Understanding the Energy Saving Potential of Voltage Management.

How does Legend Power's SmartGATE™ system save energy by managing overvoltage?

Reduced energy consumption and improved power quality can be achieved by actively managing voltage during times when a facility's supplied voltage is higher than nominal.

When installed in a facility, Legend Power's SmartGATE™ system monitors the incoming voltage from the grid, identifies instances of overvoltage, and in real-time, reduces the voltage of the entire facility to produce a power and energy reduction.

The Problem:

Electrical distribution systems in North America are designed around a common set of voltage standards to ensure reliable operation of all electrical equipment within connected buildings. In the United States, voltage levels are dictated by ANSI C84.1-2011[1]. This standard outlines voltage levels and tolerances for electrical distribution systems for commercial and residential buildings for 120V to 600V electrical systems.

Though nominal voltage levels are prescribed for each facility, the standard allows for a wide window of operation. On a typical 480V 3 phase commercial feed, the standard allows voltage to fluctuate by +- 5% (456V – 504V) during normal operation, as measured at the service entrance of the facility.

Controlling the voltage to a fine level at every facility is extremely challenging due to the layout of typical electrical grids. Since substations and feeders often supply a large number of buildings, a compromised voltage level that balances the needs of multiple buildings is typically deployed. Voltage supplied to a particular facility is rarely static; changing daily, weekly, and seasonally as conditions on the electrical grid change. As a result, all facilities experience higher than nominal voltage supply at times. Reduced energy consumption and improved power quality can be achieved by actively managing voltage during times when a facility's supplied voltage is higher than nominal.

The relationship between managing voltage and saving energy is well established in industry and within the academic community. Numerous studies from the US Department of Energy[2], New York University[3], and Con Edison[4] have shown that reducing system voltage results in substantial, power and energy reductions.

Legend Power's Solution:

Legend Power's SmartGATE™ system monitors and controls voltage coming into a facility at a 3 phase 480V level. The system consists of a high-efficiency autotransformer paired with a controller that can produce a voltage reduction of up to 8%. When installed in a facility, the product monitors the incoming voltage from the grid, identifies instances of high voltage, and in real-time reduces the voltage of the entire facility to produce a power and energy reduction.

The SmartGATE™ system always keeps the facility well within the guidelines established by ANSI C84.1-2011. The system includes the ability to produce no voltage reduction if the incoming voltage as supplied by the grid is temporarily too low to support a reduction.

How much energy can be saved?

Every facility has the potential to save both energy and its associated costs by managing voltage. Legend Power's SmartGATE™ will always produce a reduction in power and energy once installed. In order to fully understand the mechanism of energy savings, it is useful to review a load model and example.

The electrical load of a commercial building is difficult to measure at a fine level because it is comprised of many individual points of use that are constantly changing with weather, season and building use. A useful model for analyzing a building's electrical load is a 3-part ZIP model[5]. This model views static electrical loads as being comprised of 3 components: constant impedance (*Z*), constant current (*I*) and constant power (*P*). The ZIP model provides a convenient mechanism for analyzing a load's power variation in response to varying voltage.

In practical application, no individual load in a facility is entirely comprised of one component, but each load can be viewed as a linear combination of the 3 components. Within the same paradigm, an entire building can be viewed as a complex combination of multi-component loads and therefore modeled in the same way. By analyzing the response of each of these load types to a voltage reduction using basic circuit analysis techniques, the mechanism of how an entire building will save power and energy can be understood.

Every **facility has the potential to save both energy and its associated costs by managing overvoltage. Legend Power's SmartGATE™ system will always produce a reduction in power and energy once installed.**

Circuit Example Illustration:

A circuit example can be used to illustrate the mechanism by which voltage management leads to power and energy reductions. For simplicity, a 120V base system will be discussed which is commonly derived from a 3 phase 480V system. Consider a system supplied with122V from the grid with 3 loads (Figure1):

