In this example a single page was sent out as a test so the presence of a red dot indicates a successful test at that site. This type of analysis will often immediately make evident any geographic problems related to paging tower difficulties. If a paging tower had gone down, this type of map would show an entire region of sites that had not received the page. By detecting such a problem early, actions can be taken before an emergency event needs to be called. Other problems that may become evident through the use of this type of map include paging interference from other paging towers in the area. Sites that are between multiple paging towers may be susceptible to interference and therefore may have poor reception. By adjusting the timing of when pages are emitted from each tower, this interference can be minimized over the population as a whole; however it can not necessarily be eliminated for all sites.

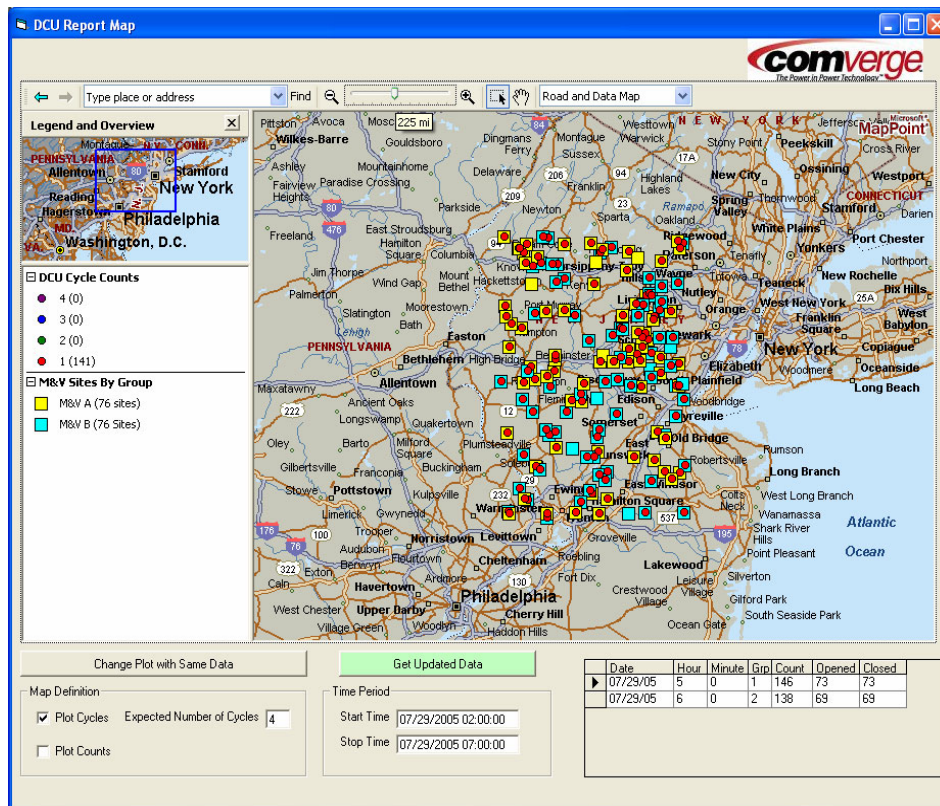


Figure 2
Communication Reception Mapping

External Antenna Deployments

When limited or no reception is detected at a site, there are a number of actions that may be taken to improve receptivity. This may include repositioning the installed equipment in the home or business or acquiring another paging transmitter. Another approach may be to install an external antenna on the digital control unit. External antennas have been shown to increase paging receptivity especially on sites that receive pages intermittently. However, if we simply installed these antennas on M&V sites, the sample would not be a true representation of the installed population which does not have these antennas installed. A key question of external antenna deployments is: How can we install the antennas in the general population in a fair and balanced manner?

