UCTE AD-HOC GROUP
'FREQUENCY QUALITY INVESTIGATION'
EXCERPT OF THE FINAL REPORT

INTRODUCTION

The last few years the UCTE grid is experiencing increasing frequency variations at hour boundaries, multiple times per day mainly during the ramping periods in the morning and the evening. Statistics show an increase of these system frequency variations, both in number and in size. There is a real danger that a further increase can create frequency deviations inside the UCTE area which could, simultaneously with a large outage, put the stability of the entire grid in danger. This paper gives the abstract of an investigation[1] by an expert team of UCTE, including a risk analysis and recommendations to work against the situation.

These frequency deviations activate a significant share of the primary reserve in the UCTE system which is initially intended for large generation and load outages. A further increase of these phenomena can create frequency deviations large enough to activate the complete available primary reserves without recognized incidents. Thus it reduces the available security margins for frequency control and puts into question the adequacy of primary reserves to limit frequency variations, and secondary reserves to restore frequency variation in case of imbalances between generation and load in each area.

BACKGROUND AND FRAMEWORK

The frequency of the UCTE system can be seen as a global quality criterion for real-time power and energy balances, system disturbances and operation of control power depending on operation of generation units, daily and seasonal availability of power resources, typical daily and seasonal changes in the demand and real-time behaviour of third parties and grid customers.

This results in a superposition of different effects and impacts on the time-series of the frequency like the range of deviations of the frequency (spread), the rate of changes of the frequency (dynamic), the persisting mean deviation of the frequency (offset) and the repeated occurrence of deterministic frequency patterns.

Especially the last item describes the phenomenon of the large frequency variations that are regularly observed during the change of the hour and is the main focus for this investigation. If during unfavourable system conditions due to a (predictable/systematic) large frequency variation, an unexpected loss of generation capacity occurs, the UCTE system might face a critical situation very fast with seldom experienced frequency levels and subsequent difficult to foresee consequences. The cause of a large frequency deviation can also create unforeseen power flows which should be covered by the TRM in the security calculations.

[1] UCTE Ad-hoc group: Report 'Frequency Quality Investigation' Final Report (30 August 2008**)**

OBJECTIVES

The UCTE TSO Forum already discussed this issue in 2006 and declared that the situation has become alarming since the end of 2005. The question was raised whether the Operation Handbook and the Grid Codes of the individual members, were sufficient. It also leads to questioning whether current behaviour of all parties (and specifically generators) in the system is sufficiently coordinated to cope with schedule changes. Scope of the investigation was to study the most significant causes for the increasing frequency variations and to make proposals which should again improve the frequency quality of the UCTE-grid. Possible causes for these large frequency swings in the UCTE grid were investigated:

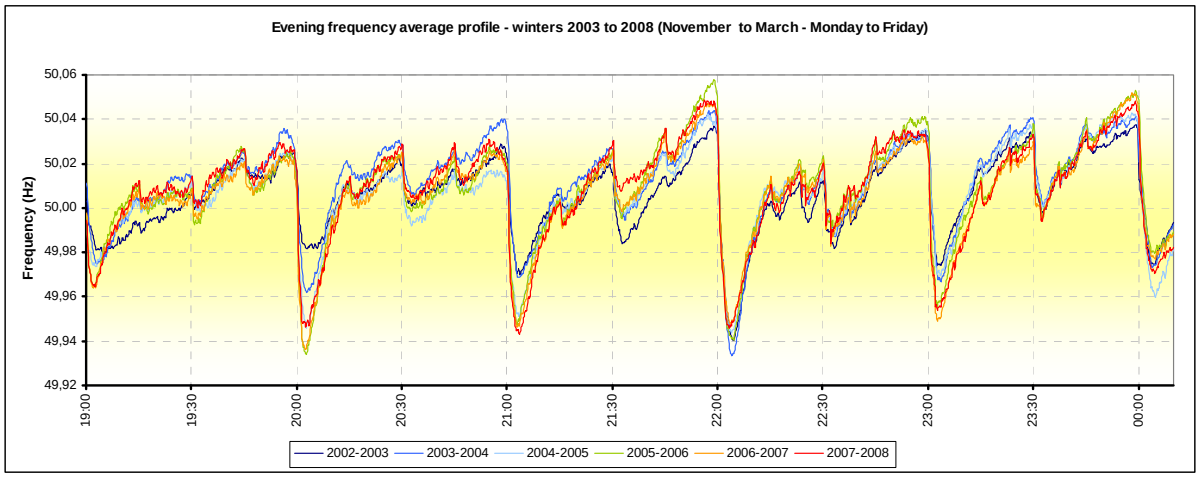
- large program changes between control blocks, between control areas or inside control areas. Observations show that, as market activity has increased inside the UCTE grid, it is accompanied by an increase in exchanges between market parties and control areas in combination with increasing exchange variation sizes for each hour of the day which tend to have an impact on the stability of the frequency.
- Differences in the control settings in each control area and the speed of the secondary controllers and reserves.
- The market rules and UCTE rules for balancing of the system and the rules concerning starts and stops of generation in each control area: They are not harmonised or coordinated which might result in differences in gradients (speed of power output change) for production units that start or stop.

