Sliding pressure operation of large conventional steam power units

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Abstract: - New condition in the energy market imposed changes in conventional steam units load curve coverage. From the classical base load this installations have been forced to migrate to semi base load. This element imposed a new way to operate, more flexibly, steam power plants. Classical operation mode for the existing sub critical parameter steam cycle is with constant live steam parameters (proper for base load curve coverage). The paper compares main plant parameters for the two operating modes in the case on an existing Romanian Power Plant. The paper is useful for the establishing of operating mode for existing conventional power plants.

Key-Words: - Conventional Power Plant, Steam Turbine, Constant Live Steam Pressure, Sliding Live Steam Parameters.

1 Introduction

Electric energy market liberation imposed a new way to operate coal power plants units. The tendency is to operate this units, not in base load (with constant and close to nominal load), but in semi base load (with important load variation). In the electrical system coal plants are participating more and more at primary and secondary tune. This element brought the discussion about switching constant live steam parameters operating to sliding live steam operating mode.

In constant live steam pressure operation mode, steam's pressure is maintained constant trough control stage admission section variation. In sliding live steam operation mode, the quantitative and qualitative control with control stages is aborted. In this case, inlet turbine areas remain constant, and the live steam pressures will naturally result, function of the live steam flows (turbine loads).

Constant live steam parameter versus sliding live steam parameters is an old problem. The main theoretical advantages of the second operation mode are [1]:

a) Pressure losses due to lamination disappear;

b) Steam turbines internal efficiencies (including control stages) are high for different loads [2,3];

Function of the constructive types of analyzed cycles, for some loads, running is more economic with sliding parameters.

The switch from constant parameters to sliding parameters operating modes can improve off design runs for the units. For example LMZ under critical parameter steam turbine K – 210 – 130 run better with sliding parameter operation, the heat consumption being reduced with 1.6 %.

Another advantage of sliding parameter operating mode is that efforts through high pressure components of steam turbines are reduced [5]. On a large scale of steam turbines loadings, complete admission on control valves assures uniform distribution of steam, and uniform temperatures on control stage. Lamination into control valves will induce high temperatures into control stages even for low steam turbine loadings. Using sliding parameter operating mode assure: greater flexibility, faster transition between diverse loads then with constant live steam operating mode, and metal fatigue into acceptable limits [4, 5]. In these conditions the steam turbines will be more adaptable for semi base load politics.

Advantages of sliding live steam pressures have influenced the last large steam turbine design. Table 1 present some examples of Europe's units operated in this way [6]. Similar operating models are present in Japan and USA [3, 7].

This paper objective is sliding live steam parameters operation mode analysis for one 330 MW, reheated, under critical, existing, steam turbine unit, frequent in Romanian Power Plants.

Location	Electrical output	Fuel	Live steam pressure
Heyden (Germany)	850 MW	Coal	Supercritical
Staudinger (Germany)	290 MW	Coal	Supercritical
Kristiina (Finland)	265 MW	Lignite	Supercritical
Hemweg (Holland)	680 MW	Coal	Supercritical
Landesbergen (Germany)	450 MW	Coal	Under critical

Table 1. Steam turbines units with sliding parameters operating modes.

2 F1L 330 MW Steam Turbine

This steam turbine is a reheat, condensing, action type, four cylinders, one shaft, and one condenser, designed by RATEAU – SCHNEIDER. High pressure cylinder has 11 stages, the first one is the control stage, intermediate pressure cylinder has 13 stages and the tow low pressure cylinders have tow fluxes each, with 6 stages. Table 2 presents the main parameters of this type of steam turbines and figure 1 present the simplified thermal circuit.

Electrical output, MW	330
Rotation speed, rpm	3000
Live steam flow, t/h	926
Live steam pressure, bar	182.4
Live steam temperature, °C	535
Steam pressure at HPC exhaust, bar	48.8
Steam temperature at HPC exhaust, °C	344
Steam pressure at IPC inlet, bar	43.7
Steam temperature at IPC inlet, °C	535
Condenser Cooling water temperature, °C	15
Boiler's Feed water temperature, °C	264

Tabele 2 F1L 330 steam turbine main parameters

3 Methodology

The sliding live steam parameter operation was analyzed with a mathematical model witch allow steam thermal circuit computation. The main components of the model are [8]: turbine process modeling, and feed water heating system calculus.

Control stage process was especially treated by this model because it is the main difference between the actual operating mode (constant live steam pressure) and the purposed operating mode (sliding live steam parameter operation).

