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SUBOPTIMAL AND ECONOMIC FREQUENCY CONTROL APPLICABLE FOR INTERCONNECTED ENERGY SYSTEM

Interconnected power system (IPS) stability is one of the strategic issues much influencing the state energy independence today. The problem of IPS reliable functioning became even more dramatic after Ukrainian authorities approved the strategic plan to join the European Network of Transmission System Operators (ENTSO-E) during the coming decade. An incidental system's frequency deviations comprise the matter of concern here: frequency deviation value should be controllable not to exceed the critical values with respect to the scheduled one [1].

We need to provide active power balancing in terms of economically efficient supply and consuming of electricity (herewith thermal energy consumption is treated as a co-product) – by means of relevant frequency control within the requirements drawn by the 3-d European Energy Package thus to comply the key conditions of IPS dependable operation. The paper presents a technical approach for adjusting the frequency gain value of the Area Generation Controller (AGC) basing on the use of the best approximation of the static power frequency characteristics of the IPS. We propose the reasonable method, which is stemming from continuous monitoring results and the vast practical experience obtained by the engineers at the dispatch center of National Grid Operator – State Company NEC "Ukrenergo" [2].

Information uncertainties are the main difficulties, lying in wait for dispatchers, providing control of power and frequency in the steady-state modes of the IPS. Namely, the dispatcher does not get any information about instant *small power imbalances value* and in what particular area (regional subsystem, coordinated by RSO or TSO) that steady-state power imbalance has occurred. This urgently needed information being the key issue to comply the requirements, stipulated by ENTSO-E provisions (Operating Handbook, P1, [1]) for secondary control: each area (RSO) is obliged to compensate its inner frequency disturbances, if occurs, by means of controllable blocks, and should not to react to the disturbances of the neighboring areas. Simultaneously, if the inner disturbance occurs, the deviations of net interchange power flows should minimized with respect of the planned value. This specific feature of complicated control process is reasonably treated as AGC *selectivity* towards the location of disturbance [3].

Given the approach, the AGC of each control area is supposed to participate in the processes of secondary control of synchronous frequency, eliminating internal imbalances. However, in the case when AGC is not available or inactivated, the dispatcher does predominantly act by intuition, still being far from the optimal routine.

Mathematically the dispatching conditions for steady-state modes with respect of power and frequency we write in the form of simple equations [4]:

$$\begin{aligned} &P_{Li}^{\Sigma}(f) - P_{Tj}^{\Sigma}(f) = 0\,; \quad f - f_{plan\_value} = 0; \\ &P_{OHL\,1}^{\Sigma}(f) - P_{plan1}^{\Sigma} = 0\,; \dots P_{OHL\,z}^{\Sigma}(f) - P_{plan\,z} = 0 \end{aligned} \tag{1}$$

where $P_{Li}^{\Sigma}(f)$ – is the network electrical power of IPS, MW, consumed with *n* distributed consumers, $i = \overline{1,n}$; $P_{Tj}^{\Sigma}(f)$ – net value of total mechanical power of IPS, MW, represented with turbines (primary engines) of m operated generators, $j = \overline{1, m}$; $P^{\Sigma}_{OHL\,1}(f)$–subtotal instant frequency dependent interchangeable power netflow of the intersystem connection number 1, MW, supplied by means of k overhead lines; $P^{\Sigma}_{OHL\,z}(f)$– an instant frequency dependent interchangeable power netflows of the intersystem connection number z, MW, supplied by means of l overhead lines; P^{Σ}_{plan1}, $P_{plan\,z}$– planned values of power flow for intersystem connections number 1 and z respectively, MW; $f - f_{plan\_value}$– a steady-state frequency deviation, given the instant and planned frequency values f and f_{plan_value} , Hz.

Technically, the solution of problem (1) is provided by means of primary and secondary automatic control of IPS regimes with respect of power and frequency: once a rotating reserves specified for power automatic control are exhausted, or sustained activation of secondary control is expected – tertiary reserve's activation is needed, which is operated manually or due to time-scheduled procedure.

As far as interconnected power system of Ukraine (IPSU) is not equipped with AGC yet, the power and frequency control problem for normal steady-state modes of the IPSU entirely laid on the operational staff and engineers of technological services, responsible for energy regimes continuity through preparing the necessary data for dispatchers.

Conclusions

Here we stipulate that suboptimal control of IPS frequency is attainable technically and economically when the AGC frequency gain is set as much closer to the *stiffness factor value* of the IPS static characteristic, computed as the algebraic difference of the biases of the static characteristics of net mechanic and network electrical power. Enhanced AGC gain tuning will provide AGC selectivity conditions more accurately.

Both cases of isolated power system and IPS with two synchronous areas have been considered to demonstrate that ENTSO-E Policy requirements towards load-frequency control are eligible and satisfied, and no extra fuel resources for excessive cross-border power flows' generation should be spent. However, feasible techniques capable to determine the IPS stiffness factor with respect to the frequency should be developed further to implement the proposed approach.

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