GUIDELINE: GUIDELINE HOW TO CREATE A CONSUMPTION BASELINE

Abstract

The following text provides guidance on various methods for reference consumption definitions, which can be used for the calculation of the demand response adaptations. These methods are based on calculation of the baseline consumption or production. The guideline differentiates the approaches for specific types of users in given circumstances and describes pros and cons of the various concepts. The guideline is intended for demand response service providers (e.g. aggregators, suppliers, researchers). It is a required that the reader is familiar with energy monitoring.

What is it?

The main purpose of this guideline is providing you with an overview of different methods and their pros and cons with respect to different user processes and environmental characteristics. The use of inconsistent methods for their calculation and corresponding load reductions can cause confusion and dissatisfaction among participating users, resulting in the refusal of the demand response and other smart grid services. This is especially true for industrial participants and other large energy consumers, who have more interest in the financial consequence of the determined consumption reference.

Reference consumption in demand response is a consumption baseline calculated from the past user's consumption characteristics and past measurements. The baseline is the reference used to assess the effects of the demand response of a given consumer or set of consumers (see Figure 1). The demand response effect is defined as the difference between the metered consumption and the baseline calculation (presented with the shadowed area between black and red line during the 4 hour event interval on the Figure 1). For more information on how to monitor consumption, see our guideline How to monitor demand response performance. The event interval could be a curtailment period, a period with higher electricity prices, etc., basically any time when the consumer is urged to consume less electricity at that moment. The baseline is determined for the whole event interval which includes also a period before and after beginning of the of the demand response intervention.

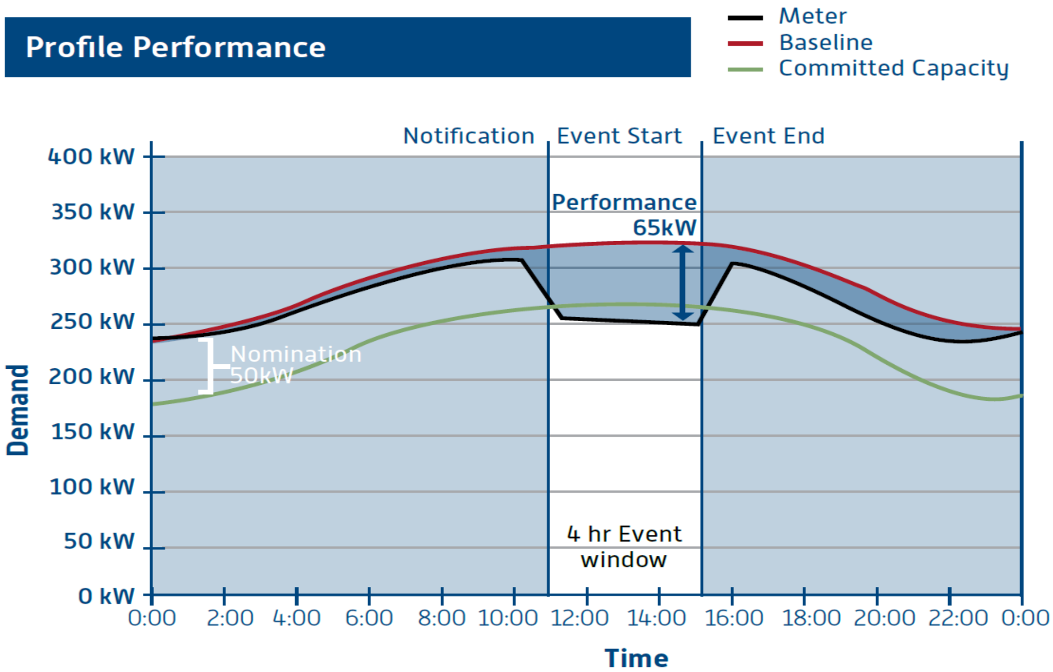

Figure 1: Comparison of baseline with measured consumption during the demand response event (Enernoc, 2009)

When to use?