First, we may begin with the assumption that intermittent reception is largely due to geographic location. Often inspectors can check whether the reception problems are hardware related before proceeding with external antenna deployments. If geographic location is the problem, it is fair to assume that M&V sites with poor reception will be in the vicinity of generally enrolled sites with the same problem. It is then possible to send a signal out to all sites which sets a counter at 0 and increments for every page received. If inspectors then go visit field units and read the counters, we can determine the level of reliability at generally enrolled sites. The field visits can be expensive for a big program so these inspection may begin with sites closest to the poor performing M&V sites and emanate outwards until a large portion of all tested sites have high reliability. The map in Figure 3 shows areas of installed units surrounding an M&V site with poor reception that were checked for paging receptivity. In this example, 1 page was sent every hour for over 100 hours to test paging reception.

An external antenna was installed at any site that had reception levels below 95%. The blue sites represent sites that were checked but had high paging receptivity while the red sites had low receptivity and therefore had an external antenna installed. The yellow sites represent M&V sites with poor paging reception. The cluster of red sites in the northwest corner of the map suggests that that geographic area generally has poor paging reception. In the other areas however, the M&V sites with poor reception were very sparsely surrounded by other poor reception sites, suggesting the problem was not geographic in nature. In fact, the general population was found to have received up to 5% more pages than the M&V units. A possible explanation of this could be interference from the M&V equipment.

