EVOLUTIONARY ALGORITHM BASED POWER PLANT WORKING POINT OPTIMISATION USING PLC AND SIMULINK MODEL

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Abstract

The contribution describes an application of power plant working point optimisation, which runs on the industrial control systems and the power plant is modeled in real-time in Matlab/Simulink. Each block of the power plant (turbo-generator, steam producer) has its own cost characteristics (produced power / costs) and our aim was to calculate continuously the optimal distribution of power production for each block of the plant in order to cover the required and continuously changing power production of the entire plant. The optimisation procedure is based on the genetic algorithms and it runs on an industrial programmable logic controller (PLC). The models of the turbo-generator and steam producer are in Matlab/Simuling (with Real-time toolbox) and the controllers are industrial PLC's.

1 Introduction

In the power plants various types of turbines and generators are used, depending on the type of energy sources and other technological and construction conditions. Each turbo-generator and steam producer for the turbine has its own cost characteristics, which represents the dependence of the costs (Eur) on the produced electricity power of the block (MW). The aim of the efficient production is on-line setting of each power-plant block in such a working point, that the power production of the entire power plant covers the required power demand with contemporary minimisation of all production costs.

In our application the optimisation algorithm is based on genetic algorithm and the computation is realised on a powerful industrial PLC. It calculates set-points of steam producers and turbo-generator controllers of particular blocks. The power plant blocks are modelled as numerical models in Matlab/Simulink and the controllers are standard PLC's. The Matlab/Simulink model has been used for the development and tuning of all control and optimisation algorithms running on the PLC's. The algorithm is able to optimise the working points of practically unlimited number of power plant blocks with various power/cost characteristics.

2 The power plant control

Block scheme of the power plant control is in the Fig.1. The upper control level (optimisation) receives the desired electricity power value P_D of the entire plant from the Electricity System dispatcher (Secondary power control level). The production of the electricity power is ensured by N generators, which summary electricity power is P_{el}. Each generator is mechanically coupled with a steam turbine. The turbines are supplied from M steam producers, which summary mechanical power is P_{mech}. The following condition should be fulfilled

$$P_D = P_{el} = P_{mech} + P_{loss}$$

where P_{loss} are losses in steam transport and energy transformation. Each turbo-generator and each steam producer has its own cost characteristics, which can be approximated by quadratic function in the form

$$C_{mech,i}(P_{mech,i}) = a_i P_{mech,i}{}^2 + b_i P_{mech,i} + c_i \text{ ; } i=1,2,...M$$

$$C_{el,j}(P_{el,j}) = d_j P_{el,j}{}^2 + e_j P_{el,j} + f_j \text{ ; } \qquad j=1,2,...N$$

where C_{mech} are the costs for steam production (Eur), C_{el} are the costs of electricity production (Eur), $P_{mech.i}$ is the mechanical power of the i-th steam producer (MW), $P_{el,j}$ is the electric power of j-th generator (MW), *a,b,c* and *d,e,f* are real constants, *N* is the number of currently used turbo-generators, M is the number of currently used steam producers in the power plant. The goal is to minimise total production costs C

$$C = \sum_{i=1}^{M} C_{mech,i}(P_{mech,i}) + \sum_{j=1}^{N} C_{el,j}(P_{el,j}) \rightarrow \min \tag{1}$$

under ensuring the desired power production of the entire power plant

$$P_D = \sum_{j=1}^{N} P_{el,j}$$

and

$$P_{mech} = P_{el} + P_{loss}$$

According the cost characteristics of particular blocks the optimal working points of power production for all currently used turbo-generators and steam producers is calculated. After each change of the P_D the minimisation algorithm using genetic algorithm is calculated on the PLC (B&R SYSTEM 2005) [1]. The outputs of this step are the new set-points of particular turbo-generator controllers and steam producer controllers (PLC Simatic S-200) [2]. In our case the turbo-generators and steam producers are modelled using Matlab/Simulink with the Real-time toolbox and analog I/O.

