DYNAMIC SIMULATION OF THE IMBALANCE NETTING PROCESS AND CROSS-BORDER ACTIVATION OF AUTOMATIC FREQUENCY RESTORATION PROCESS

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Abstract

This paper discusses the Imbalance Netting Process (INP) between interconnected control areas (CAs) that was implemented in Continental Europe due to the high costs of balancing energy. The primary goal of INP is to net the demand for balancing energy between participating CAs with different signs of interchange power variation. In this way, INP reduces the amount of activated regulating reserve, consequently, costs related to ancillary services are also reduced. What is more, INP should also improve frequency quality. In addition, the new network codes require further cost optimization in a way that optimizes the activation request for automatic frequency restoration process (aFRP). Therefore, INP will be further developed in a way that will enable cross-border activation of aFRP. However, contrary to INP, cross-border activation of aFRP is possible only between participating CAs with equal signs of interchange power variation. Therefore, the impact of INP and cross-border activation of aFRP on frequency quality and provision of Load-Frequency Control (LFC) is analyzed thoroughly. Results obtained with dynamic simulations of a three CA testing system confirm that INP, as well as cross-border activation of aFRP, reduce balancing energy and, consequently, release regulating reserve. In addition, the unintended exchange of energy is also reduced. Furthermore, the obtained results also indicate the impact of INP and cross-border activation of aFRP on performance of the frequency control.

The imbalances between production and consumption are reflected in the frequency deviation, which must be limited by different target values, and the frequency is regulated at different levels [1]. Frequency quality has been declining in recent years [2], and INP, as well as cross-border activation of aFRP, are expected to have a positive impact on its quality and on the provision of LFC. In [3] it is shown that INP releases regulating reserve without affecting the provision of LFC. According to [4], INP reduces the frequency deviation, but cases of frequency degradation also exists. Basic framework of cross-border activation of aFRP is given in [5].

Each Transmission System Operator (TSO) provides LFC in its CA, thus eliminates the frequency deviations and interchange power variations of the cross-border transmission lines. Interchange power variation and frequency deviation of the i-th CA are defined as $\Delta P_i = P_{ai} - P_{si}$ and $\Delta f_i = f_{ai} - f_{si}$, respectively. Here P_{ai} and f_{ai} denote actual, i.e., measured values, whereas P_{si} and f_{si} denote scheduled values. The imbalance between production and consumption of the i-th CA, which also includes the frequency deviation, is measured as $ACE_i^{'} = \Delta P_i + B_i \Delta f_i$, where B_i is the frequency bias coefficient.

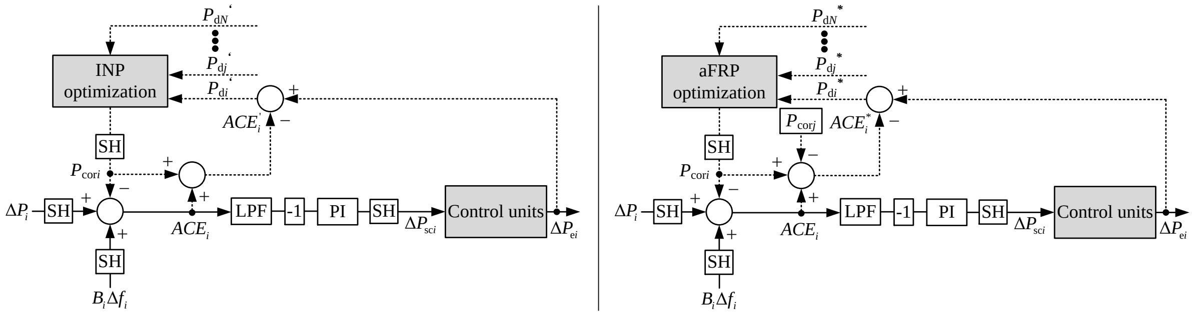

Figure 1: Block diagram of LFC (solid line) with INP optimization (dotted line) – left and with aFRP optimization (dotted line) – right for the i-th CA.

