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CERNAVODA N.P.P. INTEGRATION IN THE ROMANIAN GRID

Prepared by: Mr. R.C. Prodan
C.N.P.P. Control Room Operator

ABSTRACT: The intention of this material is to present our point of view about some specific matters that arise from having a relatively large power production unit (706 MW) connected to a National Grid in which the second largest units are only 330 MW.

The material consists in three major parts.

In the first section is presented the "big picture" of the Romanian National Grid.

The second section covers the role played by CNPP in the grid power balance and frequency/voltage adjustment. CNPP is located at the base of the daily load curve and thus not normally participating at frequency adjustment. CNPP also has a contribution in increasing the dynamic stability of the National Grid.

The third section is a more detailed presentation of CNPP behavior during grid upsets, with reference to the reactor and turbine control systems, and also the types of transients that our plant could induce to the grid due to internal malfunctions. The over-all unit control is based on the "reactor power constant" policy, all the fluctuations in the power output to the grid being compensated by the Boiler Pressure Control System. Some features of the Turbine Electro-Hydraulic Control System and how it interacts with the Boiler Pressure Control Sys. will also be presented.

The types of transients that CNPP could experience are reactor power setbacks (automatic ramped power reductions), reactor power step-backs (fast controlled power reduction) and unit trips, which are the most severe. There are two ways from the grid point of view to deal with such transients: to compensate the power loss by increasing the production and to disconnect unimportant power consumers. These actions are taken both automatically and manually (some details will be presented).

1. INTRODUCTION

The Cernavoda Nuclear Power Plant operates a P.H.W.R. CANDU 600 type reactor (main features: natural Uranium as fuel; on-line re-fuelling; two separate heavy water circuits, one is the moderator and the other is the fuel coolant). The heat transfer to the secondary circuit takes place in four vertical steam generators which deliver steam to the turbine-generator (General Electric; 706.5 MW; 1500 RPM; 24kV).

The output of the unit is in the 400 kV switchyard, which provides the connections to the National Grid via five overhead lines. There are also connections with the local 110kV-distribution network as back up for internal service supply. The average net power delivered to the grid is 660MW, the rest being used for internal services. The power delivered accounts for almost 10% of the grid in service power.

Although not the largest power plant in the country, C.N.P.P. has the largest production unit (more than twice the size of second highest-330 MW gross power units).

2. ROMANIAN NATIONAL GRID OVERVIEW

The big components of the Romanian National Grid are:

- The power production units (thermal, hydro and nuclear power plants);
- 400kV and 220kV transportation net-work;
- 110kV (and lower voltage) distribution network.

Most of the energy is produced in thermal power plants, which are using coal as fuel (generally low caloric power coal). The largest ones such *Turceni* and *Rovinari* consist of several 330 MW units (*Turceni* has 8*330MW, *Rovinari* 4*330MW and 2*200MW). There are also natural-gas-burning 330MW units and several other 200MW or smaller, which are using oil, gas or higher quality coal.

The hydraulic power plants represent also an important part in the energy production. The largest one is *Portile de Fier* on the Danube with 1050MW installed in relatively small units (~100MW) on the Romanian side, which is producing the cheapest energy in the grid.

The 400kV interconnections with power grids in neighbor countries are important for increasing grid stability and for economic purposes (import-export).

The National Grid Dispatcher in Bucharest and several steps of subordinated Zonal Grid Dispatchers conducts the National Grid operation.