3 Optimisation algorithm

As mentioned above, the genetic algorithm [3,4] has been used for the optimisation calculation. The algorithm is characterised by the following steps:

1. initialisation of the population
2. fitness (cost function) calculation of each individual of the population
3. selection of parents and their crossover = children1
4. mutation of children1 = childern2
5. completion of the new population from selected old individuals and children2
6. jump to step 2

Each individual (chromosome) of the population is in form:

chromosome = [$P_{mech,1}$, $P_{mech,2}$, . . . , $P_{mech,M}$, $P_{el,1}$, $P_{el,2}$, . . . , $P_{el,N}$].

Real coding of the chromosomes has been used. The fitness represents the evaluation of equation (1). The population size used in this application is set to 20. Number of parents selected for crossover is 14. The mutation rate is 0.1. The best individual of the actual population is copied into the new population.

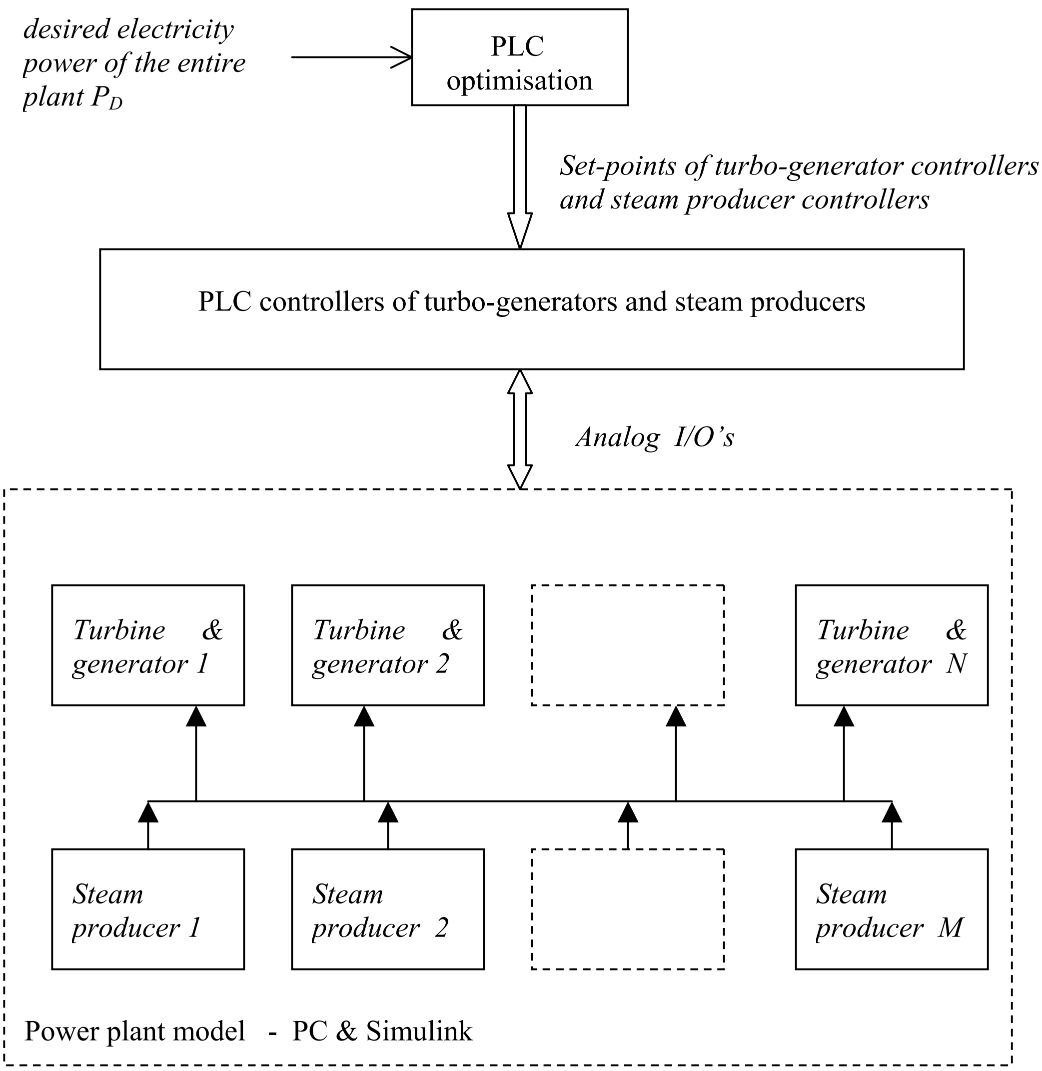

Figure 1: Power plant control

4 Experimental results

The presented application has been tested on a model with 2 or 4 blocks. The desired value of the produced power of the plant P_D has been changed during the experiment. After each change the optimisation procedure has been started. The computation time of the optimisation procedure takes approximately 80 seconds, where the new set-points have been calculated. The time responses of power after P_D change from 240 to 300 MW are depicted in the Fig. 2. In the Fig. 3 the time responses of P_{mech} are shown (graphical output from Simatic software).