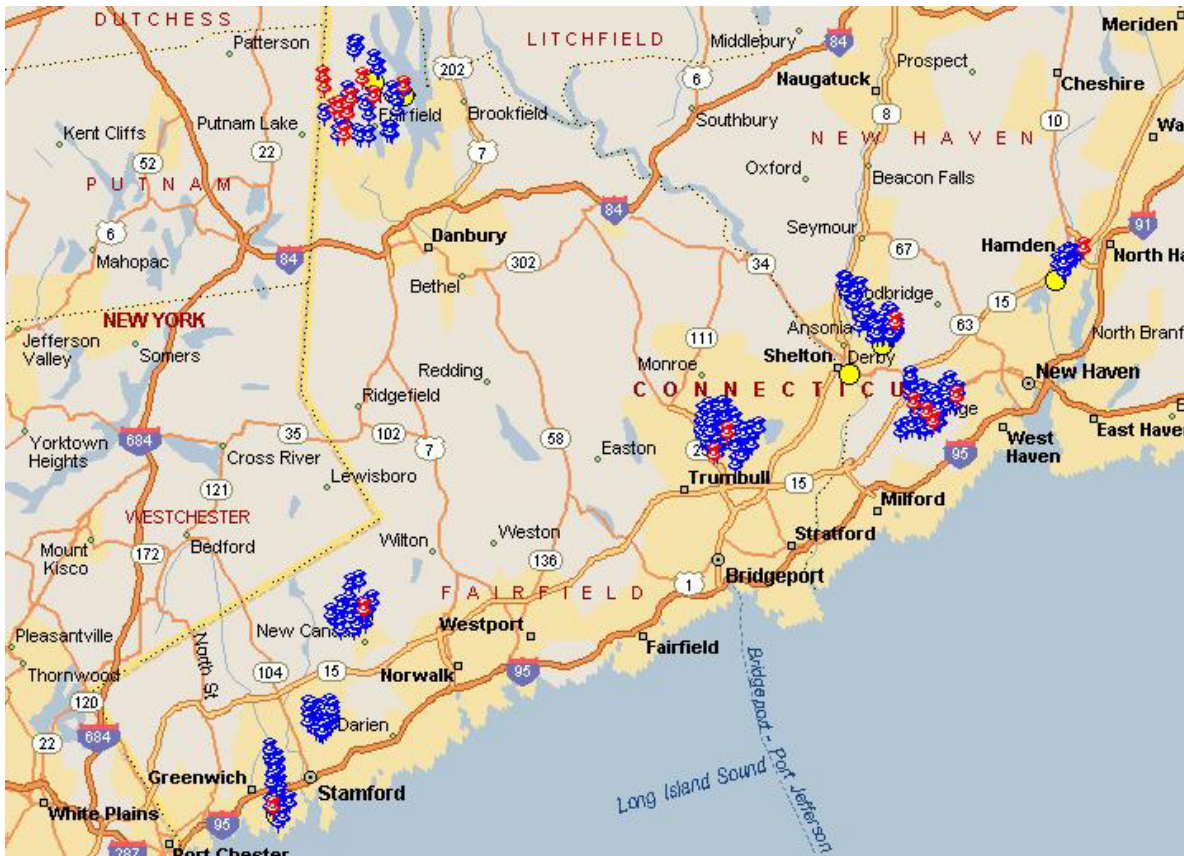


Figure 3
External Antenna Deployment Testing

Figures 4 and 5 show what the DCU installations look like before and after the installation of the external antenna. External antenna costs are not significant compared to the benefit from the increased communication however there are also labor costs involved in their installations. If the target area for the antennas is across a small geographic region the more antennas may be installed per hour than if the region is large.



Figure 4
Digital Control Unit, Meter, and Gateway



Figure 5
Digital Control Unit with External Antenna

Paging Simulations and Tower to Site Profile Analyses