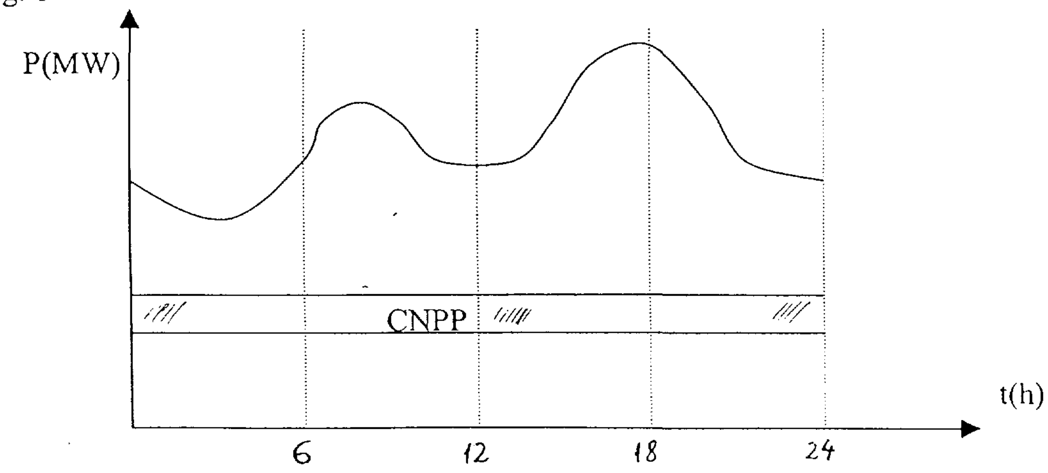
As we mentioned before, the largest conventional power units are the 330MW ones. C.N.P.P., with it's 706MW, delivering power via a rather complex switchyard (1.5 circuit breakers/circuit) directly into the transportation grid, is closely monitored by the National Grid Dispatcher being under he's direct coordination.

3. C.N.P.P. ROLE IN THE NATIONAL GRID

As we mentioned before, C.N.P.P. produces around 10% of the grid power. The production costs are smaller than in the fossil fuel plants. That is why C.N.P.P. is located in the bottom part of the daily load curve, and thus not participating at the "secondary" frequency regulation (i.e. adjustment of the frequency required due to the slow variation of the power demand during the day).

Fig.1 is a representation of a typical daily load curve. Hydro plants with accumulation lakes and some fossil fuel plants, which are producing at high costs, cover the top of the curve. Even though, in the periods of very low industry power demand such as winter holidays, C.N.P.P. is requested by the national grid to reduce the power, in order to allow the combined thermal-electrical power plants to stay at power and to provide heating for the major cities.

Fig. 1



The operation at reduced power is not desirable for C.N.P.P. on the long term due to the fact that the costs per kWh produced are increasing at low power, because the fuel represents only a small contribution to the overall costs while other expenses are rather constant, regardless of power. Investment reimbursement is especially a concern because of the high contribution in the cost.

Some technical issues now; C.N.P.P. has an important contribution to the dynamic stability of the grid. It means that during and after a disturbance in the grid such as short-circuit on a transportation line, our plant will help in maintaining the key parameters in the grid (voltage and also to some extent the frequency).

Some features that enable this, are:

- advanced voltage regulation system;
- fast acting turbine control valves (Electro-Hydraulic Turbine Control System will be referred later);
- large rotor inertia (comparative to smaller units).

Although the initial design included the possibility of automatic frequency control, operational tests revealed that this is not acceptable from C.N.P.P. point of view. That is because there are not enough "partners" in this process in the National Grid, so the plant will be forced to continuously vary it's load in a band of at least 20MW causing the reactor power to cycle in the same manner.

The decision was made to maintain the reactor power constant as a policy, and to adjust the turbine according to that by automatically sending a load set point for the turbine control system. This feature was also incorporated in the original design, but was considered as the "alternate" mode (second option). Further developments from grid and also from C.N.P.P. part would still be desirable in this matter.

Automatic voltage control, on the other hand, is an important feature and the grid is taking advantage of it by leaving to our plant the task of maintaining the voltage in the S-E region of the 400kV network. During a normal day the generator reactive power may vary from –80MVAr during low load hours to +50MVAr at highest load demand (the amount of reactive power produced or consumed gives the contribution to the voltage regulation in the grid). CNPP 400kV switchyard is also equipped with two 100 MVAR reactive power coils for rough voltage control.

