DIAGNOSTIC SYSTEM FOR PROCESS CONTROL AT NPP DUKOVANY LOAD FOLLOW

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Abstract

The NPP Dukovany is being operated in the frequency control since 1996. In last year a project for the plant load follow has been developed. One part of the project is to install a diagnostic system for process control. At present the main control loops of the plant control system are regular tested after unit refuelling only. The functionality and control system parameter adjusting is tested by certificated procedures. This state is unsuitable in view of the plan load follow operation. The relevant operational modes are based on minimisation of influence on plant component life time and on achievement of planned unit parameters. Therefore it is necessary to provide testing of main control system parts in shorter time period. Mainly at time when the unit is really in load follow operation. The paper describes the diagnostic system for process control which will be at NPP Dukovany implemented. The principal of the system will be evaluation of real and expected changes of technological variables. The system utilises thermohydraulical relation among main technological variables and relation among controlled and manipulated variables. Outputs of the system will be used to operational staff support at the plant operation. It enables:

- determination of control system state
- estimation and check of future control system state
- early indication of the deviation of process from normal conditions
- check of efficiency of operational staff intervention into plant control

The system gives the plant operator new information for the plant process control. Simultaneously the coupling of new system outputs on existing signalisation is solved.

1. INTRODUCTION

The NPP Dukovany is being operated in (primary) frequency control since 1996. Modification enabling the plant operation at extreme frequency deviations were implemented in 1996-1997. In last time the successful tests were performed which verified the developed solution which makes possible operation of NPP Dukovany units in secondary frequency control (power changes in range 100-90% P_{nom}) and in tertiary control (power changes in 100-50% P_{nom} weekendly in limited number of cycles per year).

The developed solution is a result of evaluation of load follow operation on the plant live time, on extent of necessary plant system modifications (I&C especially), on plant safety and on plant economy. The tests performed on the second unit confirmed the expected minimal influence of load follow operation on the plant system life time. On basis of this work a project was developed which defines modification in plant technological and in I&C systems and improvement in plant information and diagnostic system.

2. PRESENT STATE

The primary frequency control is operated within the range ±2,5% P_{nom} at average power level 97-97,5% P_{nom} at frequency deviation ±87,5% mHz. The change of turbine power is performed within time of 30 s after frequency change.

Introduction of primary frequency control meant implementation of following modifications in plant systems:

1) reactor and turbine power control (control of reactor power is provided by the self-power control)

2) completitions of operational procedures and of plant information system

3) development of computerised operator support (enabling easy malfunction distinguish)

4) development of procedures for automatic documentation elaboration (for the State Office for Nuclear Safety etc.)

The system of secondary frequency control in Czech electric network at present does not include NPP Dukovany because project of the NPP does not involve this control. The plant has no link with central controller (located in central dispatching) which performs evaluation of the power system balance.

The NPP Dukovany is operating in load diagram of constant steam pressure (at the whole unit power range). As far influence of load follow operation on primary circuit components life time this diagram is not suitable.

The reactor power control is performed by the sixth control roads group which has relatively stronght influence on reactivity. This makes not easy effective reactor power control.

Also the turbine has rather small reserve in control valves position which limits the achievable turbine power increase.

The tertiary power control can be at present provided at NPP Dukovany manually with minimal diagnostics with unpleasant influence into unit economy (accuracy of boron concentration changes etc.). The load diagram of constant steam pressure used in plant operation excludes operation in tertiary control in power range 100÷(75-50)% P_{nom} without boron concentration changes.

In accordance with the project the NPP Dukovany could not be operated at extreme deviated frequency. Measures enabling this operation were in the plant implemented in last years (1996-97).

3. ASSUMED POWER RANGES FOR FREQUENCY AND POWER CONTROL

Power range for primary and secondary control (without limitation number of power cycle)

Type of control	Control range of the NPP	
	P_{min}	P_{max}
primary control ±2,5% P_{max}	99	101,5%
secondary control	90	100%
primary and secondary control ±2,5%	94	99%

Power range for tertiary control

Power range	limiting boundaries
100-75% P_{nom}	without boron concentration change
100-(75-50)% P_{nom}	with partial boron concentration change at decreases power level

The tertiary power control operation is assumed for the weekend power control in very limited number of cycles only which enables the Technical specifications.