This guideline provides different methods to estimate the baseline electricity load profile for different types of consumers. A baseline is used as a basis for determining payments or incentives for users included into the demand response programs. The baseline methods are used for consumers like SMEs, medium-sized and commercial consumers participated in demand response programs. It is also convenient for the residential consumers equipped with online metering device. For the users where it is cost-prohibitive to install interval meters at every house it is recommended to use the alternative approach based on aggregation of consumption data of several similar consumers (Enernoc).

The baseline methods reduce the barriers related to inconsistency and confusion about how energy shift will be calculated. Its intention is to ensure that only real and verifiable load reductions receive payments. Adhering to a certain method of baseline calculation allows no room for misunderstanding how energy shift is calculated.

What to do?

The baseline calculation method consists of the three criteria: i) data selection method, ii) estimation method and iii) result adjustment. The combination of these criteria depends on user consumption, weather dependency (incl. seasonal behavior) and load behavior and should all together fit the user consumption pattern.

Data selection method

Data selection criteria consist of the following parameters: data interval, day type and subset selection. The data interval defines the time period of measurements before the demand response intervention, which are included into the calculation of the baseline. The time period may extent from couple of days to several months. The length of the period influences the deterministic and variable part of the baseline. The longer period makes the calculation more stable as it reduces variability.

User operation is usually different during workdays compared to weekends, therefore is recommended to select the measurement data for baseline calculation according to the day in question. Moreover, previous demand response interventions affect the consumption profile therefore the periods where these interventions have happened should be excluded from the selected sample.

Additional extensions of the criteria may be a selection of the subset from the first selection – i.e. the selection “High 10 of 20” means taking the subset consisting of the 10 days with highest consumptions from the last 20 days. The extension is usually used in weather and season dependent consumption types or when the user has significant variable (stochastic) component. For example, in the case when the user stops/changes its processes due to the interruptions or maintenance longer periods with proper subset selection eliminates their influences.

Estimation method

Estimation method is a calculation routine that determines the profile for the upcoming event using the data selected by the data selection criteria. Basically there are two approaches of the routine, first a) average method and another b) extrapolation (weather) based regression model.

The “average” method combines the selected data for each hour with an averaging algorithm. Figure 2 shows the hourly loads for 10 days and their average. In addition, it shows the realized consumption on the present day, which is much higher than past consumptions. This is a common situation when the consumption is weather sensitive and requires some adjustment, what is explained in the subchapter “Result adjustment” below.

The drawback of this method is that it tends to understate the baseline for weather sensitive loads, for example on hot summer days (as shown in figure 2). The use of the High 10 of 20 (or High 5 of 10) subset can partially adjust the problem but it may reoccur in the form of e.g. load reduction credit on cool days. For the loads less affected by seasonal behavior the subset “High 10 of 11” may be a good compromise.

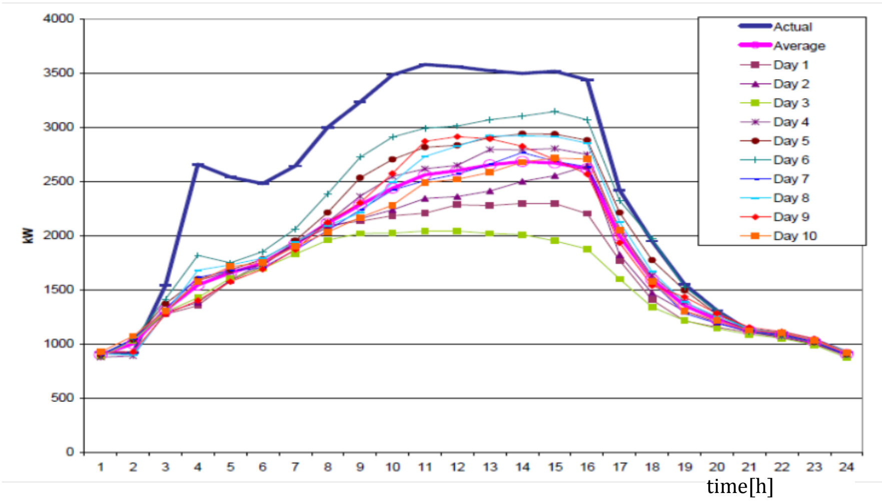

Figure 2: Baseline calculation based on averaging (California energy commission, 2003)

The regression model uses past consumption averages correlated with some independent parameter, e.g. external temperature. The method introduces a model, which assumes e.g. linear dependence of the consumption from independent parameter. The calculated baseline is then an extrapolation of past averages according to the independent parameter value on the day of the demand response intervention (see Figure 3). The model improves the accuracy of the baseline for weather sensitive accounts.

