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INTEGRATING ISSUES OF POWER SYSTEM SCHEDULING AND OPTIMAL POWER FLOWS PROBLEM

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ABSTRACT
This paper presents problem of integration of short-term power generation scheduling problem and optimal power flows. The task of short-term power generation scheduling in the power system is to minimize the total production costs, which should satisfy demand and required reserve in the system as well generation constraints of all units in the system. Generally the requirements for constraints such as the transmission network constraints, already incorporated in the formulation of problems, detailed models of the network are not considered in these problems. To solve this problem the multiphase iterative method is proposed. The basic idea of the multiphase iterative methods for solving the integrated problem-type short-term scheduling/OPF-problem is set schedule problem and OPF problem in a different optimization phases. The results of the first phase are used to change the parameters of second phase. In this way the problem is decomposed to standard short term generation scheduling problem and series of OPF problems, one for every hour. This paper proposed specific approach to obtaining primal feasible scheduling of generation units which can support primal solutions. Possible solutions which are in relation with these schedules can be obtained by solving OPF problems for each hour.
Keywords: scheduling, multiperiod, duality, optimal power flow.

1. INTRODUCTION
The task of short-term power system scheduling in the power system is minimize the total production costs, which should satisfy demand of the system and required reserve in the system as well as individual limits of the units during the period,[1],[2].
OPF can be a specific goal, such as short-term loading/generation scheduling system. However, OPF considers only one moment of time.
In the general case it is not possible to model the time-related restrictions. Inability to determine the hydro-coordination may be one of the main difficulties in practically applications OPF,[3].
With deregulation and open access to the system as a global trend, there is increasing demand for optimizing not only the work of hydro-thermal coordination in the system, but also optimize the use of the transmission network. Thus integration of short-term planning and OPF is becoming inevitable,[3].
Integration of short-term power system scheduling and OPF problem is based on multiphase iterative method. The basic idea of the multiphase iterative methods for solving the integrated problem-type short-term scheduling/OPF-problem is set schedule problem and OPF problem in a different optimization phases. The results of the first phase are used to change the parameters of second phase. In this way the problem is decomposed to standard short term generation scheduling problem and series of OPF problems, one for every hour. This method is also known as decomposition method.

2. MATHEMATICAL FORMULATION

In this paper the power system with N aggregate, which includes turbo and hydro-generators and pumping plants is considered.

The aim is to minimize the total cost of production during the active time horizon. Minimization is carried out with the satisfaction of constraints such as demand and reserve, transmission network constraints including power flow equations and limitations of each aggregate. An interval is one hour and the planned time horizon T can vary from one day to one week. Integrated problem is formulated as a mixed integer problem.

Objective function: the cost of production of the active power

$$f = \sum_{t=1}^{T}\left[\sum_{i=1}^{I} C_i\left(p_i(t) + S_i(z,t)\right)\right] \quad (1)$$

$S_i(z,t)$ are costs including start up costs and fixed costs, z is discrete variable which correlate with generator in some period of time, $C_i(pi(t))$ are generation costs, usually square function of generation p_i . Equality constraints of the power system are demand of the system and power flow equations.

Inequality power system constraints are operation constraints and transmission lines constraints:

Constraints related with the energy are ramp constraints, overall hydro energy constraints and fuel constraints. Individual constraint of the aggregates are directly related to the aggregate or group of aggregates as capacity of aggregates (it means overall power), minimal *up/dow*n time of specific aggregate, hydro balance and constraints of the water mass volume.

3. INTEGRATING ISSUES OF SHORT THERM SCHEDULING AND OPTIMAL POWER FLOWS

The main difficulty of integrated planning and problem-OPF problem lies in the complexity of the problem. Enabling full limits the transmission network, together with limitations related to the energy significantly makes difficulty the process separation of power system scheduling and OPF problem. Transmission system modelling with AC power equations is very complex, so the system presents with the DC power flow equations,[4]. Many practical constraints and control actions considered in the OPF-in or the problems of power flows can not be sufficiently accurate modelled with DC power flows. These restrictions and limitations of action include reactive power, control transformers, phase angles. Transmission restrictions are often associated with voltages and it is known fact that DC power flow model can not provide such labor restrictions. Possible solution of schedules generally can not be obtained by simply performing regular economic dispatching for each hour, for transmission constraints limit the options of distribution, and restrictions related to the energy generator correlate levels from hour to an hour. The basic idea of the multiphase iterative methods for solving the integrated problem-type short-term scheduling/OPF-problem is set schedule problem and OPF problem in a different optimization phases. The results of the first phase are used to change the parameters of second phase.

4. PROPOSED METHODS FOR HANDLING INTEGRATING SHORT TERM SCHEDULING ISSUES AND OPF PROBLEMS

The basic idea of optimization method for solving the problem of integrated power system scheduling and OPF-problem is to define the vector variable that duplicate all continuous control variables, such as the active power generation, which exist in short term scheduling problem and in OPF problem.

With this scheme the dynamic problem is transformed into series of decomposed nonlinear problems. The main problem determines the operating schedule, starting and shutting down of the plants and for fixed schedule determined by the main problem sub-problem determines the total operating costs, fill out the appropriate limits of transmission capacity and takes into account the losses of the lines.

