

STABILITY STUDIES CONCERNING THE INTEGRATION OF CENTREL NETWORK INTO THE POWER SYSTEM OF UCPTÉ

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Abstract

The CENTREL members from Poland, the Czech Republic, Slovakia as well as from Hungary started synchronous parallel operation with the West European power system of UCPTÉ in October 1995. As a precondition stability calculations have been carried out in advance to obtain findings about the dynamic behaviour of the interconnected networks. On the basis of different load scenarios, steady-state and transient stability of UCPTÉ-CENTREL networks are assessed in the study both with regard to synchronous and hybrid interconnection.

The dynamic equivalent model is described. Its correspondence with reality is illustrated by comparing available measurement recordings with simulated results.

Selected results of the study are described and conclusions are drawn about the measures that have to be taken to maintain stability. Due to the complexity of the study, the work involved in data collection, data processing and calculations has been divided and coordinated between the companies concerned in accordance with the state of progress of the study.

Keywords:

Power system extension, Stability - transient - steady-state, Modelling - dynamic, Measures to improve stability, Approach - division of work, Operational tests

1. INTRODUCTION

In the course of current political changes, closer cooperation develops between the electricity sectors of the countries of Western, Central and Eastern Europe. As a first step, the EHV networks of East Germany and Berlin were disconnected from the East European IPS/UPS network in September 1995 and inter-connected with the West German power system [1, 2]. One month later, the synchronous parallel operation was started by way of trial between the West European interconnected system of UCPTÉ and the networks of the interconnected power companies in Poland, the Czech Republic, Slovakia and Hungary. This interconnection was preceded by the consolidation of these four countries into CENTREL with a view to preparing the integration. A Catalogue of Measures ("Massnahmenkatalog") was agreed upon between CENTREL and the neighbouring interconnected power companies in Germany, Austria and the former Yugoslavia. As part of the "Massnahmenkatalog", comprehensive studies about system dynamics were carried out in the framework of the Deutsche Verbundgesellschaft (DVG). The dynamic studies were closely coordinated between the UCPTÉ and CENTREL companies concerned. The present paper describes details of the study as well as pertinent frame conditions.

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2. SITUATION OF CENTREL / IPS / UPS

The networks of the power companies of Poland, the Czech Republic, Slovakia and Hungary were in parallel operation with the IPS/UPS system of the former Council for Mutual Economic Assistance (CMEA). In 1990-91, the four companies announced their intention to realize parallel operation with the UCPTE. The main aims of this decision were to ensure a higher quality of supply, to improve reliability and to find a better commercial environment. To establish the institutional form for cooperation, CENTREL was founded in 1992. The aims of CENTREL are to realize parallel operation with UCPTE, to promote technical and economic cooperation and to maintain cooperation with the eastern neighbours.

In 1994 the installed capacities totalled 61,249 MW with a peak load of 41,159 MW.

3. SITUATION OF UCPTE

Members of the UCPTE, that was founded in 1951, are today interconnected power companies from 15 West European countries. The UCPTE aims to achieve the most efficient utilization of power generating facilities and transmission networks. It endeavours to facilitate and promote the international exchange of electrical energy. In 1994, the installed generation capacity of the West European power system totalled 394,000 MW; its peak load amounted to 243,000 MW.

4. THE "MASSNAHMENKATALOG"

An important factor for the smooth cooperation within UCPTE are the high quality standards achieved in primary and secondary control of the systems (very low frequency deviations). An extension of the synchronous system area is only possible if the new systems attain equal operational standards. Owing to their former integration into the IPS/UPS power system, the CENTREL networks were designed for other modes of operation, control concepts and technical standards. As a first step, a catalogue of requirements (the so-called "Maßnahmenkatalog") was signed in 1992 by neighbouring UCPTE and CENTREL companies [3]. This catalogue includes the technical and organizational requirements as well as requirements in terms of energy economy which have to be satisfied before parallel operation can be started. In accordance with the requirements of the UCPTE recommendations, the technical requirements of the "Massnahmenkatalog" demand that the new grids meet the generation-demand balance in a self-sufficient way and that they dispose of the required reserve capacity, regulating power plants, installations for primary control and power-frequency control, and that the networks are adequately dimensioned and equipped with appropriate protection devices.