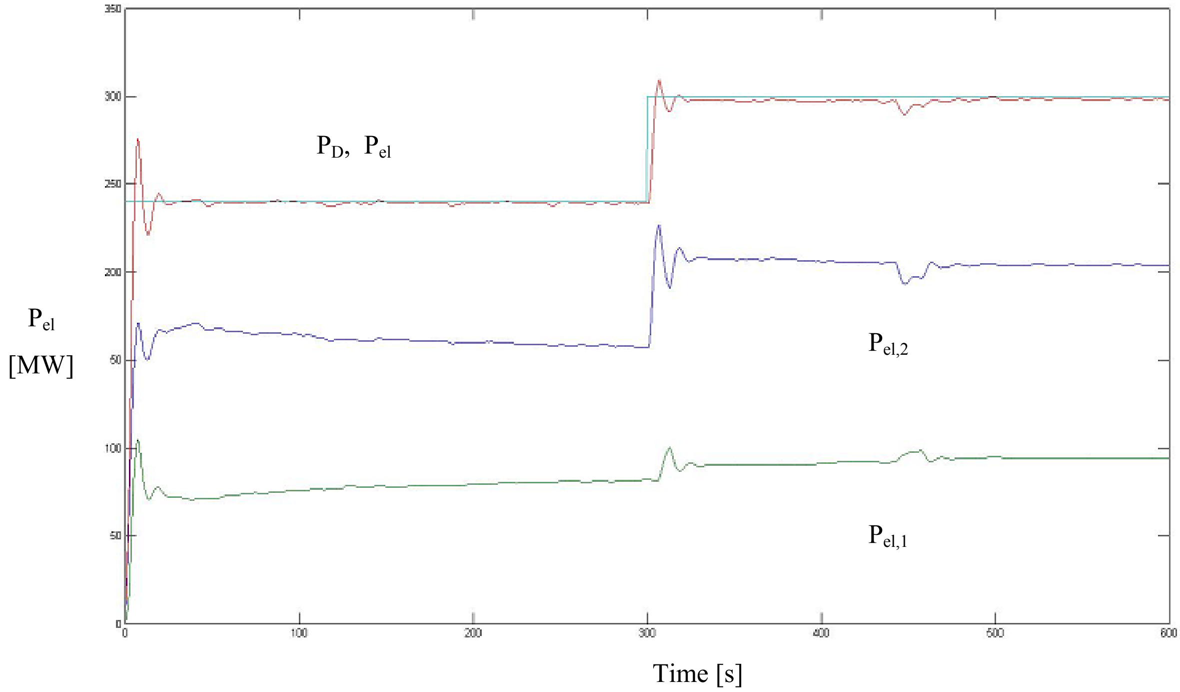

Fig. 2 Time responses of P_{el} after new optimal set-point calculation

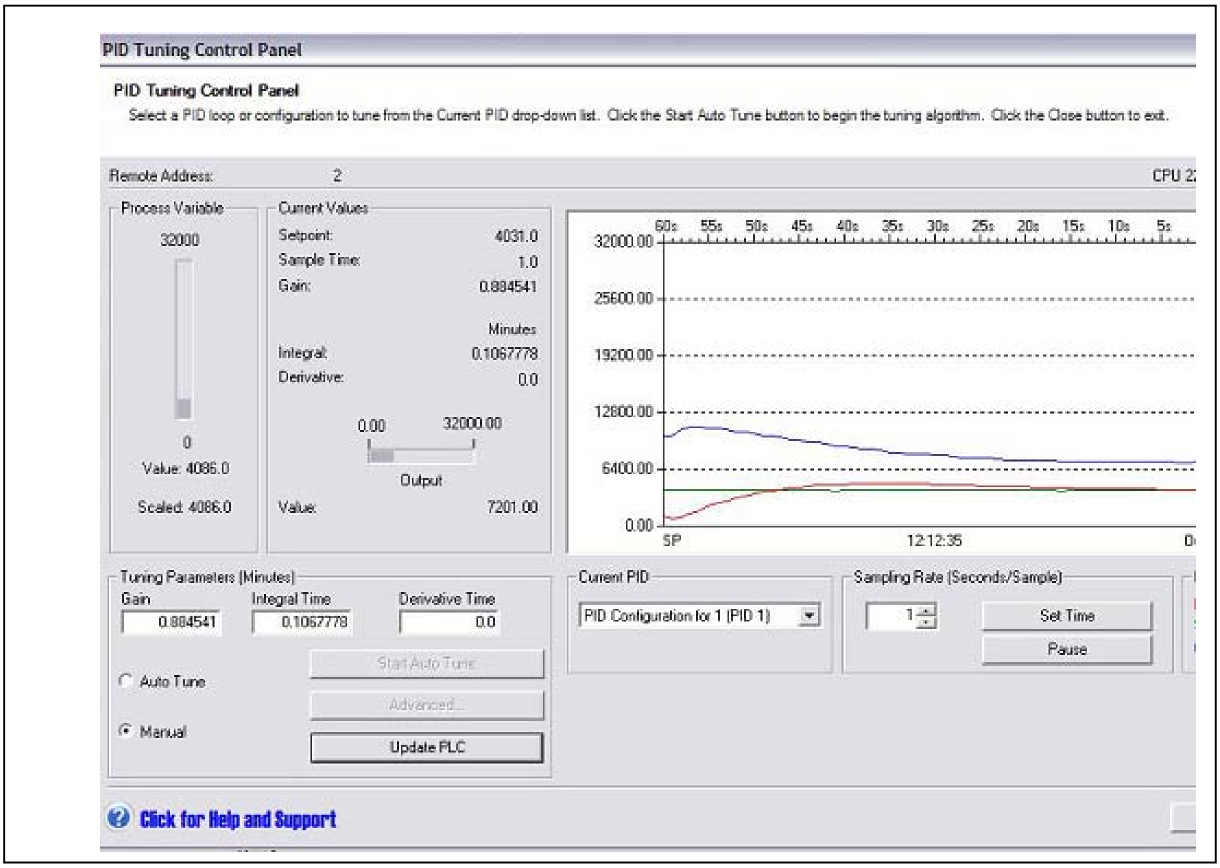

Fig. 3 Time responses of P_{mech} after new optimal set-points calculation

5 Conclusion

The aim of the project presented was to apply genetic algorithms for minimisation of the production costs in the power plant control using industrial control systems. Because of high computational complexity of the algorithm a powerful PLC has been used. The real turbo-generators and steam producers has been replaced by the dynamical model in Matlab/Simulink with real-time inputs and outputs. The turbo-generators and the steam producers are controlled by standard PLC's using PID algorithm. The genetic algorithm is a powerful algorithm, which is able to solve such minimisation tasks of the power plant with many (tenth) operating blocks.

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