Scheduling electricity generation using heuristically augmented genetic algorithms and Lagrangian relaxation

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In order to meet the customer demand in a power system, the generating units must be scheduled to minimise the total cost and satisfy operating constraints. Calculating the optimal commitments (on/off) and dispatched generations (in MW) of the units at a sequence of times in the scheduling period is known as the unit commitment/economic dispatch problem. This is a highly constrained combinatorial problem and continues to present a challenge for efficient solution techniques.

This paper describes the application of a genetic algorithm (GA), augmented by problem specific knowledge, to the unit commitment problem. The merits of the heuristics augmenting the GA are demonstrated, and the performance of the method is compared with Lagrangian relaxation for a test system.

We seek to minimise the total cost of generation,

$$\min_{\alpha_i^t,\, x_i^t} \sum_{t=1}^{T} \sum_{i=1}^{N} \beta_i^t U_i + \alpha_i^t F_i + W_i(x_i^t). \tag{1}$$

Here α_i^t is the commitment of unit i at time t and β_i^t is a corresponding variable indicating the start-up of a unit (both binary), x_i^t is the dispatched generation, U_i is the start-up cost, F_i is the fixed cost, and W_i is the incremental cost which is in general piecewise linear. The generation of each unit is bounded by

$$\alpha_i^t x_i^{min} \le x_i^t \le \alpha_i^t x_i^{max} \qquad i = 1, \ldots, N,\ t = 1, \ldots, T. \tag{2}$$

After start-up certain units must remain on a minimum time τ_i^{run},

$$\beta_i^t + \sum_{t'=t+1}^{\min(t+\tau_i^{run}-1,T)} \gamma_i^{t'} \le 1 \qquad t = 1, \ldots, T, \tag{3}$$

where γ_i^t is a binary variable indicating the shutdown of a unit. Similarly minimum off time constraints must be satisfied. The change in generation of a committed unit in successive times is bounded by ramp rate constraints,

$$-\Delta x \leq x_i^t - x_i^{t-1} \leq \Delta x \qquad t = 1, \ldots, T. \tag{4}$$

The schedule must meet the forecast demand D^t,

$$\sum_{i \in \mathcal{I}} x_i^t = D^t \qquad t = 1, \ldots, T, \tag{5}$$

and maintain sufficient reserve generation,

$$\sum_{i \in \mathcal{I}} \alpha_i^t x_i^{max} \geq D^t + R \qquad t = 1, \ldots, T, \tag{6}$$

where R is a given reserve margin. The generation of a subset of the units is also bounded by a transmission constraint,

$$\sum_{i \in \mathcal{I}_c} x_i^t \geq l_c \qquad \forall t \in \mathcal{T}_c. \tag{7}$$

The problem is formulated above as a linear mixed-integer programming problem. Since the computational time of exact methods such as branch-and-bound grows prohibitively with problem size, a range of methods for calculating suboptimal schedules have been investigated [4]. Recent work has favoured Lagrangian relaxation, in which the global constraints which couple the units are admitted into the objective function, and the problem decomposed into a master problem and unit subproblems [3].

The combinatorial aspect of the commitment problem is a natural target for the application of genetic algorithms [1]. GAs are methods in which an initial 'population' of solution strings is evolved via stochastic operators. Good solutions (low cost, low constraint violations), are selected from the population, and recombined ('crossover') and perturbed ('mutation'), to form new solutions.

Here we implement a GA in which the commitments α_i^t form the solution string, and the x_i^t are calculated by solving economic dispatch in the evaluation function. In order to gain a computational advantage the GA is augmented with problem specific knowledge, by (i) initialising the population of unit commitments, (ii) using a fast heuristic method to calculate the dispatch variables, and (iii) employing problem specific crossover and mutation. Results for a small test problem were previously reported in [2]. Here the augmented GA is applied to a system of 10 units over 24 time periods, and results will be presented comparing the solution cost and computational speed to Lagrangian relaxation.

References

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