The concrete requirements to be satisfied by the four new partners were determined by feasibility studies. Available studies from universities, consulting firms, UCPTE and UNIPEDE could not be used to demonstrate that a stable operation of CENTREL power stations would be possible in the extended UCPTE power system including the CENTREL countries [4]. Due to the differences in the simulation models used, it was not possible to obtain homogeneous and sufficiently precise findings. Therefore, a common study about the dynamic behaviour and the dynamic system reliability of the grids concerned was carried out by the DVG on behalf of the UCPTE-CENTREL Executive Committee "East-West" which was responsible for the coordination of the preparatory work. Essential requirements in terms of an adequate system stability could be deduced from the study [5].

5. TERMS OF REFERENCE OF THE STABILITY STUDY

The assessment of the stability behaviour of a synchronously operated interconnected power system after a major extension calls for a global investigation comprising the original power system and the new candidate systems. In this way, it can be ascertained whether, particularly after a fault, limiting values are exceeded only for a short time and whether a new operating point of the total system of power stations-network is reached without causing sustained oscillations. Different points of emphasis have to be considered with a view to assessing steady-state and transient stability. A summary of stability terms is given in [6].

Winter peak-load and summer low-load have been assumed to study the dynamic system behaviour. Furthermore, the effects of additional transports in a West-East direction and vice versa (assumptions of theoretical operating cases) on stability have been investigated.

Steady-state stability and transient stability were examined with a view to simultaneous synchronization of the networks of Poland, the Czech Republic, Slovakia and Hungary with the network of UCPTE. Network scenarios such as

- mere synchronous interconnection by means of AC links and
 - hybrid interconnection by means of AC links and existing HVDC back-to-back stations between the networks of UCPTE and CENTREL
- were considered.

Three-phase short circuits on interconnecting lines between UCPTE - CENTREL and on selected interconnecting lines and busbars in the CENTREL network have been simulated to assess transient stability. The maximum admissible fault clearing time defines the maximum time during which a three-phase

short circuit may last before calling forth instability of generators. The observance of fault clearing times must be ensured by protection devices and circuit breakers.

For the investigation of steady-state stability and the damping behaviour, sinusoidal disturbances of variable frequency were incited at the voltage controller inputs of power station generators in the CENTREL network.

Finally measures for the improvement of the stability behavior have been recommended.

6. GENERAL APPROACH

Considering the great importance of the study and the large number of investigations as well as the confidential character of data but also in view of the capacity available to the German interconnected power companies in terms of experts and their experience, computers and programs, it was decided to carry out the study within the framework of the DVG.

A group of experts was constituted comprising specialists from different interconnected companies. This group of experts divided the work according to contents and established a schedule. According to the agreement made in the East-West Executive Committee and with a view to splitting up work, DVG companies contacted interconnected power companies whose high-voltage networks had to be completely taken into consideration in the study. On the basis of bilateral contacts, they collected the comprehensive data required for the study. The subsequent preparation of data sets, data processing as well as the realization of calculations were also carried out by splitting up the work involved, though two DVG companies took charge of the major part of work. The other partners solved particular tasks (such as preparation of controller models).

A directive committee composed of leading engineers of the interconnected power companies defined the objectives of the study. This committee was regularly informed by the group of experts about the progress of work, and it determined the further proceeding.

On the occasion of regular discussions carried out for the purpose of coordination, the directive committee informed the colleagues from Austria and from the CENTREL countries about the results of the study and about the further proceeding. Besides, the volume and the structure of network and power station data which the DVG made available to the CENTREL partners for their own stability calculations were determined on this occasion in mutual agreement.