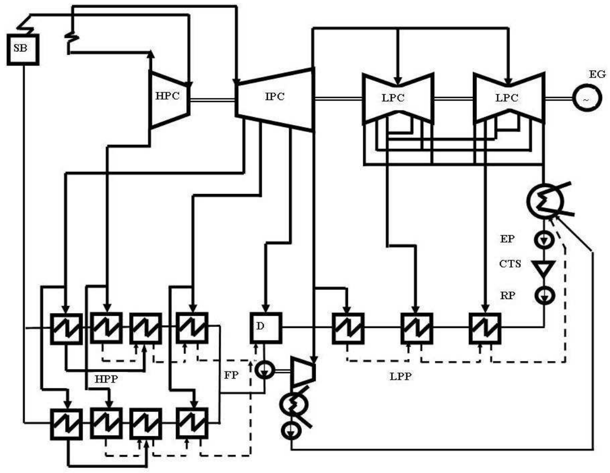

Figure 1 Simplified thermal scheme of the F1L 330 unit

SB – steam boiler; HPC – High pressure cylinder; IMC – intermediate pressure cylinder; LPC – low pressure cylinder; EP – extraction pump; CTS – Chemical treatment station; RP – reprise pumps; D – Deaerator; LPP – low pressure feed water heater; FP – main feed water pump; HPP – high pressure feed water heater; EG – electric generator.

Control stage steam feed is assured trough four control valves, unaffected by the operating mode (with or without sliding pressure), at design load those valves are completely opened.

In the case of constant live steam pressure operating mode, at partial load, the control valves are sequentially closed. The closing valve is characterized by exergeic losses through lamination. This process is shown in figure 2 (line 0 – 0”). We also see in figure 2 tow detention lines: one for the completely opened valves (line 0’ – 2’) and one for the closing valve (line 0” – 2”). Enthalpy at the stage end in the weighed mean between the tow processes.

In the case of sliding live steam parameter operating mode, all control valves remain opened for a large load range, lamination through valves disappear and energy loses in control stages diminish. In this case the detention line is 0’ – 2’ in figure 2.

Steam detention process in the rest of the steam turbine stages and the feed water preheat calculus are similar in the two cases, being presented in [8].

Based on the mathematical model, specialized software was developed. It admitted the analyses of different operating regimes for the 330 MW units.

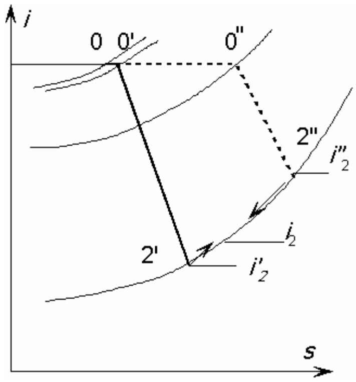

Figure 2 Control stage expansion line

4 Results and conclusions

Regimes analyses in the constant live steam pressure operation mode and, respectively, the sliding live steam parameters operation mode were completed in the following initial conditions (encountered in the most Romanian sites): the unit works with the complete feed water preheat system, the main pump is steam drive, condenser cooling water have 15 °C, electrical output varies between 130 and 330 MW, and live steam temperature and reheat temperature are constant and with design values.

4.1. Isentropic expansion efficiency of the steam turbine

Control stage internal efficiency at sliding live steam parameter operating mode is bigger then constant live steam pressure operation mode. This conclusion is a consequence of lamination process that misses in the first case (especially for low loads). See figure 3.

Most of the analyzed domain shows that the rest of HPC stages have greater efficiencies in the first case. The same conclusion is valid for IPC and LPC stages. See figures 4, 5, and 6.