Other tools that can lead to increased paging receptivity include paging simulations and tower to site profile analyses. Figure 6 below shows a simulated paging scenario in the Salt Lake City region. The green areas represent areas of high receptivity while the red represents areas of low receptivity. The simulation is based on simulated settings at the various paging towers that are being used for the demand response program. These simulations can allow the user to adjust paging tower settings to try to obtain optimal reception performance based on the installed populations' geographic location.

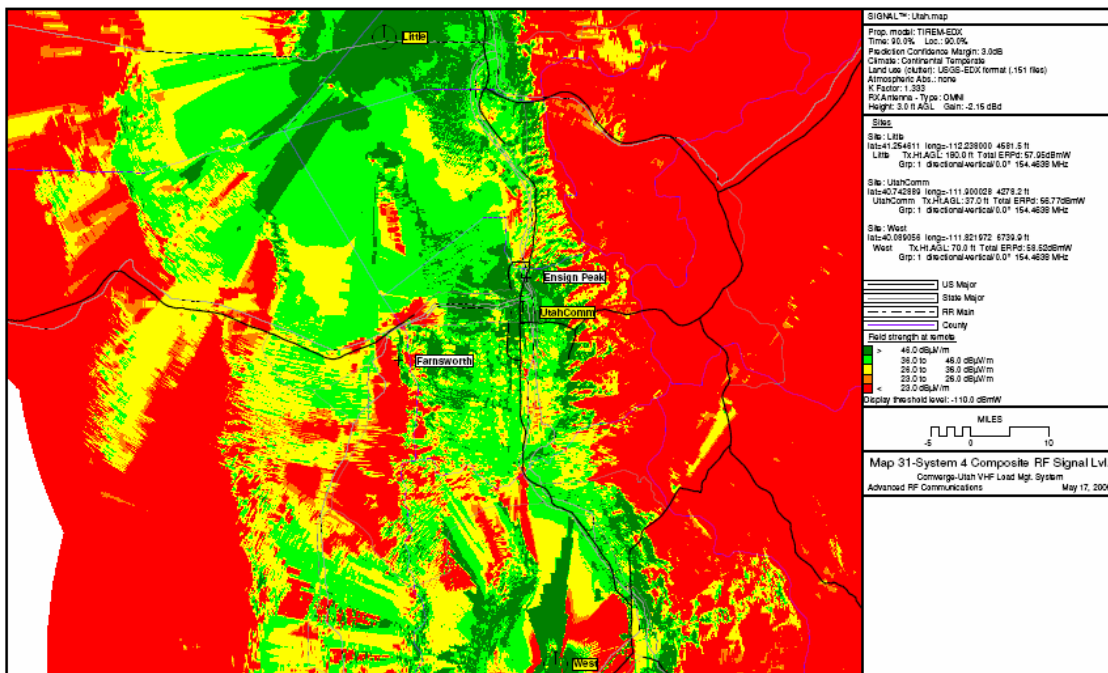
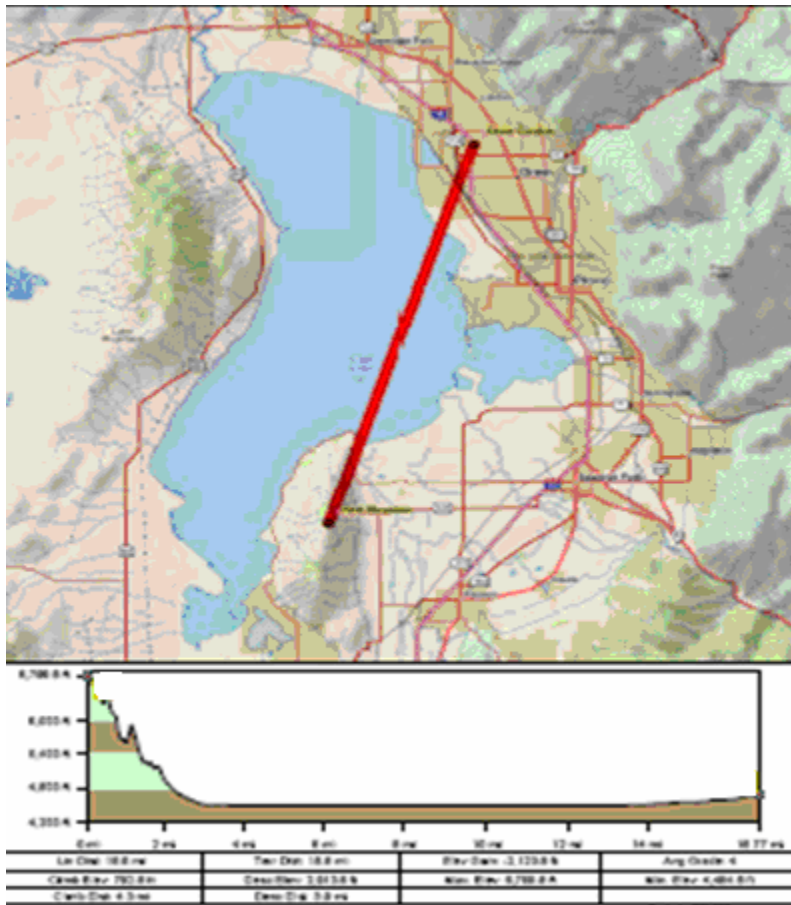