7. DYNAMIC MODELLING AND MODEL VERIFICATION

To limit the data volume, to confine the calculations to the transient phenomena important to the study and to reduce the computing time, the HV and EHV networks

were modelled by graduated degrees of reduction (Fig. 1):

- Real modelling, in most points, of interconnected networks and of the generating units supplying these voltage levels of the CENTREL countries and of the UCPTE countries adjacent to CENTREL as well as of possibly important 110 kV supply sources in the CENTREL network. The lines planned in accordance with the "Massnahmenkatalog" have been taken into account.
- Equivalent representation of the remaining UCPTE subsystems west of a line along Denmark - Switzerland - Slovenia. The network of former Yugoslavia has been modelled in its condition as before the outbreak of the Balkan war.

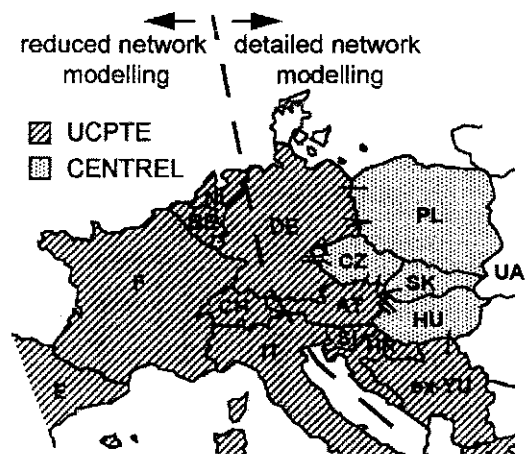


Fig. 1 Dynamic modelling with graduated reduction degrees

Calculations were based on a commonly used stability program that has proved to be a reliable tool in practice [7]. The complete data set included 325 synchronous machines and 1,600 system nodes for the peak-load case.

The reality of the simulation model has been verified by means of measurement recordings from interconnected system operation of UCPTE and by comparative calculations on selected trials of the CENTREL-system test carried out in September 1993 [8, 9]. To check the results of the preparatory work carried out to fulfil the "Massnahmenkatalog", CENTREL and the East German network still in parallel with the latter realized a first two-day test. To verify the simulation model the measured values were recalculated. Therefore the model was adapted to the network situation as during the system test.

Plausible results were also obtained from the recalculation of the unintentional temporary interconnection of the networks of UCPTE and CENTREL in January 1994.

Fig. 2 shows a comparison between the measurement recordings and the simulation results of the frequency. It can be seen, that the main characteristics are covered by the simulation model.

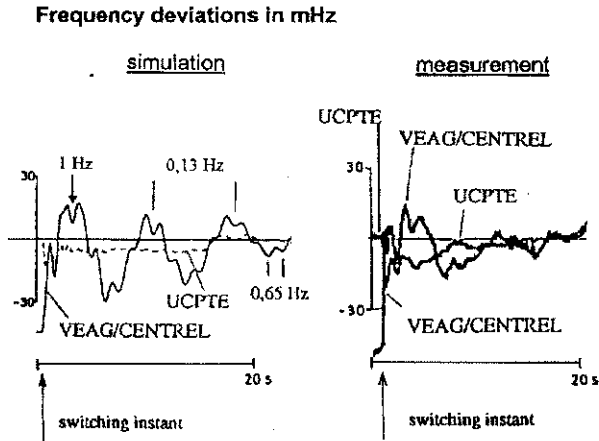


Fig. 2 Network coupling on January, 31, 1994 comparison of simulations and measurements

8. SELECTED SIMULATION RESULTS AND CONCLUSIONS

8.1 Transient stability

Starting from the basic load-flow for winter peak-load the following minimum values of admissible fault clearing times are obtained in the case of synchronous operation:

Short-circuit on busbar: 195 ms,
Short-circuit on lines: 200 ms

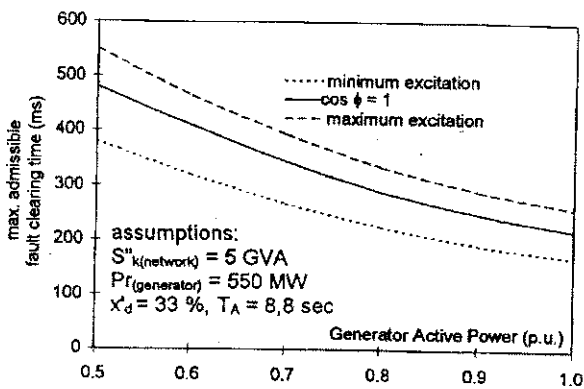


Fig. 3 Influence of generator operating condition on transient stability

Even in the case of additional power transports of 3,000 MW in a West-East or East-West direction and the hybrid operation mode, there are only insignificant changes of fault clearing times as compared to the peak-load case.

