Load Management with Ripple Control Technology

1. Introduction

Reducing cost is a constant challenge for all energy supplying companies. A significant part of the expenditures for energy are performance-related costs. Reducing the peak power by only a few percent will already lead to big savings. Therefore, making use of load management with ripple control technology in order to reduce peaks will pay off within a few years.

Expanding the distribution network is a permanent task, causing investments that need to be considered (interests, write-offs). If the consumption can ideally be distributed over the course of the day it is possible to shift peaks to less busy times. Load control enables you to do so and save expenses for interests and amortisation.

In this document you learn about how an electric network would be managed ideally (chapter 2), what loads can be controlled (chapter 3) and how the Swistec controller is fulfilling the load management task (chapter 4).

2. Ideal Control

It would be ideal for any energy supplying company to deal with an energy demand, evenly spread over the 24 hours of a day. However, this is never the case. If the energy supplying company services rural or urban residential areas, industry, trade or agriculture there will be peaks at night, in the morning and during early evening hours. Most distribution networks also have a peak shortly before noon.

There are three means to control peaks:

- Only turn on loads if the overall system load allows for it; e.g. geyser and storage heating.
- Block loads during high demand times; e. g. heat pumps, air condition, ground water pumps, washing machines, pool and pond pumps as well as floor heating.
- Turn on energy generating groups, e.g. own power plants and emergency power groups.

In addition, load control is also used as a so called „virtual power plant". In this case an energy supplying company reduces its system load in order to help power plant operators in case of a breakdown or to help a power supplying partner company that experiences a load peak at that time.

The load regulator has to maintain the specified performance target value and control geysers, storage heaters, heat pumps, air conditioning systems and other load groups in such a way that the customer hardly notices it.

The contractually fixed on- and off-times have to be observed. The target value has to be controlled flexibly (depending on time and incident as well as remotely) so that the various tariff structures are represented.

3. Control Objects

In a ripple control system loads with the same physical characteristics are combined to one control object. For example: as many 6 hour geysers with the same ripple control commands are attributed until the installed power of these geysers amounts to about
1% to 3% of the target value.

Control objects own different characteristics. These need to be known by the load regulator. The given example refers to a geyser:

- Geysers may only be charged during low-tariff periods. This might require two loading times: 8:00 pm - 06:00 am and 2:00 pm - 4:00 pm.
- At the beginning of the low-tariff-period all geyser thermostats are set to ON since the geyser water is cold. Once the geyser control object is activated, the installed performance of all geysers of these control objects is turned on. While charging more and more geysers reach the target temperature and the thermostat that is installed in the geyser turns the geyser off.
  If the load regulator turns the geyser control object off, it doesn't turn off the installed power of all geysers anymore but only those geysers that have not reached their target temperature yet. If, at a later point, the load regulator turns on the control object the switching capacity depends on the duration as well as the interruption of the loading process.
- The use of hot water varies throughout the year. Usually, there is more demand for hot water on weekends than on workdays. Also, its use usually is higher in winters than in summers. Storage heaters are not at all used during summers and in case of holiday apartments / houses, they are mostly only used on the weekends.
- Water usage can be influenced by individual habits and e.g. the TV program but also by meteorological conditions.
- Naturally, all energy supplying company customers expects to find a fully loaded geyser in the morning.

In addition to geysers that are charged during low- tariff periods, there are other loads that have similar or additional characteristics. Here are a few examples:

- Air conditions may not be turned off for more than 7 or 8 minutes. On- and off-times have to be minimal to avoid damaging the compressor.
- In case of heat pumps the maximum off-time may not be exceeded within a 24-hour-period. If a heat pump gets turned off, it needs to be turned on again for a certain amount of time – depending on the time it had been turned off. Due to the built-in compressor, on- and off-times have to be minimal to avoid damages.
- Power generating groups are sometimes triggered in steps, thus requiring the control objects to be triggered in a certain order.

4. Load Regulator

The load regulator has two main tasks:

- The medium power during a metering period (target) preferably needs to be observed.
- Customers should not feel load regulation.

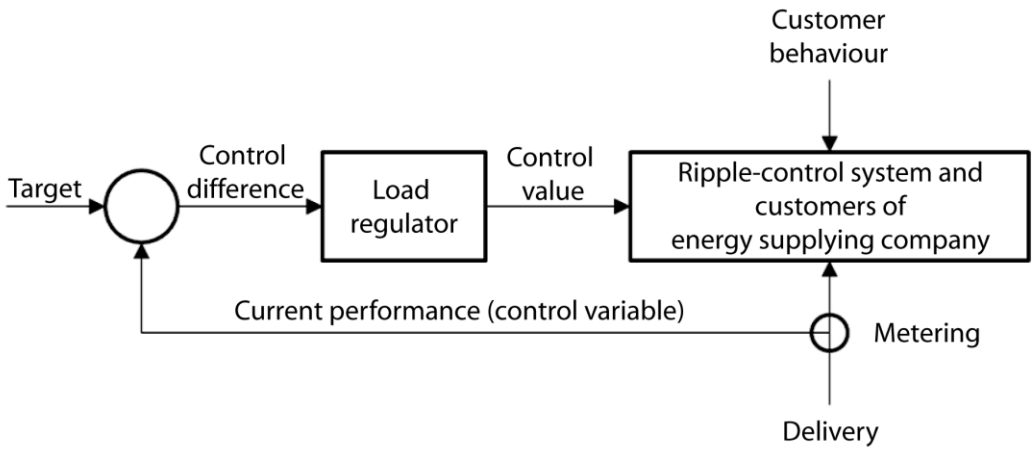
These tasks cannot necessarily be solved by the load regulator. If the target is set too low, all control objects will be turned off. And if they remain turned off for a longer time, this will surely be noticed by the customers. Also, it is possible that the target is exceeded since control objects