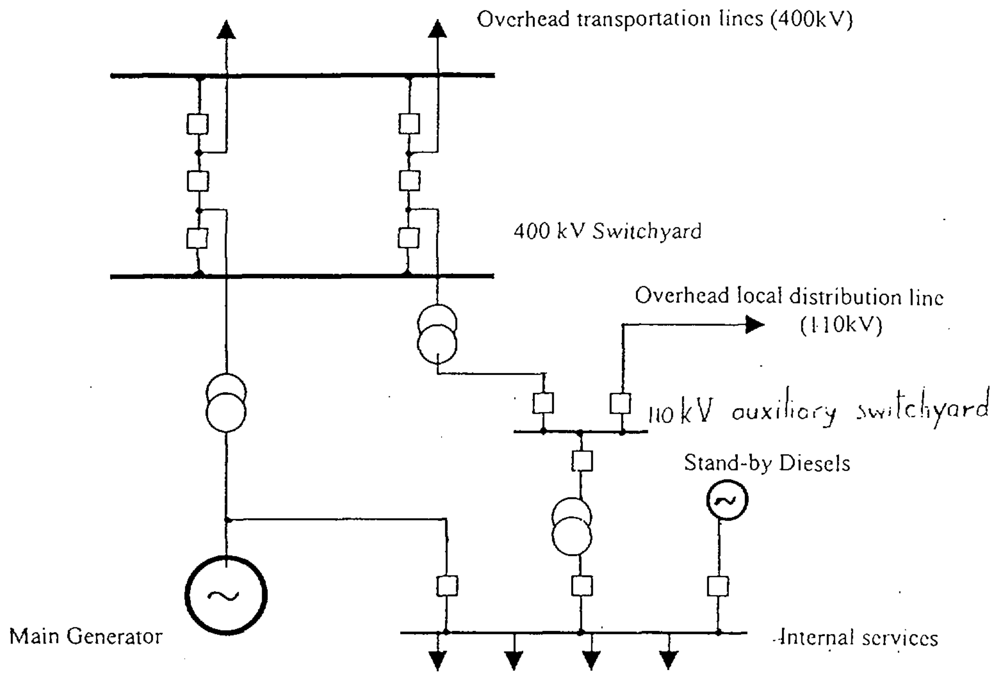
4. C.N.P.P.-GRID INTERACTION

4.1 GRID UPSETS AND EFFECTS ON CNPP

4.1.1 Load rejection

The most severe grid induced transient for CNPP is a total loss of output capability (total load rejection). This is the situation when the unit 400 kV breakers open in response to an electrical fault, leaving the Generator "islanded", with only the internal services as load. (This could also be combined with the loss of back-up services power supply if there is a more extended failure of the grid (zonal), in which case if the turbine also trips, the unit will rely on internal stand-by Diesel Generated power for services supply.)

Fig.2



This case is covered by the design of Unit control. When only the internal services (approx. 60 MW) suddenly remain as load for the generator, the large unbalance between the turbine driving torque and the Generator load, which is acting as a brake, will trigger the P.L.U. circuit (incorporated in the Turbine EHC System). This will send a signal to initiate a Fast Reactor Power Reduction (step-back) to 60% FP and also will open fully the turbine bypass valves to the condenser (which could only take 60% of full pressure steam load-reason for power reduction). In the same time, the EHC Sys will close the Turbine CVs on high-speed signal (5% variation of frequency required for full closure of CVs- regulation constant).

As the rotor slows down, the CVs will gradually re-open to maintain the rated speed. Re-synchronization to the grid after all plant parameters stabilize is now considered.

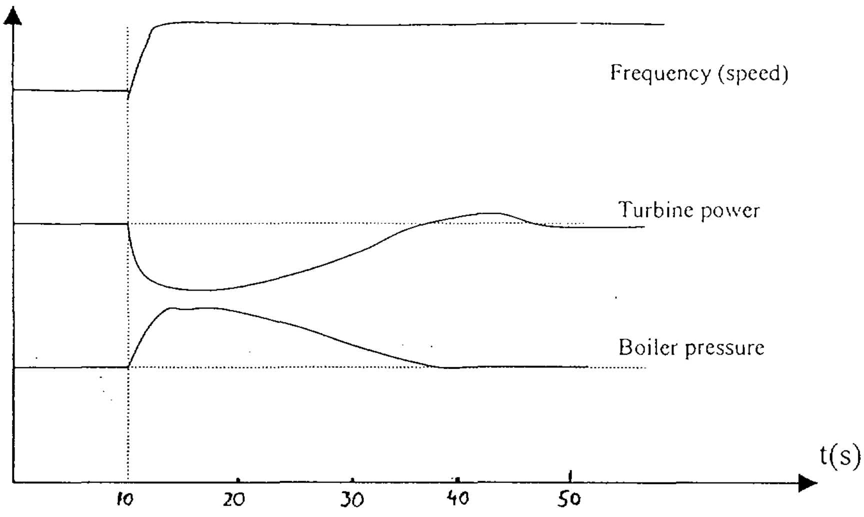
This type of transient will have an effect on all the major plant parameters. Boiler pressure will increase in the beginning due to the fast closure of the CV's even with the anticipating effect of the power reduction – there are 20 seconds delay for R. Thermal Power to be transferred to the secondary side so the rector power reduction will have somehow delayed effect. Also the primary side pressure will increase in the beginning but after the fast power reduction will decrease and recover after a while.