As compared to the peak-load case, it can be ascertained for the low-load that altogether fault clearing times are somewhat shorter. Nevertheless, marked increases or reductions in fault clearing times are obtained in individual cases. This is due, on the one hand, to the different influences of smaller generator excitation (reduction of fault clearing times) and, on the other hand, to a reduced utilization of generators (increase in fault clearing times, Fig. 3).

The studies about transient stability show that there is a sufficiently long interval between most of the determined admissible fault clearing times and fault remedy times of the 1st protection stage (150 ms) which can be achieved by means of protection devices and circuit breakers of the usual technical design.

8.2 Steady-state stability and oscillation behaviour

The stability study shows that after the connection of CENTREL networks to the UCPTÉ power system weakly damped power oscillations of low frequency may occur in the frequency range between 0.2 Hz and 0.6 Hz. These oscillations are not locally limited but spread both between the CENTREL networks and between the CENTREL system and the UCPTÉ power system (inter-area mode oscillations) (Fig. 4). The damping behaviour of these oscillations depends, among other things, on the number of interconnecting lines between the different interconnected networks as well as on the case of operation, the volume of power exchanges and on the network topology. As former experiences have showed peripheral networks weakly integrated into the UCPTÉ network are fundamentally more sensitive to oscillations.

Therefore, the study recommended to increase network damping in the CENTREL system. To this end, there are different possibilities available which can be subdivided into measures concerning generator control and measures taken in the network.

The most simple and economic measure consists in the use of Power System Stabilizers (PSS) as an ancillary device of the voltage controller. PSS have to dampen both the natural oscillation of the generator connected to the network, which is often in a frequency range of between 0.9 Hz and 1.5 Hz (local area mode oscillation), and the low-frequency network oscillations in a frequency range of < 0.6 Hz (inter area mode) [10].

Figures 5a and 5b show the damping effect of a PSS on the active power output of a Hungarian generator in the case of shutdown of another generator; the results were obtained from simulation and from measurements. The PSS has a very satisfactory damping effect on the local area mode (here about 1 Hz). The intended effect on the inter area mode (here about 0.5 Hz) is sufficient as can be seen from a comparison without PSS in Figure 5c.

