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High Frequency Power Modulation - TRIMET smelters provide primary control power for stabilizing the frequency in the electricity grid.

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Abstract

The strong growth of renewable energy in Germany leads to high price fluctuations, varying with the availability of these energy resources. To deal with this situation, TRIMET is using the tool "power modulation" since 2008 to compensate these strong price effects.
Simultaneously the strong growth of renewable energy sources leads to a need of primary controlreservefor stabilizing the electricity grid at 50 Hz. In this context, TRIMET is the first electricity consumer in Germany, which provides primary control power by modulating a consumer. Traditionally, this source of energy is only provided by power plants or energy storage plants, e.g. pumped energy storage or stationary batteries.

Introduction

The high energy pricein Europe and particularlyin Germany poses an enormous challenge for the producers of primary aluminum. The energy costsare already40 – 50 % of theproduction costs, whereby producers have faced precarious economic situations (e.g.Voerdal, Germany orAlcoa,Italy) orcomplete shutdowns of reduction lines, such as occurred for ZALCOin the Netherlandsbythe end of 2011.

Since 2007, TRIMET operates a smelter in Hamburg, Germany with two potlines of 270 pots at 178 kA. The smelter was shut down by the previous owners of HAW due to the high energy prices. Right from the start, TRIMET was forced to deal with this situation and one answer was the usage of the tool "power modulation" to decrease the average energy cost for the smelter.
It soon became clear that an unbalanced modulation, which exceeds the boundaries determined by the cell geometry, process control and process variationwould lead to a significant decrease in process efficiency.

In 2008, TRIMET Hamburg operated on a modulation scheme that was significantly below nominal energy input without means to minimize heat loss accordingly. During this time, serious losses in current efficiency of more than 1.5 % were recorded.

In 2009, modulation was stopped as energy prices were on a low level without any huge price spreads. The reason for this situation was the economic crises, which also led to a cut in 50 % of the production.

After restarting to full capacity at the end of 2009 and early 2010, modulation was also restarted. Simultaneously, a lot of work was conducted to optimize the procedure and determine the process limits for the system.As a result, a theoretical limit of 1.2 MWh was calculated for the energy difference that can be stored in the cell(P19) as it is installed in Hamburg. The amount is the difference of the total energy contained in a cell at 955 °C on one side and 970 °C on the other side. The main contributor to this potential is the effect of dissolving side ledge and reforming it during cooling.

Additionally,various testswere conducted in the first half of 2011 to determine the effect of several modulation schemes on the cell state. A linear relation between temperature increase and energy input was confirmed. However, a smaller cooling was found compared to the temperature increase during a positive power modulation to the same extent. This indicates that either cells can compensate for a smaller heat loss more easily, or that heat is immediately withheld from aluminium production, thus lowering efficiencies [1].

In addition,further possibilities for reducing the energy costs for the smelter were examined. Especially with regard to the unpredictable trend of the energy prices and the aim for a constant reduction in the energy costs. Figure 1shows the energy prices of two different days in comparison. In February, power modulation helped to reduce the energy costs, in August there was no need for power modulation.

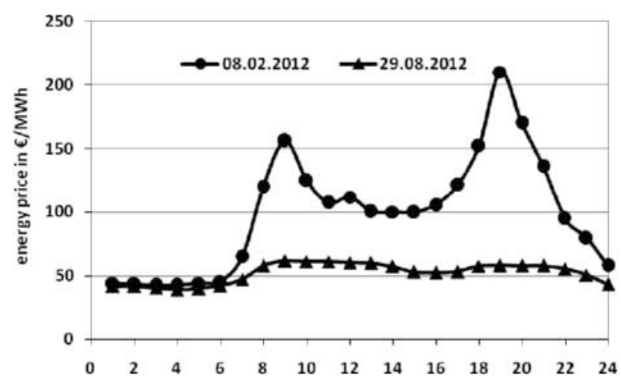

Figure 1: Comparison of energy prices at 8 February vs. 29 August [2]

Another problem is the need of energy balance in the system. That means the surplus of energy which is applied during positive power modulation must be compensated with periods of negative power modulation and vice versa. However, this should be done within 24 hours. In the majority of cases this strategy does not match with the development of the energy prices at the stock exchange.
Figure 2 illustrates this trend. In February, power modulation can help to decrease the average energy price, but 70% of the time modulation must be negative. A huge power input at the beginning and at the end of the week is necessary to compensate the period of lower energy input. In this case, the risk is to exceed the limits for the system with significant losses in process efficiency. The price trend for the week in August shows no need for power modulation. Only a positive modulation at the

beginning of the week is possible, resulting again in an unbalanced system.