1. Z - Constant impedance of 150 Ω
2. I - Constant current of 1A
3. P - Constant power of 100W

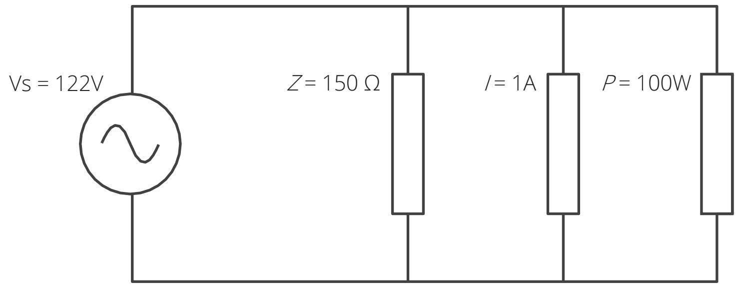

figure 1 - example circuit

The total power is given by: $P_{total} = P_1 + P_2 + P_3$ where P_1 represents power for *Z*, P_2 represents power for *I*, and P_3 represents power for *P* (a fixed constant of 100W). With 122V supply solving for P_1, P_2 and P_3 yields:

$$P_1 = \frac{V^2}{Z}$$

$$P_1 = \frac{122^2}{150}$$

$$P_1 = 99.2W$$

$$P_2 = VI$$

$$P_2 = 122 * 1$$

$$P_2 = 122W$$

$$P_{total} = P_1 + P_2 + P_3$$

$$P_{total} = 99.2 + 122 + 100$$

$$P_{total} = 321.2W$$

Therefore, the total load at grid supplied voltage of 122V is 321.2W.

With a Legend Power product installed, the voltage is reduced by 8% for an incoming grid voltage of 122V. The voltage to the load is now 112.2V. Note both 122V and 112.2V are well within the range of 110V to 126V established by ANSI C84.1-2011. Solving for P_{VM1}, P_{VM2} and P_{VM3} where P_{VM1} represents power for *Z*, P_{VM2} represents power for *I*, and P_{VM3} represents power for *P* (a fixed constant of 100W) under reduced voltage. Using the same equations and methodology as previously shown:

$$P_{VM1} = \frac{V^2}{Z}$$

$$P_{VM1} = \frac{112.2^2}{150}$$

$$P_{VM1} = 83.9W$$

$$P_{VM2} = VI$$

$$P_{VM2} = 112.2 * 1$$

$$P_{VM2} = 112.2W$$

$$P_{totalVM} = P_{VM1} + P_{VM2} + P_{VM3}$$

$$P_{totalVM} = 83.9 + 112.2 + 100$$

$$P_{totalVM} = 296.1W$$

Therefore, the total load at grid supplied voltage of 122V is 296.1W with a Legend Power product operating with voltage management at maximum 8%.

The difference in power between grid supplied condition and the Legend Power product can be expressed as:

$$P_{reduction\%} = \frac{(P_{total} - P_{totalVM})}{P_{total}}$$

$$P_{reduction\%} = \frac{(321.2 - 296.1)}{321.2}$$

$$P_{reduction\%} = \frac{(25.1)}{321.2}$$

$$P_{reduction\%} = 7.8\%$$

Resulting Savings:

Therefore, in this example there is a power and energy reduction of 7.8% with a voltage reduction of 8%.

The above example illustrates the mechanism for achieving real and significant power and energy savings in a commercial building.

Find out how much money your building can save on electricity by contacting us today at 1.866.772.8797 or savings@legendpower.com.

[1] C84.1-2011 – "American National Standard For Electric Power Systems and Equipment — Voltage Ratings (60 Hertz)"

[2] KP Schneider, FK Tuffner, JC Fuller, R Singh – U.S. Department of Energy - PNNL-19596 "Evaluation of Conservation Voltage Reduction (CVR) on a National Level", July 2010

[3] Marc Diaz-Aguiló, Julien Sandraz, Richard Macwan, Francisco de León, Senior Member, IEEE, Dariusz Czarkowski, Member, IEEE, Christopher Comack, Member, IEEE, and David Wang, Senior Member, IEEE, 2013,'Field-Validated Load Model for the Analysis of CVR in Distribution Secondary Networks: Energy Conservation', IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 28, NO. 4, pages 2428-2436

[4] D. Kirshner, "Implementation of conservation voltage reduction at commonwealth Edison," IEEE Trans. Power Syst., vol. 5, no. 4, pp. 1178–1182, May 1990.

[5] A. Bokhari, A. Alkan, A. Sharma, R. Dogan, M. Diaz-Aguilo, F. de León, D. Czarkowski, Z. Zabar, A. Noel, and R. Uosef, "Experimental determination of ZIP coefficients for Modern Residential, Commercial and Industrial Loads," IEEE Trans. Power Del., IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 29, NO. 3, JUNE 2014