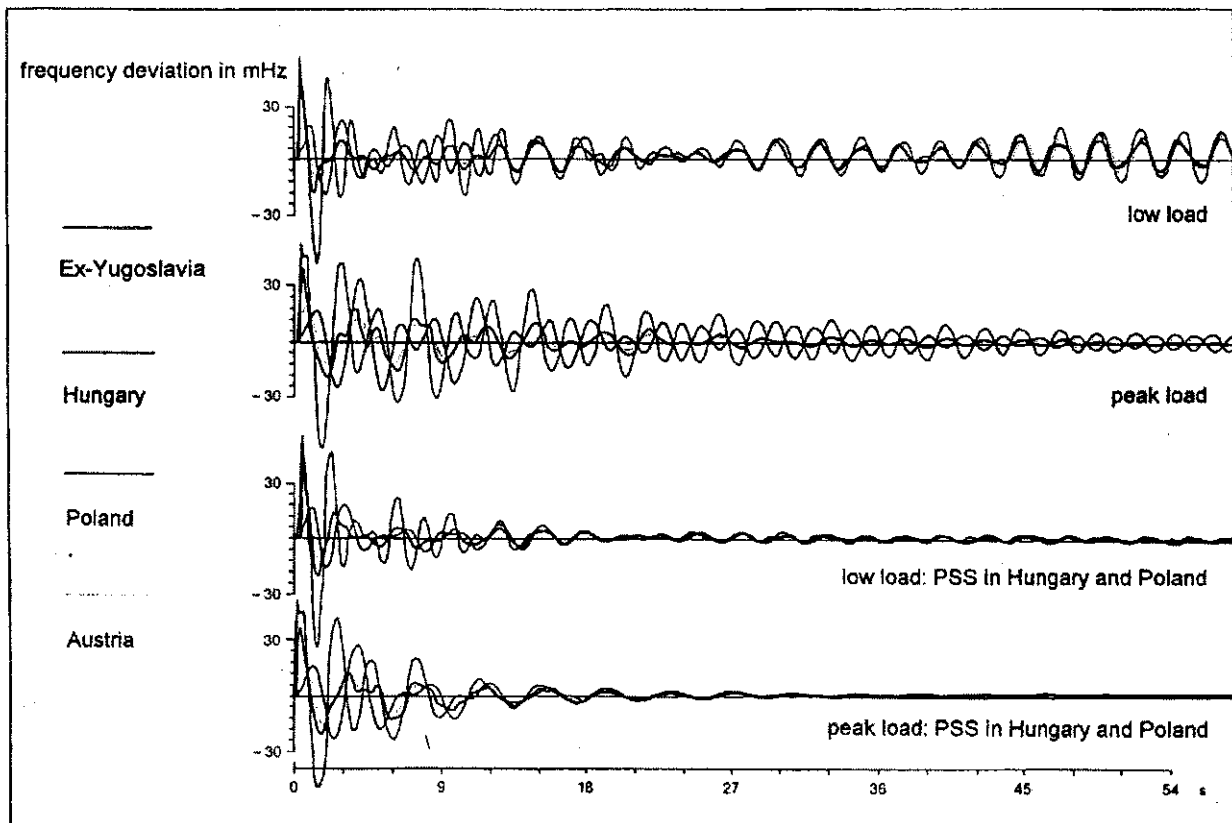


Fig. 4 Three-phase short-circuit in the CENTREL network
Fault duration 50ms

The damping effect of PSS is also revealed by the frequency response of the generator active power output for the generator under consideration with and without PSS (Fig. 5d).

In conclusion, the study about system dynamics shows that stable parallel operation of the CENTREL - UCPTE power systems is feasible if certain preconditions are satisfied.

8.3 Predetermined breaking points in Austria

The "Massnahmenkatalog" [3] mentions among other things the inter-Austrian 380 kV line from Vienna Southeast to Kainachtal. Owing to the resistance of environmentalists, this line is not likely to be realized before the year 2 000. This 380 kV link is of particular importance to Austria since it means an essential relief to the Austrian 220 kV network and in particular to the North-South interconnections. Even without synchronous parallel operation with the Czech and the Hungarian networks, the Austrian 220 kV network approaches already the admissible load limits.

In order to protect the Austrian 220 kV network against extreme overloads after decommissioning of the HVDC back-to-back links in autumn 1996 and until the commissioning of the 380 kV link from Vienna

Southeast to Kainachtal, particularly in the event of major disturbances, a predetermined breaking point with the CENTREL network is installed in Austria as a relief for the missing 380 kV link. In the case of overload on 220 kV lines, this predetermined breaking point is intended for automatic gradual disconnection from the CEZ or MVM network, respectively, provided that some additional conditions are met (plausibility controls) and that load can thus be removed from the endangered network area.

As stability analyses completing the DVG stability study have shown, it is unlikely that this Austrian predetermined breaking point constitutes a problem to the adjacent UCPTE network area.

9. TRIAL PARALLEL OPERATION CENTREL- UCPTE

In November 1993, problems occurred in the IPS/UPS system whereupon this system has split into three islands. One of them was the CENTREL system with East Germany and a small Ukrainian island. This was the form of operation carried out up to the time when East Germany was connected to the UCPTE. This two-year autonomous isolated operation was favourable to CENTREL with regard to the preparatory work that had to be done to fulfil the "Massnahmenkatalog".