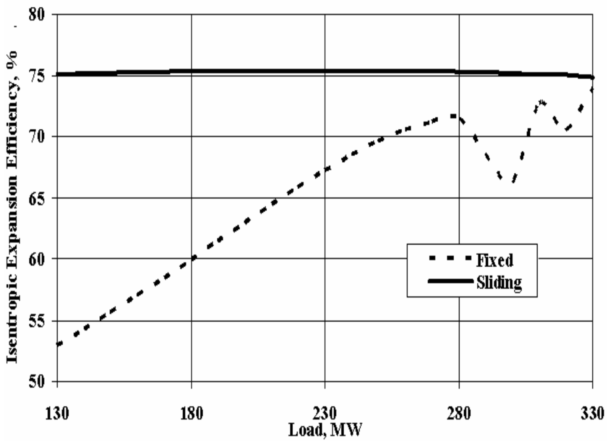

Figure 3 Control stage isentropic expansion efficiency load variation

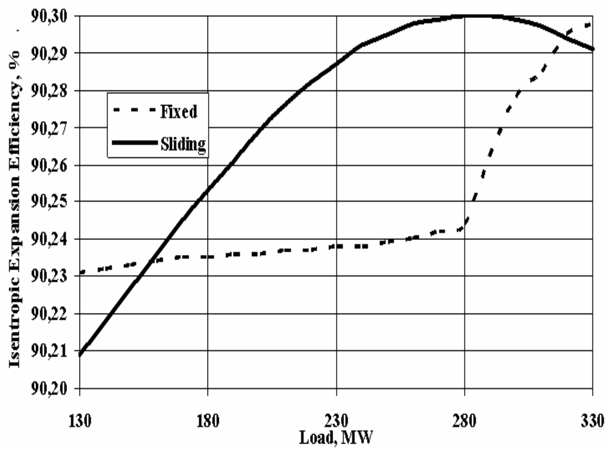

Figure 4 Pressure HPC stages isentropic expansion efficiency load variation

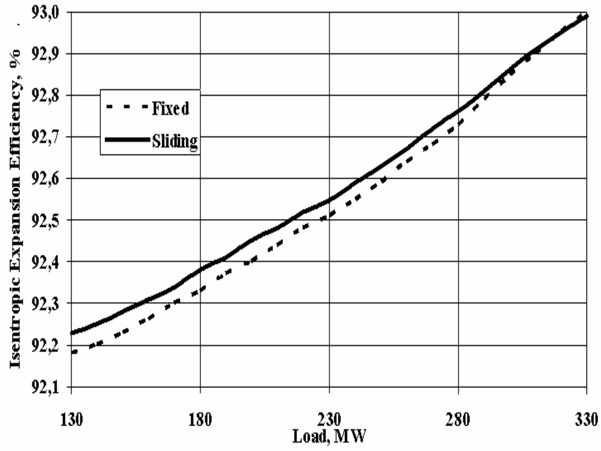

Figure 5 IPC stages isentropic expansion efficiency load variation

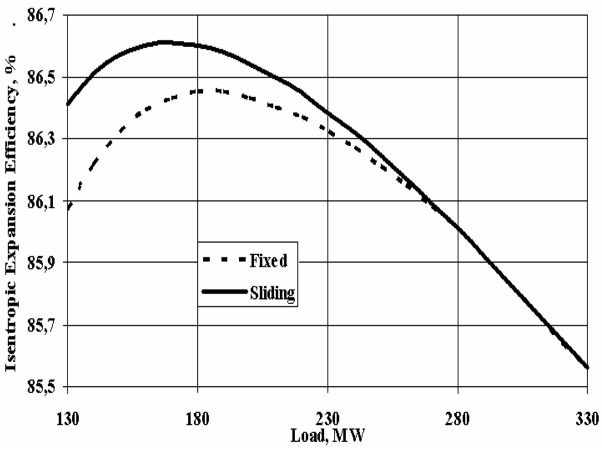

Figure 6 LPC stage isentropic expansion efficiency load variation

4.2. Thermal efficiency of steam turbine cycle

Thermal efficiency is influenced by the next two factors in the sliding parameter case: live steam parameter decrease and internal stages efficiencies growth.

On the analyzed domain the two factors have opposite effects on thermal efficiencies. There are no substantial differences between the cases. We underline the following: closely to the design operating mode live steam pressures in almost the same for the two variants. In the constant live steam pressure case laminations induce a slight reduction on efficiency because the last control valve does not open completely.

In the 200 – 310 MW range, live steam pressure reduction effect (in the sliding parameter case) is evident and thermal efficiency is bigger in the constant live steam pressure case.

In the under 200 MW range, lamination effect (in the constant parameter case) is stronger then live steam pressure reduction (in the sliding parameter case). For this reason thermal efficiencies are greater for sliding parameter.

See figures 7 and 8 presents live steam load, and thermal efficiency load variation.