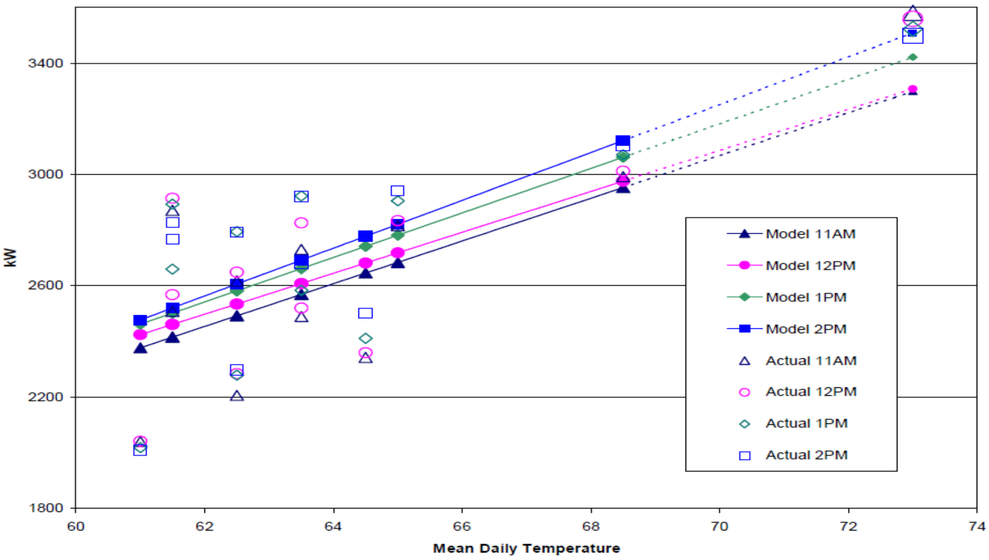

Figure 3: Baseline calculation based on and regression method (California energy commission, 2003)

The graph on the Figure 3 presents a calculation of the profile on the actual day. Empty points show the measured consumption. The model calculates the linear dependency of the consumption from the outside temperature for the each hour of the day (full points). For example if yesterday's consumption at 11 AM is 2000 kW and temperature is 61 ˚F and a day before the consumption was 2400 kW at 65 ˚F at the same time, then a dependence line can be drawn, which assumes e.g. 2200kW at 63 ˚F. Usually more than two days are taken into account and an averaging method such as the least square method is applied [7]. Figure 3 presents the dependent lines for the time moments 11AM, 12 PM, 1 PM an 2PM. The baseline is calculated on the actual day for that interval (from 11AM to 2PM) when the temperature was 73 ˚F for all the intervals. The final result of the baseline profile is the small points on the right hand side extrapolated from the calculated lines for each hour.

We recommend using a long (full season) period to exploit the benefit of the regression model. The drawback when using long periods is that it may not calculate correctly the changes at user operating processes, which are often changed on the shorter time scale (e.g. SME adapts its process according to the order activity). This may be compensated by using the combination of averaging and regression.

The extension of the (weather) regression model is the so called "conditioned weather model", which is recommended in the situation where some consumers have weather sensitive profiles and some do not. The conditioned model measures the accuracy of the baseline calculation of each user and excludes the use of the weather parameter conditions in case it improves the accuracy.

The regression method is more complex and harder to understand therefore it is not used so often. On the other hand it provides baseline corresponding to the weather conditions of the day adaptation event. If extended with the "conditional" variant it may achieve the same accuracy also for weather non-sensitive accounts as the average method.