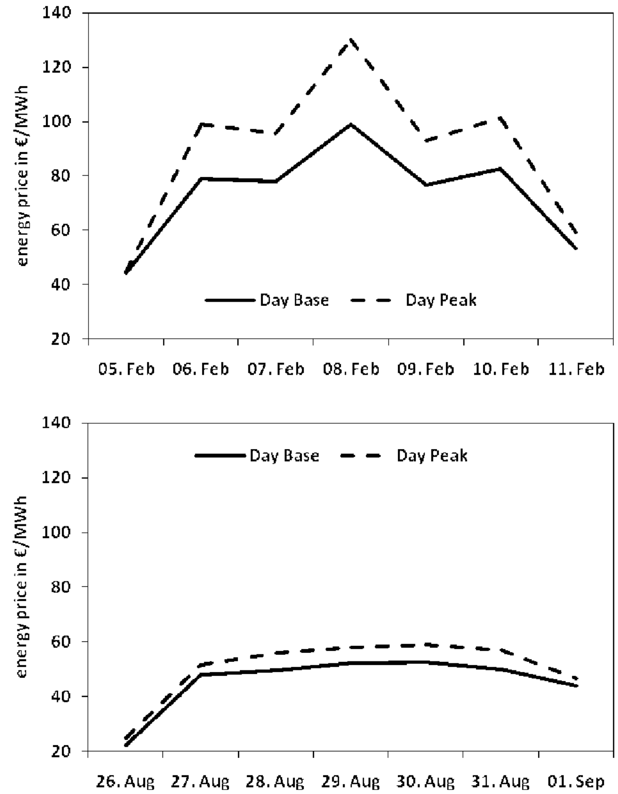

Figure 2: Development of the energy prices in one week in February in comparison to one week in August [2]

With regard to the unpredictable development of the energy prices and the need for reducing the energy cost on a long term, a new way of power modulation was detected. It concerns the market of primary control energy.The transmission system operators (TSO) require to maintain a permanent balance between power generation and demand in their control area.

Primary Control Power (PCP)

In any electrical system, the active power has to be generated at the same time when it is consumed. Power generated must be in constant equilibrium with power consumed, otherwise a power deviation occurs. Disturbances in this balance will lead to a deviation of the system frequency from its set-point value. In Europe, a system frequency of 50 Hertz is used for the interconnected grid. The permissible tolerance is between 49.8 to 50.2 Hertz.

There are limited possibilities of storing electrical energy. It can be stored as a reservoir (e.g.water) for large power systems or as chemical energy (e.g. battery packs) for small systems. It is crucial that the production system must have sufficient flexibility in changing its generation level to deal with power imbalance.

As electrical energy cannot be stored in large volumes, the production of electrical energy has to exactly match consumption at any given time. This requires accurate consumption forecasts to ensure that generation is in line with actual consumption.

The electric frequency in the network is a measure for the rotation speed of the synchronized generators. By increase in the total demand, the system frequency (speed of generators) will decrease, and by decrease in the demand the system frequency will increase. Regulating units will then perform automatic primary control action and the balance between demand and generation will be re-established [3].

A need for control energy will arise when from generation side (e.g. apower station unit is suddenly on outage), or from load side (e.g.meteorological influences, daily load forecast error due to more wind) differences occur. In such a case, control energy must be made available within a matter of seconds. This is where primary balancing comes in, with the corresponding power plants or controllable consumer loads of all interconnected AC networks participating.