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The basic LFC structure for the i-th CA is shown in Figure 1 with solid line, where LPF denotes a Low-Pass Filter, PI is a Proportional-Integral Controller and SH denotes Sample and Hold with a sampling time T_s. A negative control-feedback is incorporated as -1 gain. The output of LFC is scheduled control power ΔP_{sci}, which is distributed between the different control units that participate in LFC. Individual control units change active electric power accordingly and their sum is denoted as ΔP_{ei}. The input variable for INP and cross-border activation of aFRP is demand power P_{di}' and P_{di}^*, which determine the total power to be compensated with participating CAs that have either opposite sign of ACE_i' or equal sign of ACE_i^*. The demand power is given as $P_{di}' = \Delta P_{ei} - ACE_i'$ for INP and $P_{di}^* = \Delta P_{ei} - ACE_i^*$ for cross-border activation of aFRP, where $ACE_i^* = \Delta P_{ei} + B_i \Delta f_i - P_{corj}$. Output variable of INP and cross-border activation of aFRP is incorporated as $ACE_i = (\Delta P_i + B_i \Delta f_i) - P_{cori}$. The structure of the LFC with INP is shown in Figure 1 – left with a dotted line, whereas cross-border activation of aFRP is incorporated in Figure 1 – right with a dotted line.

The initial load value ΔP_{Li} was set to zero in all three CAs. A simultaneous step change of all the loads was applied at t = 10 s and t = 100 s, where the magnitudes were set according to Figure 2.

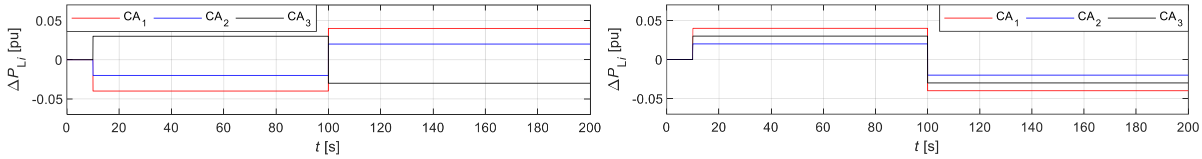

Figure 2: Step change of ΔP_{Li} used in numerical simulations for three CAs with INP – left and with cross-border activation of aFRP – right.

The impact of INP is shown in Figure 3 – left, where in all three CAs, the values of ACE_i and ΔP_{sci} were reduced. In addition, the impact of cross-border activation of aFRP is shown in Figure 3 – right. Clearly, the values of ACE_i and ΔP_{sci} were increased for the system with cross-border activation of aFRP in CAs that had to activate its control units due to the demand from connecting CAs and vice versa.

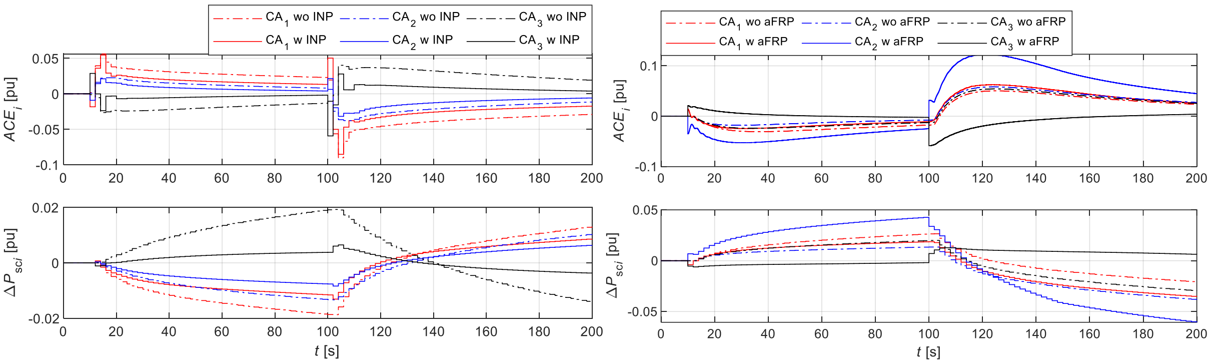

Figure 3: Time response of ACE_i and ΔP_{sci} for three CAs, where "wo" is without and "w" is with INP – left and with cross-border activation of aFRP – right.

In the full paper, thorough analysis will be performed with dynamic simulations of a three CA testing system. In this way, positive impact of INP and cross-border activation of aFRP on frequency quality and provision of LFC will be shown, in addition to the main differences between INP and cross-border activation of aFRP.

References

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