Figure 6
Paging Simulation

Another important mapping tool involves looking at the geographic profile between a paging tower and a site which must receive the paging signal. Figure 7 shows a profile with a tower located at a high elevation and a site at a low elevation with no obstructions in between. Figure 8 shows another similar example with a 2-D map over the profile.

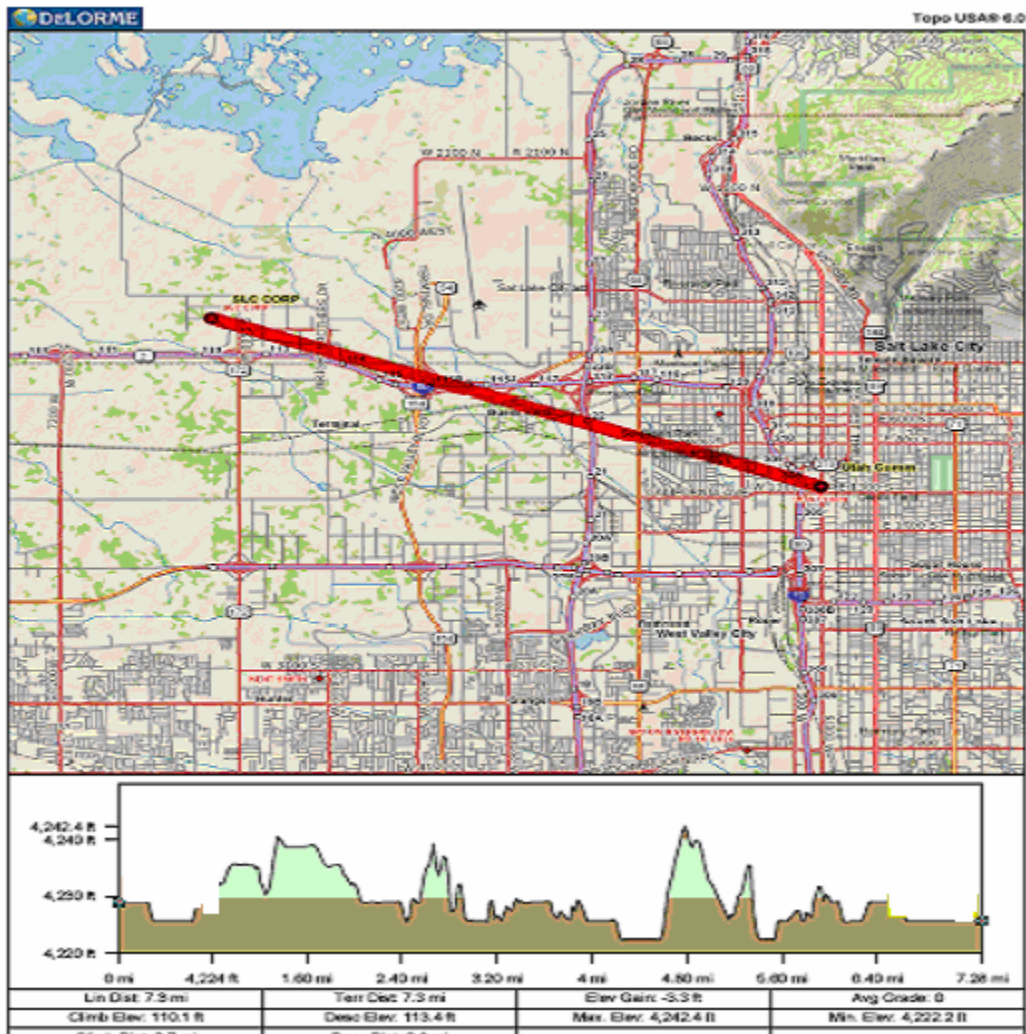


Figure 7
Tower to Site Profile



*Figure 8
Tower to Site Profile with 2-D Map*

Figure 9 shows an example of a site that is obstructed from the nearest paging tower. For a site such as this one, it may be difficult to improve paging reception unless another paging tower could be accessed. The tower to profile analysis is a useful tool particularly when examining a sample of M&V sites where no other clear explanation exists for poor receptivity.



*Figure 9
Tower to Site Profile with Hill Obstruction*

Conclusions

The success of a demand response program is often measured by the amount of load reduction it can provide. In order to provide load reduction capacity as efficiently as possible, it is important to that the communication systems have high levels of reliability. A program using paging communication would generally be considered highly reliable when over 90% of units receive messages regularly. Of course, different geographic regions will have different reliability expectations depending on the paging network and contours of the land. In order to optimize this reliability, there must be a methodology in place for data collection and analysis before the program starts. For the example described in this paper, digital control units are tested daily on an M&V sample set. Daily nicking tests are used to determine which units respond perfectly, intermittently, or not at all. Unresponsive sites may be investigated further for hardware failure or problems due to their geographic location. Intermittent sites may improve performance using an external antenna however external antenna usage on M&V sites must mirror their usage on the generally installed population.

These studies have led to over 10% improvement in communication reliability on a year to year basis. This reliability improvement can translate up to a 10% improvement in load reduction provided depending on the curtailment strategy being used. In turn, this increased effectiveness leads to cost savings since fewer customers need to be recruited to obtain particular MW levels.

References

Connecticut Valley Exchange (2006). <http://www.cvx.com/>.

Hess, G. (1997) Handbook of Land-Mobile Radio System Coverage, Artech House