Simultaneous unit operation in secondary control, secondary and primary control and in tertiary control in not acceptable.

Operation in secondary and tertiary control is planned so that the present length of fuel cycle will be not changed.

4. ASSUMED HARDWARE MODIFICATIONS IN UNIT SYSTEMS NECESSARY FOR FREQUENCY AND POWER CONTROL

The following unit system modifications with be performed:

- establishment of new load diagram (increased steam pressure at decreased reactor power)
- development of criteria (or limits) for implementation of the unit into load follow operation
- modifications in I&C instrumentation
  - turbine power and turbine by pass controller
  - reactor power controller
  - reactor power limitation controller
  - new steam flow measurement (behind the steam generator and ahead of turbine)
- implementation of new modules in I&C
  - organiser of secondary control (assures the link between the terminal installed in the central control dispatching and the turbogenerator, establishes boundary conditions for the plant operation in load follow

  - block adjusting the steam pressure flow set point (for the turbine and reactor controller)

- modifications of the plant technological system enabling
  - adjusting and check of new modules after refuelling before the start up
  - running check of new modules after refuelling
  - statistic evaluation of technological variables changes at load follow operation
  - evaluation of load follow on selected component degradation
  - elaboration of records documenting new operational mode for the regulatory body

- modification of diagnostic system
  - diagnostics of material degradation (described in chapter No. 5)
  - diagnostics of correct control system function (described in chapter No. 6)

- development of modifications in operational and project documentation

5. DIAGNOSIS OF TECHNOLOGICAL COMPONENT LIFE TIME AT UNIT LOAD FOLLOW OPERATION

Introduction of NPP Dukovany in to load follow means the increase of transients with rather strong change of reactor and turbine power. This contributes to:

a) increase of number of controller actions (influence on reliability)

b) increase of failures of control road and control valves

c) decrease of life time by low frequency fatigue

d) increase of transient which could lead to the Technical Specification violation

e) increase of probability of incidents

To reduce the negative influence of load follow operation on technological systems, the unit load diagram of unconstant steam pressure will be applied. The load diagram will be characterised as follows:

- the steam pressure increase with decreasing power will be done with respect of transients (the steam generator safety valves will be not readjusted)

- the decrease of thermic turbine efficiency will be compensated by the steam pressure increase

- the inlet coolant temperature to the reactor will be in the power range 100-50% P_{nom} almost constant

- lower compensation of reactivity at power changes will be achieved (decrease of control rod position movements)

- decrease of primary circuits controllers inputs into process

The following diagnostics which aims to reduce the negative influence of load follow (see items a, b, c, d) will be implement at the NPP Dukovany:

5.1. On-line registration (filling) operational modes connected with primary, secondary and tertiary control and with „island operation“

The present way of registration of operational modes is performed from point of view:

a) check of the Technical specifications at plant operation

b) documentation development and additional analysis of transients

It is planned to extend this way to:

a) on-line SW - processing of selected analogy technological variables

b) calculation of unmesurable variables (boundaries and limits of the plant regarding to the load follow)

c) estimation of selected values of variables and substitution of wrong values based on informational redundancy

5.2 Monitoring of selected types of failures and material degradation of plant components

The material degradation monitoring of main plant components is at present performed by manual registrating of unit transients number and by its comparing with allowed numbers. Computation of material degradation is then performed consequently.

Main task of monitoring of load follow operational conditions is to distinguish individual unit states and transients from load follow transients (primary, secondary and tertiary control).

The following technological equipments will be monitored:

– reactor vessel (surfice of the vessel in axial direction, cold and hot part throat of the vessel)

– primary circuit (inlets and outlets of the primary circuits)

– steam generator (feed water inlet throat, bottom part of steam generator vessel)

Measured values will be stored and off-line evaluated by diagnostic system DIALIFE. This system is at present under development in Czech republic (Institute for Applied Mechanics, Brno). This system provides temperature and tension analyses and from achieved results makes assessment of technological components degradation.

