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Auto tuning for new energy dispatch problem: A case study

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HIGHLIGHTS

- We propose a real-size rolling model to predict the Unit Commitment scheduling.
- We formulate the model to maximize new energy generation.
- We implement an auto-tuning solver CMIP for our model.
- We use auto-tuning techniques to optimize presolving, primal heuristics, etc.
- We compare the performance of other solvers and our auto-tuning solver.

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ABSTRACT

The new energy dispatch problem has aroused more and more attention. In this paper, we investigate the problem of determining the optimal usage of generating power during a scheduling period. A set of MIP formulations are adopted for precise modeling of the variety of power systems (different power generation units) and the actual situation in china. Based on these formulations, we construct a new energy dispatch model which includes many MIP sub-problems. An auto-tuning MIP solver CMIP is given to effectively improve the performance of solving the proposed model. The CMIP focuses on optimizations for presolver, the LP solver for corresponding relaxation problem, and the primal heuristics. Actual predict data is used in performance experiments. Computational results conform to the viability of optimization. Our optimizations further reduce 27.6% of the average execution time compared to CPLEX.

1. Introduction

New energy (including wind power and photovoltaic power) abandonment becomes more serious in china every year. In 2013, the forced wind curtailments give up the opportunity to generate 15 billion kWh of electricity as the amount of wind-generated electricity that was prevented from feeding into the grid. The wind curtailments result in a financial loss of CNY 7.5 billion ($1.2 billion). Thus, we need to resolve the new energy dispatch problem to relieve the impact of large scale wind power integration on power system peak shaving.

To maximize the new energy generation, a precise Unit Commitment (UC) model should be constructed according to the variety of power systems and the actual situation. The proposed model needs to consider in the characteristics of different power generation units including Condensing Steam turbine, Extraction Turbine, Back-Pressure steam turbine, Hydro-Power generating unit, and Cogeneration Units with combined heating systems, while satisfying constraints, such as ramp rate, storage capacity of reservoir, generation variation of Extraction Turbine and Cogeneration Units during the winter heating period, transmission line, system reserve requirements, minimum/maximum generation of wind power and photovoltaic power, and so on.

Because the UC problem [1,2] has complexity and high dimensional nature, it is impossible to solve the real-size system in the medium term and long term. Some of simplifications and approximations [3] are needed to cope with this problem. Though the UC problem can be decomposed into multiple Mixed-Integer Programming (MIP) sub-problems in rolling mode, it still take a long time to find a solution to the each problem, which cannot meet the requirement of real-time decisions. Recently, more and more researchers have paid attention [4–7] to accelerate the solution of UC problem. However, they concentrated mainly on model construction and heuristics for a MIP problem without using the information of adjacent periods. A variety of heuristics methods [8,9] are proposed to use a black-box MIP solver to find a solution

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Table 1
Involved indices in the problem.

Involved indices	Descriptions	Range
T	The total number of periods	
t	Time interval (hour) index	$t \in [1, T]$
N	The total number of regions	
n	Region number	$n \in [1, N]$
I	The total number of lines	
i	Line number	$i \in [1, I]$
j	Power generation unit number in a region	

to the problem. The main contributions of our work lie in three aspects:

(1) We propose a real-size rolling model to predict the UC scheduling. The proposed model has been used to help to make the decision in a province of China.
(2) Based on the characteristics of our model, we have implemented an auto-tuning solver CMIP based on SCIP (Solving Constraint Integer Programs) which is an open source framework for constraint integer programming and branch-cut-and-price. The auto-tuning solver improves the performance of key modular of MIP software.
(3) We analyze and compare the performance of commercial solver, non-commercial solver and the proposed auto-tuning solver.

The rest of this paper is organized as follows: Section 2 gives the model description for corresponding variables and constraints. Section 3 proposes the tuning steps for the proposed model. Our auto-tuning methods for presolver and heuristics are given in Sections 4 and 5, respectively. Computational results are then presented in Section 6. Related work is discussed in Section 7, while some conclusions and future work are drawn in Section 8.

2. Our rolling model

In order to reduce the deviation between our model and real scenario, we adopt the rolling generation scheduling. We formulate the following model to maximize new energy generation including wind power and photovoltaic power, which is equivalent to minimize the thermal power and hydroelectric power. According to annual prediction of power load, the annual scheduling corresponding to the rolling model is decomposed into week or days scheduling. Each week or days scheduling can be calculated by solving a MIP problem.