cannot be turned off anymore. Therefore, setting targets is the most important task of energy supplying companies. Luckily the load regulator supplies a lot of data which facilitates this process.

4.1 The Environment of the Load Regulator

The load regulator needs two values:

- The current performance (controlled variable)
- The beginning of the metering period so that load regulator and transfer counter of the supplier measure performance peaks in exactly the same way.



The target is the reference variable. The load regulator calculates the control value (control objects that need to be turned on and off) out of the difference between control variable and reference variable. The ripple control system sends the corresponding ripple control commands to the ripple control receivers which turn the loads on respectively off.

For the load regulator it needs to be considered that it takes time (dead time) to transfer the ripple control commands and that the amount of ripple control transmissions per time unit is limited.

Furthermore it needs to be taken into account that the network load can only be adjusted in defined performance steps (turn control object on or off) and that the current performance of each control object varies with each switching action.

4.2 The Load Regulator's Control Algorithm

Technical literature describes control algorithms for various control tasks.

P-, PI- and PID-controller are especially suited for regulations of continuous processes (infinitely adjustable, little dead time) whereas model predictive controllers are better suited for discontinuous processes (adjustable in steps, long dead time) as can be found in ripple control load control.

The model predictive controller stands out since it maps the reality as a model in the controller – thus mapping the distribution network with all controllable geysers, storage heaters, heat pumps, etc.

Control object operations and the exceeding of the upper or lower limits are evaluated via arrays of curves with optimization points. By comparing these optimization points at the present time with those at the end of the forecasted time (with or without the switching of control objects) an ideal switching model can be calculated.

When choosing a switching model the following aspects need to be considered:

- May the selected control object be turned off?
  Possible reasons being: Complying with minimal on and off periods, charging times, order of step switch, the control object is outside of the charging time period, etc.
- Will the inconvenience that is caused by turning off or blocking the control objects be evenly distributed among all customers? (democratization of inconveniences)
- Is achieving the target more important than the comfort of the customers?
- Suppression of the controlled variable's oscillation due to dead time and unspecific prognosis.

4.3 The System's Model

The target value is the average performance that is delievered during a metering period. Since it is an average value, the current performance may either exceed or fall below that averaged performance value.

The load regulator switches control objects with a current load that cause a sudden load variation. The load regulator needs to account for those sudden load variations and still accurately meet the target value.

The system model models the course of the medium performance during a metering period and converts the deviations with an array of curves into optimization points.

When selecting a curve out of the array of curves the energy supplying company can define to what extent complying with the target shall be preferred to the customers' comfort.

4.4 Control Object Models

The load generator needs to be able to work with several load types. In order for the control algorithm to find a solution, it needs to compare the various load types with each other. In this case it is favourable to only have a control object with only one load type.

The different load types can be divided into five different models. Each model consists of curves that describe the physical behaviour. When specifying the control objects, these curves need to be defined regarding the timeline.

Here is an example for a geyser control object:

- How long does it take until a cold geyser reaches its final temperature?
- How long does it take under peak load conditions until the water temperature of a charged geyser drops to the point where it no longer can be called warm?

It is not good for geysers to be turned on and off too often since the cold and warm water is being mixed with each switching operation. Therefore it is better to turn off the direct heaters only shortly yet frequently. To model those, the parameter „amount of switching" has been integrated into the control objects.

The following parameters need to be entered for the five different control object models:

Control object model	Charge time	Dis-charge time	Switching frequency	Min. On-time	Max. Off-time
Geyser (on 24 h)	Yes	Yes	Yes		
Geyser (low tariff-charging)	Yes		Yes		
Power generating groups			Yes		
Air condition			Yes		
Heat pumps			Yes	Yes	Yes

Based on the curves optimization points can be calculated that lets one conclude the geyser's water temperature. Consequently differently sized geysers can be compared with another.

Another parameter for a control object is the current performance. As previously mentioned, the control object's performance constantly changes. The highest degree of accuracy is being achieved when the switching performance of each switching operation is measured. Since the models also record the previous history of the control objects with the optimization points the current performance value can be classified and thus, a virtual installed performance can be calculated. This virtual installed performance for a storage heater amounts to 0 kW in the summer time and to the actually installed performance in the winter time. This virtual installed performance is used to generate prognosis in the load controller.