The sub-problem in iteration ν is formulated as follows:

$$F = \min C_i(P_i(t)) \quad (2)$$

Subject to set equality (power flows- where it is possible to use approximate formulation) and inequality constraints:

$$\sum_{j\in\Lambda_n} p_j(t) + \sum B_{np}(\delta_p(t)-\delta_n(t)) + \sum_{i\in\chi} H_i u_i(t) - \sum_{p\in\Omega_n} K_{np}(1-\cos(\delta_p(t)-\delta_n(t))) = D_n(t) \qquad (3)$$

$$\underline{P}_j v_j(t) \le p_j(t) \le \overline{P}_j v_j(t) \quad \forall j\in J, \forall t\in T \qquad (4)$$

where J is set of generators in power system.

$$-C_{np} \le B_{np}(\delta_p(t)-\delta_n(t)) \le C_{np}$$
$$\forall \mathrm{p}\in\Omega_\mathrm{n}, \forall t\in T \qquad (5)$$

where p belongs to set of all power lines connected with generation nodes.

$$v_j(t) = V_j^{(\nu-1)}(t) : \lambda_j^{(\nu)}(t) \qquad \forall j\in J, \forall k\in T \qquad (6)$$

where j belongs to set of all power plants. The last equation fed up the main problem with relevant information for improving the instant schedule,[5].
The main problem
Objective function includes the assessment of overall operation costs in all periods (variableα), fixed costs, and start-up costs.

$$f_M^\nu = a + \sum_{k\in T}\sum_{j\in J}\left\{F_j v_j(t) + A_j y_j(t)\right\} \qquad (7)$$

subject to constraints which is also known as cuts adding in each iteration:

$$a \ge Z^{(\nu-1)} + \sum_{t\in T}\sum_{j\in J}\lambda_j^{(\nu-1)}(t)\left[v_j(t) - V_j^{(\nu-1)}(t)\right] \qquad (8)$$

The next two constraints present operation logic, start-up and shut-down of the power plants.

$$y_j(t) \ge v_j(t) - v_j(t-1) \qquad \forall j\in J, \forall t\in T \qquad (9)$$

$$v_j(t), y_j(t) \in \{0,1\} \qquad \forall j\in J, \forall t\in T \qquad (10)$$

$$\sum_{j\in J}\overline{P}_j v_j(t) + \sum_{i\in\chi} H_i \overline{U}_i \ge \sum_{n\in N} D_n(t) + R(t) \quad \forall t\in T \qquad (11)$$

$$\sum_{j\in J}\underline{P}_j v_j(t) + \sum_{i\in\chi} H_i \underline{U}_i \le \sum_{n\in N} D_n(t) \quad \forall t\in T \qquad (12)$$

It is necessary to mention that the only real variable in the above problem is $a^{(\nu)}$, all the other variables are 0 / 1 integer. This mixed-integer master problem is dealt with using commercial software which offers GAMS [6]. Iterative procedure is stopped when operation costs calculated in the main program and operation costs of the sub-problem are near sufficiently, $\frac{\left|a^{(\nu)} - F^{(\nu)}\right|}{F^{(\nu)}} \le \varepsilon$

5. TESTING RESULTS

The testing is performed on test systems with 4, 9 and 30 buses. In this place results of IEEE 9 bus test system is presented. Observed time horizon was 24 hours. To achieve convergence has required 10 iterations. The state of generators and their production are iterative changes for the same observed time interval. The final value is the one that is obtained at the 10th iteration. For the 10th iteration the production of individual generators and the total costs include the cost of generators are presented.

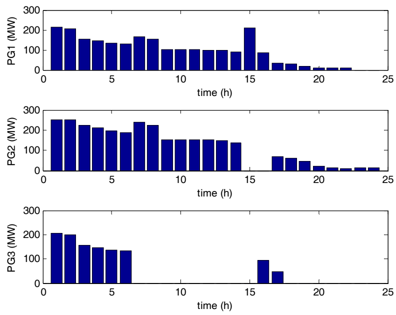

Figure 1. Power generation at 10th iteration for generators A1, A2, A3 during 24 time horzon

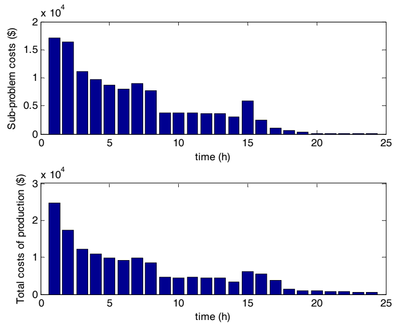

Figure 2. Sub-problem costs and total costs presented as a sum of costs generators, fixed costs and start-up costs at 10th iteration.

Optimal solution is provided by the main problem which "see" the state of all time periods, in this case it is 24 hours, so to capture specific schedule of generators which can cover the load and provide minimal cost of the main problem. Costs of the main problems are small when the number of generators which are started less, because in that case fixed costs and expenses of the start are excluded. For the fixed schedule further optimization is carried out within each of sub-problem, according to a given fixed schedule. So, no optimization is carried out in an hour to an hour on successive way, but solution regarding schedule generator provides in advance for the entire time horizon. This fact is very important for decomposed way of solving problems

6. CONCLUSIONS

Integrated power system sceduling problem and optimal power flow problem presents dynamic (multiperiod) optimal power problem which belongs mixed integer problems, calculating optimal power generation of activated generators subject to system constraints, and determines optimal schedules of generators in specific time horizon.

It's shown that for these types of problems decomposition is natural way of solving such problems. It is possible to pre-determine the optimal schedule generator, which is determined by the optimal value functions of the main problems, and then for such a schedule it is possible determine the optimal values of generators such as the cost of production in the system, power flows by lines, and the value of angles in the system, etc. Solution of the sub-problem has a reciprocal influence on the main issue, which will to "try" to improve the schedule in accordance with the solutions provided by sub-problem, in the next iteration. In this way, one reaches the optimal value of the generators schedules in the system and the optimal production in a few iterations.

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