Partial load rejections are more likely to occur and we've experienced some since the begging of the commercial operation. They usually occur during strong storms or snowstorms, when transportation lines suffer damages causing separations of the circuits. If an important load for the grid, such as an interconnect line with a positive power transfer (export) is suddenly disconnected, the grid frequency will increase in the way shown in fig.3 (step increase).

As a consequence, the Turbine Control System senses the increase in Machine speed, causing the CVs to throttle in according to the regulation constant. The excess of steam in the boilers not being used by the turbine will cause boiler pressure increase (which will also cause P.H.T. pressure to increase).

The BPC System which normally controls the CVs opening according to the "Boiler pressure constant" regulation law but which is considerably slower than the EHC, will try to restore the boiler pressure.

Fig.3



There are two different situations from BPC Sys. point of view, both with the same result - boiler pressure return to normal:

-If boiler pressure increase is within the "dead band" of 0.7bar, the BPC system will gradually reopen the CV's regardless of the frequency. Nevertheless, this action is taken against the grid power requirement at the moment; The Grid Dispatcher will request other units to reduce the power (units that have been assigned previously for frequency regulation).

-If boiler pressure increases more then 0.7 bar, the SDV's will start opening and from that moment the BPC system will not have control over the CVs anymore. BPC will only control the SDV's to compensate the boiler pressure error, while the CVs will remain at approximately the value following the initial power reduction. Operator action will be required for turbine reloading, by increasing the load set-point of the T/G, action which will cause the closure of the SDV's and restoration of the BPC system control over the Turbine CVs.

It is important to mention that in both cases the reactor power is maintained constant at 100% FP, being considered that this is the safest and less material stressing approach for reactor operation, as long as heat removal capability is not jeopardized.

4.1.2 Loss of generated power

Another type of grid transient is a sudden loss of power production such as a big production unit or even an interconnection switchyard with several production units connected to it.

This will cause a step down is Grid frequency, causing the Turbine CVs to open further according to the regulation constant of the machine. After this fast initial response of the EHC system, the BPC system will gradually re-close the control valves in order to maintain boiler pressure at set-point.

The typical response is shown in Fig.5 (attached) which is a hardcopy of a monitoring display in CNPP Main Control Room where the response of the systems can be observed.

Description:
-Speed drop: –6 R.P.M. from (-3 to -9 RPM); rated is 1500
(Frequency drop: 0.2 Hz = 0.4% of nominal in 6 seconds)
-Boiler pressure drop: 0.3 bars/8 seconds, corespondent with power increase
-Boiler pressure recovery time: approx. 40 seconds.

We can also notice in Fig.6 the voltage drop which the automatic voltage regulator quickly terminated:

-Voltage drop at the generator terminals: about 0.6 kV (2.5% of Nominal)
-Reactive power transient: from –10 to –80 MVAR and return to –10 MVAR in 10 seconds.

4.2 CNPP TRANSIENTS AND EFFECTS ON THE GRID

From the point of view of this paper a transient in CNPP is an unplanned partial or total power reduction. This could take place due to various internal CNPP upsets. The nuclear safety-related issues will not be referred here because they are not a direct concern of the grid from operational point of view. Their only concern toward CNPP is to provide the safest configuration for power output and for plant back-up internal services power supply.