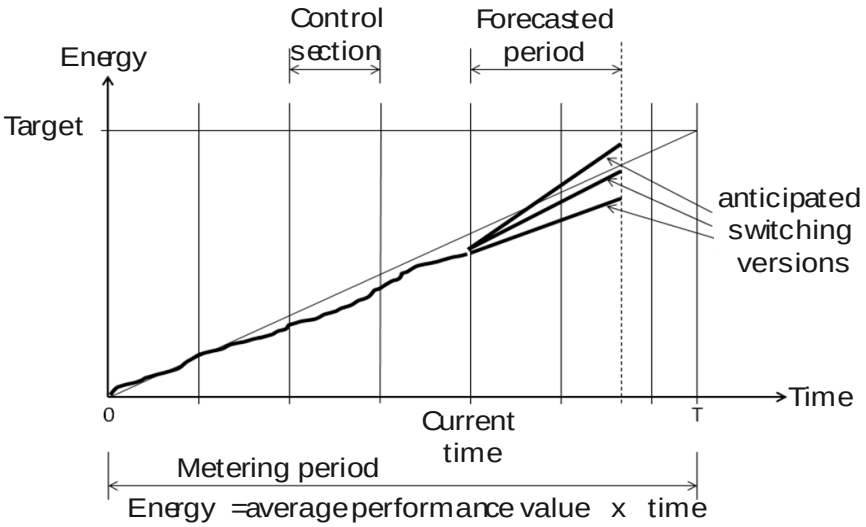
4.5 Load Monitoring

For loads such as geysers, storage heaters, heat pumps, etc. there are contractual agreements between the energy supplying company and its customers, such as:

- A geyser may only be charged during low tariff period and a certain charging time may not be exceeded.
- A geyser with short charging time shall only be charged towards the end of the low tariff period.
- Storage heaters shall be charged in two or more time intervals
- Heat pumps may only be blocked for a maximum of 4 hours during a 24 hour time frame. Each off-time should not exceed 2 hours. After each off-time of 1 hour the heat pump should not be blocked for at least another 2 hours. Furthermore, it can be defined what will happen with a control object if the pre-defined minimal charging time is not reached. Here are a few examples:
- At the end of the charging period or if the minimal charging time will not be reached an alarm can go off.
- At the end of the charging period the charging procedure will be extended until the minimal charging period has been reached.
- If the minimal charging period can barely be reached the control object will remain on until the end of the charging period

4.6 How to Calculate the Control Algorithm

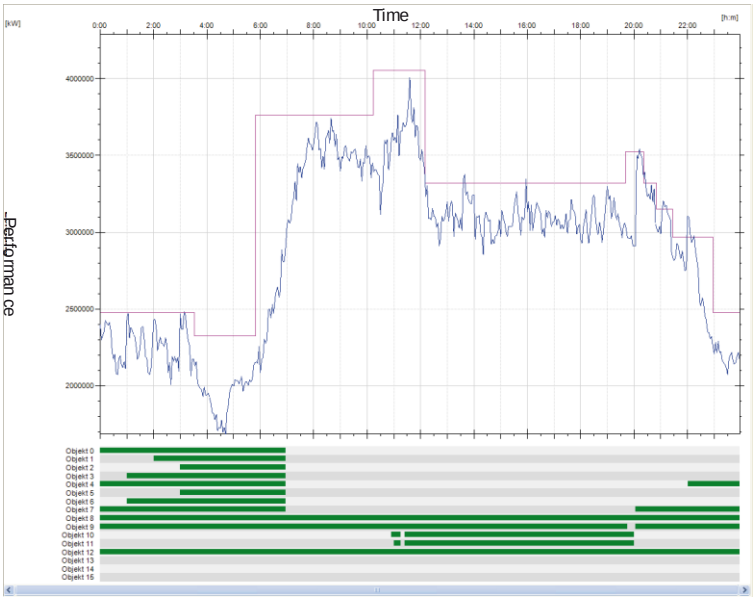
Since the execution of the switching operations at the ripple control receivers require some time, it is beneficial to divide the metering period into control phases. The first calculation of a switching version is done at the beginning of the metering period. The send and the following calculations of a switching version happens every 30 … 300 seconds. This time frame depends on the ripple control system, the metering period as well as the capacity of the ripple control installation.



The following needs to be considered when calculating switching versions:

- The forecasted period serves as a basis to calculate the system's performance provided that no control object is being turned on or off.
- If the system's performance needs to be corrected, control objects need to be found that allow for an adequate adjustment of the performance.
- If a control object has been turned off for quite some time, all control objects that are currently turned on and have not been turned off for long in the past will be turned off so that control objects that have been turned off for quite some time will be turned on again. (democratization of inconveniences).

A switching version will be applied that takes both, the observation of the target as well as the democratization of inconveniences, into optimal consideration.



4.7 Technical Data for Load Regulators

- Maximum number of control objects: 32
- Duration of metering period: 10 to 60 minutes
- Measurement input: 0 … 20 mA, 4 … 20 mA or meter pulses
- Measurement period synchronisation: External or internal

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