Result adjustment

The result adjustment modifies the provisional baseline resulted from the estimation method in order to align it with the actual consumption. This is necessary in order to reduce the stochastic influence of weather and operational conditions and make a consistent comparison between the actual situation and the baseline. The adjustment consists of two things: a certain method to be applied and the moment of application of the adjustment.

Adjustment method

The usual adjustment method is a vertical shift - adding constant consumption to fit the result of the estimation method with actual consumption. The vertical shift is recommended for e.g. stochastic industrial processes where the sudden start of particular loads results in constant change of power.

Another option of adjustment is scaling – i.e. multiplication with a positive factor. Scaling may be used when the user consumption depends on some variable factor (e.g. building occupancy).

Adjustment moment

The adjustment moment defines a vertical shift or a scaling constant by fixing the time when the baseline and actual consumption should match. The provisional baseline resulted from the estimation method usually does not fully match the actual consumption even after the introduction of the adjustment method. For example if the baseline hourly time history from 11 AM to 1 PM has the following values ; 1900kW, 2100kW and 2500kW, while the actual consumption for the same interval is 2050kW, 2300kW and 2550 kW, there is no vertical shift (or scaling) which would align those curves for all three points. The baseline method introduces the adjustment moment (only one point) at which those two consumption profiles match.

The typical adjustment moment, for the baseline coincides with the last two hours before the event. However, this period may not be the best for the loads with capacity preparation (e.g. by intensive cooling the user lowers a temperature in refrigerators before the start of adaptation and improves its efficiency). In that case the adjustment moment should be adapted to the user specific circumstances (i.e. 4 or even 6 hours).

The result adjustment may also resolve gaming. User may intuitively enlarge its consumption before the adaptation event to win unjustifiably better adaptation efficiency and savings. This may be avoided by enlarging the adjustment moment to 4 or more hours or by using so called “weather adjustment”. The latter option does not align the provisional baseline with the actual consumption but rather extrapolates it according to the weather parameter value (i.e. temperature).

The action of adjustment could be unrealistically high for users in certain circumstances. This is the case when their consumption is lower due to maintenance or unplanned interruption. To deal with this, it is recommended to make baseline alignment not to the actual value but on recent averages of the same day period (e.g. the consumers’ consumption on Tuesday 10:00 AM is down due to the unexpected maintenance, while the adaptation request is received. The adjustment should be made to the average past 10:00 AM consumption instead to the actual). Alternative option is to introduce a communication channel between user and service provider for reporting such incidents and avoiding gaming.

Recommended approach

The baseline calculation method found to work best for a range of load types consists of taking demand data of the last 10 days, with hourly granularity and identified by the day type (i.e. if the baseline is being calculated for a weekend period the selection should include the weekend period of the last 10 weeks). The initial profile is calculated by simply taking the average of each interval within the day for all days. The adjustment shifts the resulting profile up or down with the additive constant so that it matches the average observed load for the period of 1 to 2 hours prior to adaptation event. This method can be recommended for both weather-sensitive and non-weather sensitive accounts, with both low and high variability, for summer and non-summer adaptations. If the default method is problematic either because of the potential for customer gaming or because of a need to curtail more promptly, the next best alternative depends on the weather sensitivity and energy use variability of the account.