Table 1 illustrates involved indices and the corresponding descriptions in the problem. For example, there are 52 weeks in a year. Each week corresponding to a MIP problem involves of 168 h. In each problem, the number of periods T is equal to 168.

In Table 2, the major variables need to consider in formulating the MIP problem.

In Table 3, the major parameters are initialized according to actual situations and predicted power load.

Maximum objective function is given as follows:

$$max \sum_{t=1}^{T} \sum_{n=1}^{N} (windpower_n(t) + PVpower_n(t)). \quad (2.1)$$

Formula (2.1) represents that the use of the wind and photovoltaic power can be maximized.

There are at least seven kinds of constraints in each MIP problem:

(1) For thermal power unit and hydro-power generation unit, the constraints of unit j in period t for region n are as follows:

$$0 \le P_{j,n}(t) \le [maxTP_{j,n} - minTP_{j,n}] * X_{j,n}(t) \quad (2.2)$$
$$0 \le P_{j,n}(t+1) - P_{j,n}(t) \le UpRamp_{j,n} \quad (2.3)$$
$$P_{j,n}(t) - P_{j,n}(t+1) \le DownRamp_{j,n} \quad (2.4)$$
$$X_{j,n}(t) - X_{j,n}(t-1) - Y_{j,n}(t) + Z_{j,n}(t) = 0 \quad (2.5)$$
$$-X_{j,n}(t) - X_{j,n}(t-1) + Y_{j,n}(t) \le 0 \quad (2.6)$$
$$X_{j,n}(t) - X_{j,n}(t-1) + Y_{j,n}(t) \le 2 \quad (2.7)$$
$$-X_{j,n}(t) - X_{j,n}(t-1) + Z_{j,n}(t) \le 0 \quad (2.8)$$
$$X_{j,n}(t) + X_{j,n}(t-1) + Z_{j,n}(t) \le 2 \quad (2.9)$$
$$Y_{j,n}(t) + Z_{j,n}(t+1) + Z_{j,n}(t+2) + \cdots + Z_{j,n}(t+k) \le 1 \quad (2.10)$$
$$Z_{j,n}(t) + Y_{j,n}(t+1) + Y_{j,n}(t+2) + \cdots + Y_{j,n}(t+k) \le 1, \quad (2.11)$$

where the parameter k is initialized.

Formula (2.2) gives the range of $P_{j,n}(t)$ which is dependent on $maxTP_{j,n}$, $minTP_{j,n}$, and $X_{j,n}(t)$. Formulas (2.3) and (2.4) mean that the output power is not allowed to adjust quickly. Formulas (2.5)–(2.9) are the constraints for the state of unit. We need to consider the characteristics of power unit and the running cost. A power unit is not allowed to start or stop frequently. For formulas (2.10) and (2.11), the power unit is not allowed to start (or stop) for time interval $[t, t+k]$, when the power stops (or starts) in time t.

(2) Besides the above constraints, hydro-power generation unit j of region n has the following constraints in time interval $[t, t+k]$:

$$[minTP_{j,n} * X_{j,n}(t) + P_{j,n}(t)] + [minTP_{j,n} * X_{j,n}(t+1) + P_{j,n}(t+1)] + \cdots + [minTP_{j,n} * X_{j,n}(t+k) + P_{j,n}(t+k)] \le maxElectricity_{j,n} \quad (2.12)$$
$$-[minTP_{j,n} * X_{j,n}(t) + P_{j,n}(t)] - [minTP_{j,n} * X_{j,n}(t+1) + P_{j,n}(t+1)] - \cdots - [minTP_{j,n} * X_{j,n}(t+k) + P_{j,n}(t+k)] \le minElectricity_{j,n}, \quad (2.13)$$

Table 2
Major variables.

Variables	Descriptions
$windpower_n(t)$	Wind power generation in period t for region n
$PVpower_n(t)$	Photovoltaic power generation in period t for region n
$linepower_i(t)$	Output in period t for line i
$X_{j,n}(t)$	Binary variable means state of unit j in period t for region n. 0-halted state of unit. 1—running state of unit.
$Y_{j,n}(t)$	Binary variable means starting state of unit j in period t for region n. 1—the unit is starting, otherwise, the variable is equal to 0.
$Z_{j,n}(t)$	Binary variable means stopping state of unit j in period t for region n. 1—the unit is stopping, otherwise, the variable is equal to 0.
$P_{j,n}(t)$	Output power of unit j in period t for region n
$linepower_i(t)$	Transmission line i in period t
$windpower_n(t)$	Total wind power generation in period t
$PVpower_n(t)$	Total photovoltaic power generation in period t