The unplanned power reductions at CNPP could take place either manually or automatically. When power is to be reduced manually, prompt prior grid notification is required in order to allow the grid dispatcher to take some "pro-active" measures. Manual power reduction may be required in response to non-vital process malfunctions (e.g. output transformers cooling problems).

Automatic power reductions would occur due to more serious process malfunctions that could affect the safe operation of the plant. Grid notification is also required in this case to communicate the status of the plant and the possibility of returning at initial power.

In our particular case, if a power reduction (from FPSS) below 60%FP occurs and the power is not restored above this value within 30min, the reactor will over-poison with Xenon (resulted from the disintegration of radioactive Iodine isotopes-fission products). This will cause a forced s/d of 40 hours until the Xe decays off. The phenomenon is caused by the low reactivity of the natural Uranium and is common to all the reactors of this type.

There are different types of automatic power reductions depending on the system that is actually involved in the power maneuver (control system or safety/protection system); there are also different rates for power reduction when control systems are involved.

1.Reactor

- Set-back: ramped power reduction with a specific end-point (60% FP, 8% FP, 2%FP) and rate (0.5% FP, 1% FP, 2% FP) depending of the initiating parameter; it stops at end point or when the triggering parameter returns to normal; Reactor Regulating System involved in reducing the power (control system).
- Step-back: fast power reduction with controlled end-point (60% FP, 2% FP, 0% FP); stops in the same conditions as the set-back but the end-point is not very accurate due to speed of process; Step-back routine executes the power reduction (control system).
- Trip: reactor goes deeply sub-critical and manual operator actions are required for resetting and re-poising the system even if the triggering parameter returns to normal; Special Safety Systems are involved in reducing the power (protection systems: SDS#1, SDS#2).

2.Turbine

- Run-back: ramped power reduction (15MW/s); 0 MW end-point; stops when the triggering parameter returns to normal or at the end-point; turbine EHC System executes the power reduction (control system).

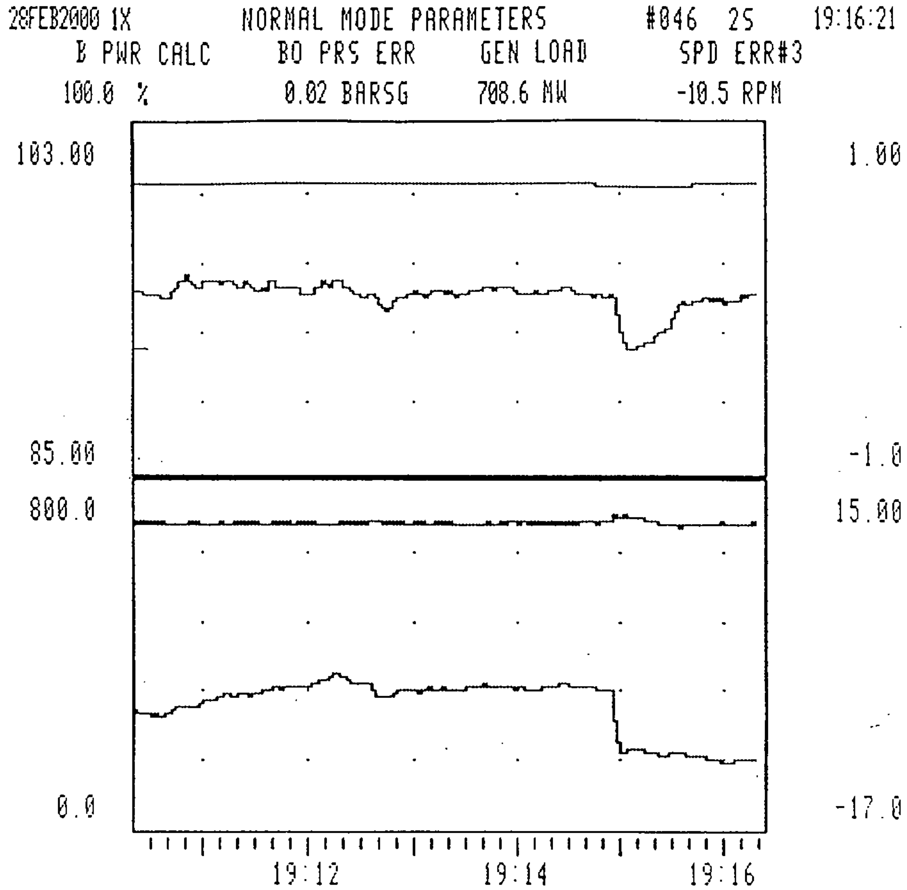
• Trip: all turbine valves slammed close, main breaker opens, field is short-circuited; operator actions required for reset and rearm (protection system).