Do's and don'ts

- **Use a simple approach.** Baseline calculation should be simple, easy to understand and implement. Implemented baseline should show financial and energy shift effects for the consumer involved in demand response.
- **Verify the accuracy.** The baseline should be accurate without deviations (i.e. no systematic tendency to over- or under-state reductions). An appropriate handling of weather-sensitive consumers and verifiability of the calculation is recommended.
- **Do not allow gaming.** The possibility for customers to influence their baseline load profile should be minimized.
- **Ensure predictability.** The baseline should be predictable or at least the consumers should have been informed about its profile before committing to a particular adaptation event.
- **Use default load profiles for simple consumers.** The baseline may be predetermined as load profile calculated from technical characteristics of loads without using the actual measurements. The method is suitable for the users with the predictable load profile (e.g. commercial buildings – department stores) not influenced by the user operation, weather conditions and seasons.
- **Adapt the calculation to consumer specifics.** The consumer should have influence on baseline calculation method used for his demand response program. It is not uncommon situation when he is the most relevant person and expert about load types and operating practices (this is mostly valid for SMEs).
- **Extract self-generated production from demand profile**. Users possessing the production units for adaptation should consider the amount of energy supplied from the metering point to the grid within the control period regardless of the user consumption. The method is suitable for the users possessing different types of back-up production units. When these back-up units are in use, their energy generation is the demand response as it reduces the amount of energy taken from the grid.

Simple average-based calculation of baseline at SMEs (KIBERnet, SI)

The KIBERnet project is an example of the automatic demand response solution. It provides the energy consumption adaptation in return for financial compensation based on the measurable effect. It uses the baseline calculation with "average" method for the calculation of adapted energy (MWh) and incentives to be provided. The selection takes the 10 most recent daily consumption profiles according to the workday/ weekend day type, then their averages are calculated and adjusted to the actual consumption 1 hour prior the adaptation event. The weather dependence of the user consumption profiles is weak so no temperature adaptation is needed.

More information: http://www.kiber-net.com

PJM practice with adaptive selection method

PJM is a regional transmission organization in the West of the United States which has established a demand response services. It uses a baseline method for calculation of the consumer payments. Its method is based on "Top 4 of 5 day" which averages the hourly demand of the highest four out of five previous similar days. It is adjusted with a 3 hour adjustment window (see subchapter "Adjustment moment of this guideline). This "look back" compares average electricity usage during the adjustment window on participation days with average usage on baseline days.

More information: Johnson Controls document (2012).

Further reading

- Christensen associates energy consulting (2013). *2012 Statewide Load Impact evaluation of California Aggregator Demand Response Programs* Volume 2: Baseline Analysis, April 2013.
- California energy commission (2003). *Protocol development for demand response calculation*, Consultant report, February 2003.
- The demand response baseline, Enernoc (2009). Web page, https://www.naesb.org//pdf4/dsmee_group3_100809w3.pdf.
- KEMA (2011). *PJM Empirical Analysis of Demand Response Baseline Methods*, April 2011
- Johnson Controls (2012). *Understanding the PJM Default Baseline Calculation for Economic Load Response*, Johnson Controls web document
- Enernoc, The Demand Response baseline, web page, http://www.enernoc.com/our-resources/white-papers/the-demand-response-baseline

This guideline was developed in the S3C project, and is freely available from www.smartgrid-engagement-toolkit.eu.

S3C paves the way for successful long-term user engagement, by acknowledging that the "one" smart consumer does not exist and uniform solutions are not applicable when human nature is involved. Beyond acting as a passive consumer of energy, users can take on different positions with respective responsibilities and opportunities. In order to promote cooperation between users and the energy utility of the future, S3C addresses the user on three roles. The *smart consumer* is mostly interested in lowering his/her energy bill, having stable or predictable energy bills over time and keeping comfort levels of energy services on an equal level. The *smart customer* takes up a more active role in future smart grid functioning, e.g. by becoming a producer of energy or a provider of energy services. The *smart citizen* values the development of smart grids as an opportunity to realise "we-centred" needs or motivations, e.g. affiliation, self-acceptance or community.

S3C performed an extensive literature review and in-depth case study research in Smart Grid trials, resulting in the identification of best practices, success factors and pitfalls for user engagement in smart energy ventures. The analysis of collected data and experiences led to the development of a new, optimised set of tools and guidelines to be used for the successful engagement of either Smart Consumers, Smart Customers or Smart Citizens. The S3C guidelines and tools aim to provide support to utilities in the design of an engagement strategy for both household consumers and SMEs. The collection of guidelines and tools describe the various aspects that should be taken into account when engaging with consumers, customers and citizens. More information about S3C, as well as all project deliverables, can be found at www.s3c-project.eu.