FREQUENCY VARIATIONS AT HOUR BOUNDARIES

The UCTE grid has developed into a large international synchronous grid with the aim to supply the consumers with high quality power, including a stable frequency. A stable frequency is desired by all grid users since most processes are designed for a frequency close to 50 Hz with only small deviations, and with an average frequency equal to 50 Hz. Large frequency deviations can have a negative effect on generating units participating in primary control, due to the required fast changes in output power, especially if they happen often.

The frequency is the only parameter common for the whole synchronous zone. To keep it stable, the UCTE Operation Handbook requires that all TSOs have to participate in frequency control by using power reserves with different characteristics and qualities. Normal operation of the UCTE grid is considered1between 50 Hz +/- 50 mHz, with exceptional excursions outside this interval. Observations show that a 1300 MW generation outage usually leads to a frequency drop of around 50 mHz.

The following figure shows the “evening frequency average profile 2003 to 2008 between 19:00 and 0:05 (November to March – Monday to Friday)”:



This clearly show that the UCTE system is now outside of its usual operation condition of +/- 50 mHz several times almost every day and the phenomenon is worsening with the tendency of frequency deviations occurring also around the half hours. Development of the electricity markets in the European countries in combination with the continuous increase in market participant activities has, as a consequence, that we are experiencing more and more and also higher and higher frequency swings around the change of the full hours, specifically at times when tariffs and schedules are being changed. There is a link between market activity (in terms of daily deviations of schedules) and frequency variations even if the (incomplete) measurement campaigns do not always show a clear correlation.

OPERATIONAL RISKS AND CONSEQUENCES

The following operational risks and consequences were identified:

- Power flow variations: in case of a simultaneous incident the system comes closer to losing an overloaded element following the frequency excursion especially in this era where TSOs operate their systems closer to the limits and even a slight change of power flow may lead to a tripping.
- Risk of insufficient primary reserve: Such behaviour usually leads to declining system condition
- Decreased damping of frequency oscillations: This can lead into uncontrollable operational situations, possibly followed by system separations and/or loss of generating units
- Repetitive and higher use of primary reserves: These effects are a disincentive to keep the primary controller in service and increases the (acquirement) cost of primary reserve.

CONCLUSIONS AND RECOMMENDATIONS

As in any synchronous power system, the system frequency in the UCTE is a reflection of the quality of electric energy supply. Based on the fact that the system frequency at any time represents the result of the balance between generation and consumption, the size of the variations reflect in real time how well the system is controlled. It has been observed that large deviations from the 50 Hz at hour boundaries have been increasing in size and number in the last 10 years. This leads to frequency deviations closer to the design limit for primary control reserve of +/- 200 mHz. Sometimes the gradient of these frequency drops is higher than 1.5 mHz/sec which becomes comparable with outage effects, given that the frequency drop caused by unit outages of the largest units in UCTE is only 4 times higher (6 mHz/sec).

During periods of high deviation of the system frequency from the setpoint, system operation is not only weakened by substantial primary reserve activation, system stability is also endangered by a lower damping of the inter-area oscillations. Analysing this phenomenon the following aspects were detected:

- Coincidence of the frequency drops or peaks with the hourly, half-hourly or quarter-hourly schedule changes between or inside individual control blocks / areas. One of the main causes for this is the non-synchronicity of upward and downward ramping between the individual involved areas or generators / balance-responsible parties, mainly observed during larger demand variation (steeper slopes of the load curve).
- Increased trading activities in the last years reflected by higher schedule exchanges, their peaks correlate with the higher frequency deviations
- Extremely high power gradients due to fast connection or disconnection of some units, for example hydro pump-storage
- Uncoordinated behaviour of balance-responsible parties due to energy compensation activities close to schedule change moments.

The main identified cause is a mismatch between fast and slow generation, leading to short term unbalances. These mismatches mainly occur at moments of schedule changes when generation patterns have to be adapted. The analysis of the phenomenon observed was completed by dynamic model calculations. The simulations prove that an increase in quality and/or quantity of secondary control reserve does not improve the frequency quality during uncoordinated ramping, due to the relatively slow (centralised) activation of this reserve. Therefore it could be concluded that the most effective way of reducing the critical frequency deviations during schedule ramping is to improve the quality of ramping by demanding this as far as possible from all acting parties in the same way: generators, loads and balance responsible parties. This will require corresponding adaptations of national grid codes, national legislation and accounting procedures, in order to create the required rules and necessary enforcement mechanisms.

Based on these conclusions the following recommendations are formulated. These should bring about a decrease of the frequency variations in the UCTE and therefore decrease the operational risks mentioned in this paper.

- All TSOs and UCTE should start discussions with generation companies to implement rules for establishing a maximum gradient for total generation output and as far as possible also for demand, at the hourly boundaries, taking at least the UCTE ramping period of the TSOs of +/- 5 minutes, to enable the remaining system unbalances (due to modifications of production, consumption and/or exchanges) to be controlled with the Load Frequency Control.
- Each TSO should coordinate with the generating companies feeding in their system the power plant schedule changes in such a way that they avoid as much as possible steep or step-wise changes in generation at hourly boundaries.
- TSOs will have to monitor the application of these rules (above a specified relevant size) and implement country specific incentives.
- Imbalance accounting could take into account the ramping rates or ultimately reevaluate the necessity of tariff periods in market environments.
- The recommendations are based on best effort from each party and taking into account the current legal framework between TSOs and genration companies.