Figure 3 illustrates the control scheme for stabilizing the frequency. At first, the primary control reserve is activated within 30 sec followed up by secondary control reserve (activated within minutes). The secondary control reserve is supported and followed up by tertiary control reserve. The aim is to avoid blackouts, which results in major economic losses.

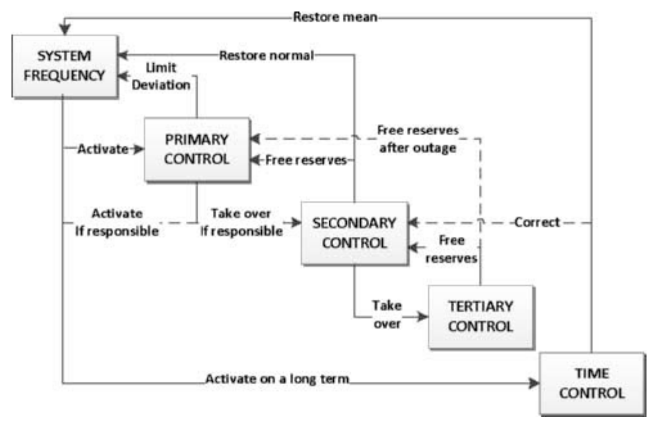

Figure 3: Control scheme and actions starting with the system frequency [3]

The "classical way" to control the equilibrium of energy production and consumption is for example the usage of pumped-storage power plants. They allow for interim storage of electrical energy with the help of water. This is needed each time much energy is generated while little is being used. At times of low energy demand, "surplus" electricity is used to pump water up into a storage basin at a higher altitude. In times of energy demand, the water from the reservoir flows back through turbines, generating electricity.

Aluminium electrolysis has also the ability of controlling the equilibrium of energy production and consumption by modulating the line current. At times of lower energy demand as planned and the risk of an increase in grid frequency is given, the line current can be increased rapidly to rebalance the frequency. On the other side, the current can quickly be decreased in times of higher demand.

Qualification for Primary Control Power

The transmission system operator (TSO) requires control reserve in order to be able to continuously balance generation and consumption of electrical energy.

Prospective providers of primary control reserve have to complete a prequalification procedure to demonstrate their ability to meet the requirements in this respect in order to ensure the security of supply. In addition to technical competence, prospective providers also have to demonstrate their ability to perform satisfactorily according to the requested operational conditions and that the economic situation does not raise any cause for concern.

The prequalification is conducted exclusively by the TSO, in whose control area the relevant technical units (generation facilities and controllable consumer loads) are connected to the grid, independently of the voltage level. In the case of TRIMET Hamburg, 50Hertz Transmission GmbH is the responsible TSO.

The main important requirements to fulfill are:

- Uniform activation of primary control power within 30 sec and supply of power for at least 15 min.
- Ability to supply primary control in the valid period for 100% of the time.
- The intensity range of the controllers should not exceed +/- 10 mHz.
- Transductor in the rectifier station in addition to the on-load-tap-changer so that a continuously and fast control of the line power is possible.
- Precise process control, achieves very little deviation from target cell parameters (e.g. 9-box-modell)

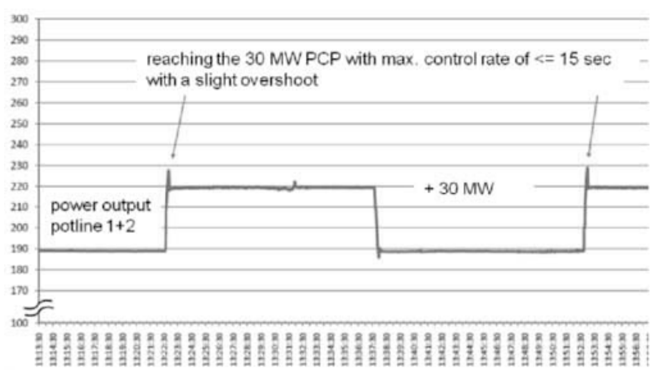

Figure 4: Prequalification for 30 MW primary control.

As an example, Figure 4 illustrates a part of the prequalification procedure for 30 MW. Based on a line power of approx. 190 MW, the power must be increased within 30 sec for 30 MW and then hold for 15 min. This load case has to be run through two times. The same procedure has to be repeated for - 30 MW. With successful completion of the load curves, the abilityto provide primary control power is demonstrated.