The system will be completed in phase of load follow project implementation by following functions:

- data estimation. It will assure, that for the component material degradation only estimated data (checked to be correct) will be used. The method based on mutual physical links between individual values will be applied

- correct operational modes classification. It will provide classification of transients to be able distiquish and select transients caused by usual failures, by manual control and transients caused by unit operation in primary, secondary or tertiary control

- automatic reports development for the documentation (for ownerof the plant, for the regulatory body)

Structure of DIALIFE implementation into the diagnostic system is displayed on Fig. 1. The three abovementioned functiones remove influence of plant personnel on results of the evaluation and enable automation of the work. The estimation of data measured by 800 temperature sensors and operational modes classification will be performed by unamtignous defined rules. Data processing will be also more convenient.

6. DIAGNOSTIC OF MAIN CONTROL LOOPS CORRECT FUNCTION

6.1 Requirements to diagnostics of main control loops

Implementation of control loops control results from following requirements:

- quality of frequency and unit power control must be done so that electrical power grid requirements are achieved

- the unit transients must be done so that following requirements are fulfilled
  - real material degradation of main technological component corresponds to the project analyses
  - real boron concentration change at power transients corresponds to the project calculation
  - short term increase of the reactor power over nominal power is achieved by combination of road control and self power control without unexpected switch of the reactor controller in to other operational modes

The check of the control system which can fulfil these requirements will be of two kinds:

- check of the system at shut down unit conditions (unit is not operating), i.e. check of signals and their transmition, adjusting of important values of the control system. This check will assure achievement of important assumptions for corret function of the control system at real plant transients

- check at operating unit, i.e. check that real changes of technological variables and movements of actuators are as expected by project analyses.

The check of control system at operating unit is performed at changing unit condition (change of unit dynamics at burn up process, influence of small mulfunctions, ageing of control system components, etc.).

6.2 Diagnostics at not operating unit conditions

The diagnostics will concern to:

- unit operation at secondary control, simultaneous secondary and primary control and tertiary control
- unit operation at extreme frequency deviations (unit transient into „island operation", operation in the „island" and connection of the unit to the restored power network.

The check will be performed at refuelling and before unit start up. The tests of systems, procedures of their implementation, methods of evaluation are prepared to be developed.

As an example, importance of this kind of diagnostics confirms an analysis of turbine switch tests performed at unit No. 2 in 1996 and in 1997. At these tests the turbine power time behaviour was the same but the turbine speed exceed was different. According to the turbine manufacture it was caused by degradation of turbine back clap valve.

6.3 Diagnostics at operating unit conditions

From requirements to I&C system modification related to the unit load follow operation the following control system equipment will be checked

- block of steam pressure setting (new block which creates the steam pressure deviation according to the new implemented load diagram for individual controllers
- turbine controller. The controller assess fulfilment of requirements to the power unit changes
- pressurise pressure water level controller. The role of the controller is very important because it can minimise temperature changes in bottom part of the component and minimise the material degradation
- primary pressure controllers. The controllers can minimise primary pressure deviations and influence the pressurise pressure degradation
- water niveau control in the steam generator. The controller must assure stable operating conditions for the steam generator at the unit power control
- reactor power control. Reactor power control will be performed by combination of road control and by self-power control
- secondary unit control organiser. The block will calculate the boundary conditions for secondary, primary and secondary and for tertiary control

6.4 Method of diagnostics of the control system correct function

The method of the diagnostics of selected controllers or modules will be based on comparing of expected state of technological variables with real (measured) state. The expected state of technological variable will be stated by calculation (mathematical simulation, etc.).

The input signals for the diagnostic system will be taken from technological information system after their estimation on quality.

Structure of the control loops diagnostic is displayed on Fig. 1.

7. CONCLUSION

The establishment of NPP Dukovany units in frequency and power control leads to new requirements on increase of the plant diagnosis level, i.e. introduction of new functions and outputs which the present system does not fulfil. Further there are new demands on higher quality and correctness of diagnostic system outputs (information) for the operator support. Simultaneously it is required an objective evaluation of the load follow operation on plant systems (degradation, life time etc.).

Fig 1 Structure of proposed NPP Dukovany Diagnostic system