The grid parameters will have different behaviors depending of the power reduction type. For trips and step-backs (being the fastest) the frequency and voltage will suddenly decrease and will be restored by automatically or manually loading the power plants designated by the grid dispatcher for frequency adjustment. If the frequency drop is sustained, sequential grid loads disconnection will automatically take place.

For reactor setback or turbine run-down, the grid dispatcher will have more time to take actions, avoiding grid operation transients.

Due to the fact that the interconnect lines with other systems are normally connected, the effects of loosing the power produced in CNPP are mitigated.

The aspects presented in this paper were intended to reveal some practical problems that result from CNPP-National Grid interaction. We can conclude that there are no unbeatable technical problems that could affect the operation of both together, especially when strong power connections exists between grids of neighbor countries. Nevertheless, it is desirable that with the over-all economic growth, several units of the same size to be built in order to provide increased stability in grid operation and also logistical support among them from operation and maintenance point of view.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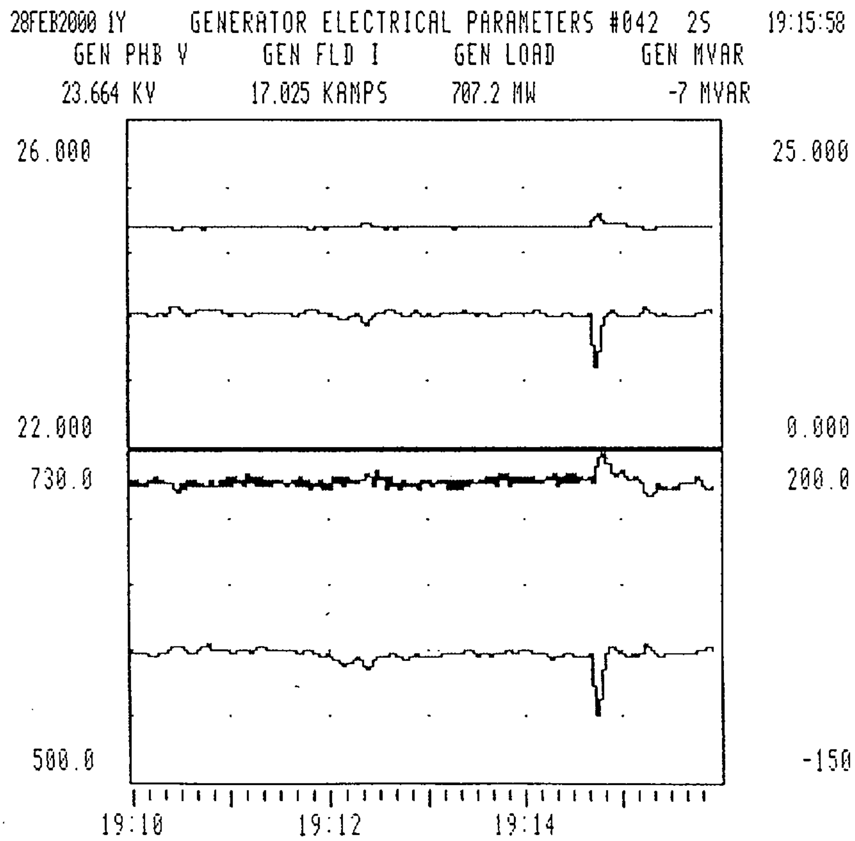
800.0
0.0
1.00
-1.0
15.00
-17.0
19:12
19:14
19:16

Fig. 4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22.000
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25.000
0.000
200.0
-150
19:10
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Fig 5