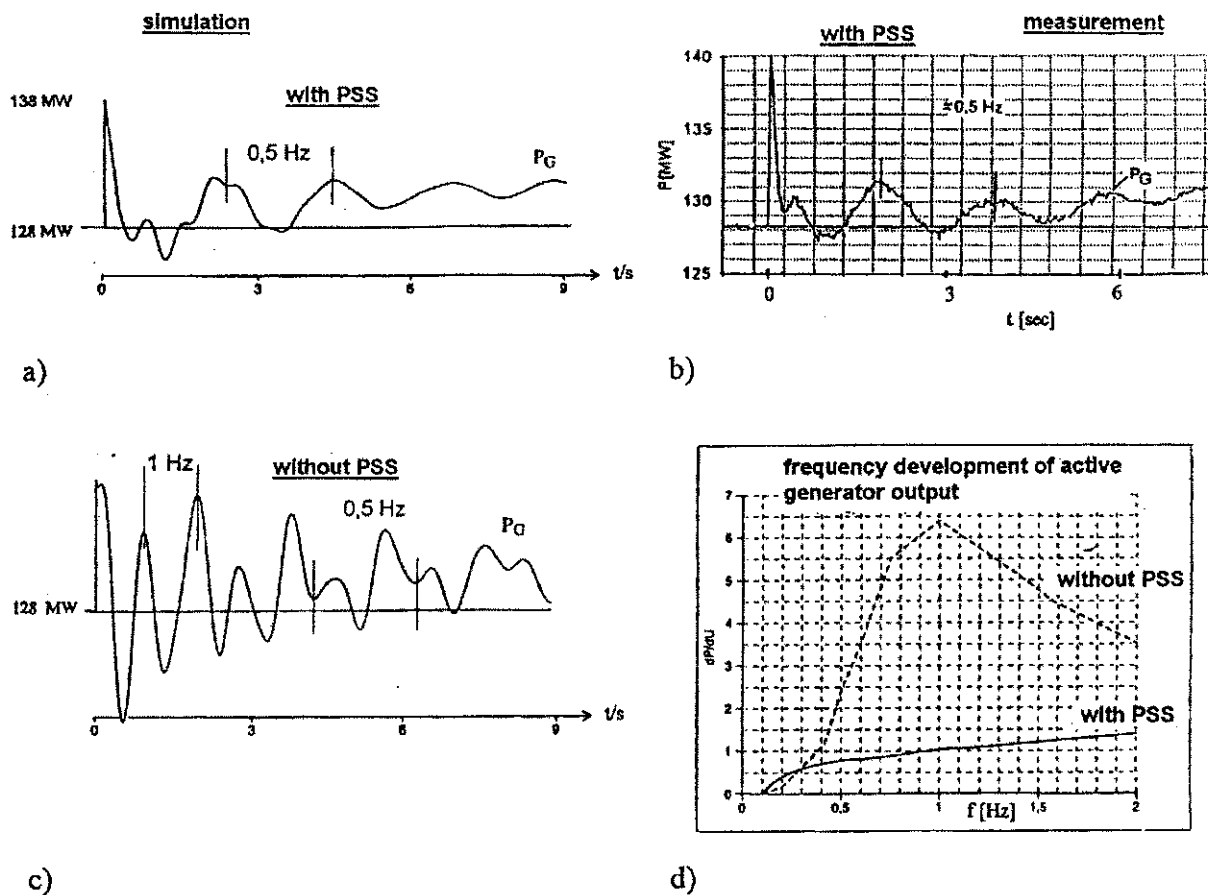


Fig. 5 Measurements and simulations to check the functioning of newly installed PSS in Hungary

A UCPTE recommendation [11] lines out the framework for operational tests to be carried out before planning an extension of the synchronous UCPTE interconnected network by direct connection to another network.

According to this recommendation, a two-week autonomous test was carried out by CENTREL, checking the operational quality in September 1995 after the changeover of East Germany to the UCPTE. The test was successful. In spite of the intended and unintended disturbances, the quality of frequency was the same as in the UCPTE power system.

In view of the results, the UCPTE accepted the trial parallel operation of CENTREL - UCPTE. The parallel operation was started on October 18, 1995.

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