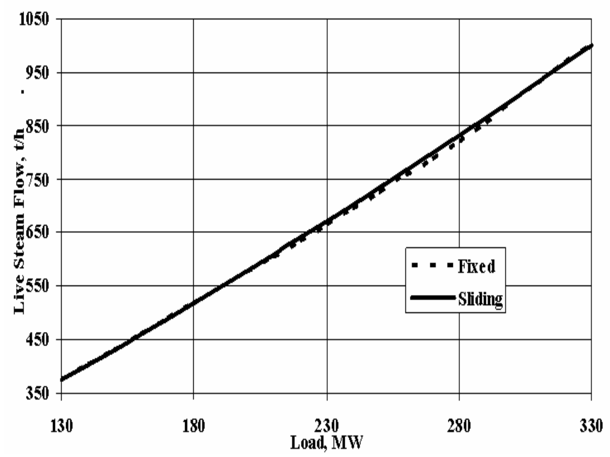

Figure 7 Live steam flow load variation

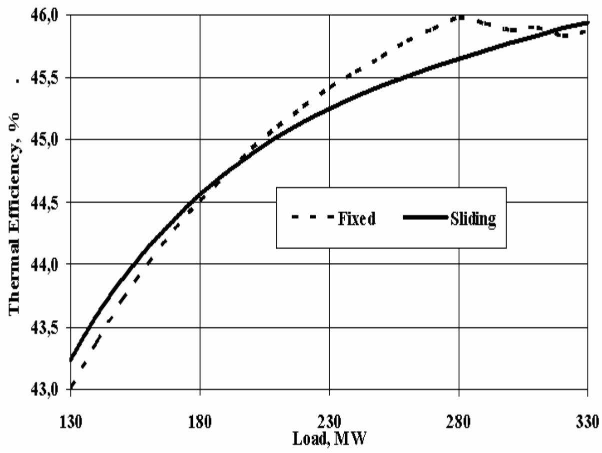

Figure 8 Thermal efficiencies load variation

4.3. 35 ºC condenser cooling water case

The analyses were repeated for the 35 ºC condenser cooling water case. (Figures 9 – 10).

At this cooling water temperature the steam turbine is unable to produce 330 MW electrical power. For this reason, on the following figures load will not grow to 330 MW.

Conclusions from previous analyses remain.

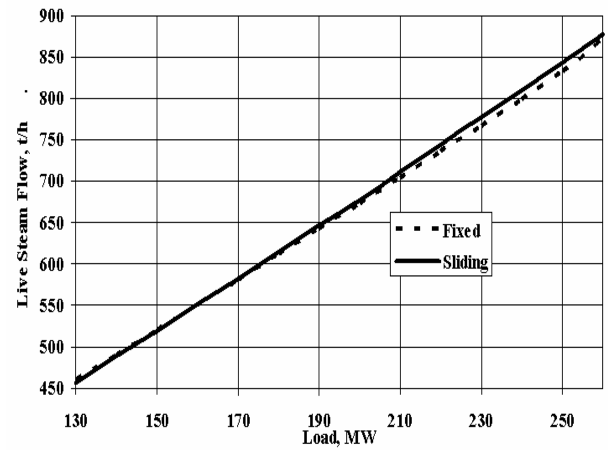

Figure 9 Live steam flow load variation (cooling water temperature 35ºC).

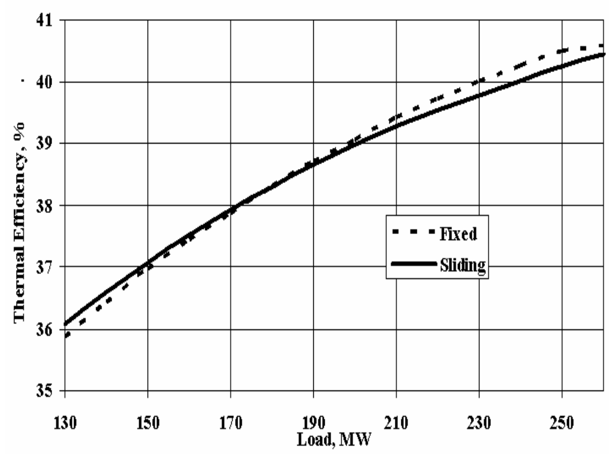

Figure 10 Thermal efficiency load variation (cooling water temperature 35ºC)

4.4. Conclusions

Live steam sliding pressure operation mode introduces two opposite effects on a conventional steam unit thermal efficiency:

- On one hand the thermal efficiency is decreasing due to the reduction of the live steam pressure.
- On the other hand the thermal efficiency is increasing due to the better behavior of the steam turbine control stage.

As a conclusion, live steam sliding pressure operation mode has not a major effect on the thermal efficiency. More than that, there are loads when this efficiency is even lower than in the case with constant parameter operating mode.

However, sliding live steam parameter operation mode assures better operation conditions for the steam turbine. The metal stress will diminish and the operation flexibility at partial loads will increase.

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