Tendering for Primary Control Power

Since 1 December 2007, German transmission system operators (TSO) have been meeting their primary control reserve requirements through competitive bidding on a tender basis. Therefore a shared internet platform has been used for implementing the joint call for tenders. On this platform, calls for tender are published, bids are processed, and bidders are informed whether their bids have been accepted or rejected. Since 27June 2011, the tender submission period has been one week and the minimum supply offer is set at +/- 1 MW. The total control power demand of all German TSOsis approx. 7400 MW, with approx. 600 MW portion for primary control power.

Primary Control Power at TRIMET Hamburg

Since January 2012, TRIMET is providing primary control power for stabilizing the grid frequency. As described above, each week on Tuesday TRIMET tenders its amount of primary control power for the following week at the shared internet platform of the TSOs. After receiving the information that the bid is accepted, the control for PCP is activated in the rectifier station. As long as the PCP is activated, the grid frequency is measured continuously. In cases of frequency instabilities, that means deviations > |10 mHz|, the set point of the pot lines is controlled automatically for stabilizing the grid frequency. All data are recorded with a resolution of one second, as evidence for the TSO. Figure 5 illustrates the trend of the grid frequency and the corresponding line power as a result. The regulation of the power output is automatically controlled by the grid frequency, no manual control is necessary.

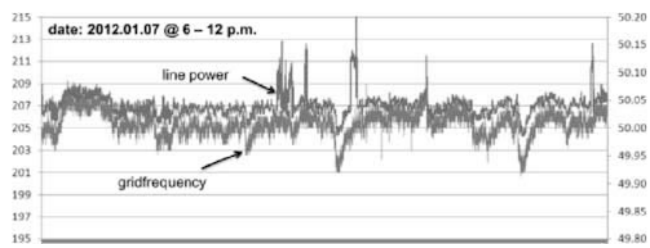

Figure 5: Trend of the grid frequency and the output of the line power during activated primary control power.

In Figure 6 the average portion of primary control power in dependency of the offered power is shown. Most times of the week only a small amount of PCP below < 25% of the tendered power is needed. 35 – 55% of the time the modulation of the line power is in the deadband. The maximum tendered power was not accessed and > 50% of the power was used in a range of seconds.

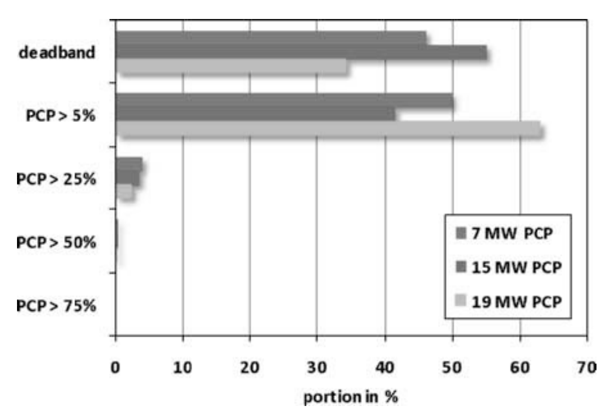

Figure 6: Average portion of primary control power in dependency of the tendered power.

Conclusion and Outlook

Since January 2012 TRIMET Hamburg is providing primary control power for stabilizing the frequency in the electricity grid. The advantages of this "new" type of power modulation compared to the "classical" power modulation based on the energy prices at the exchange are:

- Permanent possibility to reduce the energy cost for the smelter.
- Low risk of imbalanced energy input, as the grid frequency needs stabilization in both directions.
- Little manpower, because the power output (line current) during activated primary control power is controlled automatically.
- Usually less than 50% of the tendered primary control power is accessed.

In the future a model is conceivable, which combines both types of power modulation depending on the development at the energy exchange.

References

[1] Reek, T.; A noval approach to power modulation; Australasian Aluminium smelting conference 2011

[2] European Energy Exchange www.eex.com

[3] UCTE Operation Handbook, Appendix 1 Load-frequency control and performance, p. 3