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Impacts of emission trading schemes on GENCOs' decision making under multimarket environment

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ABSTRACT

The implementation of Emission Trading Schemes (ETS) in the electricity supply industry has driven generation companies (GENCOs) to put efforts to reduce their produced emissions. Under a multimarket environment, a GENCO generates electricity subject to physical, fuel and environmental constraints. Separate and evolving research efforts are currently shaping electricity market, fuel market and carbon market without paying adequate attentions to how each market affects the others, though the markets have overlapping goals with respect to the global economic and environmental benefits. Under this background, this paper investigates the impacts of carbon policies on a GENCO's decision making under multimarket environment. A dynamic decision making model is proposed to deal with the multimarket trading problem for a GENCO during each trading period. Differential Evolution (DE) algorithm is employed to solve the multi-period optimization problem for each time interval. Comparisons between different scenarios demonstrate the economic and environmental influences of different policies on a GENCO. With the proposed model, a GENCO can make a rational tradeoff between profit making and emission reduction under the three interactive markets environment. Policies defining the three interactive markets can accurately reflect the intended goals such as reducing emissions, promoting renewable and keeping electricity cost at a reasonable level.

1. Introduction

Electricity industry worldwide has been deregulated on the generation and retail sides; as such there are two major changes: (i) generation companies (GENCOs) are free to operate and compete in the market. (ii) GENCOs are subject to competition in the electricity market (EM). The model proposed in this paper builds upon the EM consisting of a power pool and bilateral trades [1]. The primary goals of EM are to provide energy securely, reliably and efficiently. While EM usually meets these goals, other valued outcomes, including conserving finite resources, maintaining stable and reasonable electricity cost, and protecting the environment, are at the stakes. To address these problems, policies such as Emissions Trading Scheme (ETS) have been adopted to mitigate emission by market-based mechanisms. Under this scheme, specified amounts of emission allowances are allocated to various industrial installations, including generators. A unit of allowance is the permission to emit one ton of CO_2 within the emission commitment period $\{0, C\}$. In this study, the planning period is assumed to be within the emission commitment period ($0 \le d_0 \le D \le C$). A GENCO's stock of allowances is composed of two parts: initial allowance (allocated freely) and purchased allowance (trade or auction from a carbon market). Generally, initial allowances are assigned to a GENCO annually through grandfathering, output-based allocation or an auction based method [1]. These allowances can be used either for producing corresponding amounts of CO_2 or trading in Carbon Market (CM). If the total emission over the emission commitment period (which is the period within which a country/region must remain the national/regional emission level specified by its target) exceeds the allocated allowances, a GENCO has to either purchase allowances from a carbon market or pay a penalty. Reference [2] indicated that EM would be affected by emission trading scheme. Electricity prices would be affected by the scheme as GENCOs seek to pass their additional cost to consumers. Operational decisions of GENCOs on electricity production and related fuel portfolio would also be affected significantly. The deregulation of EM and the implementation of CM require each GENCO builds up its own fuel portfolio according to the prices variation in Fuel Market (FM). In the long run, GENCOs therefore have to contract their fuels in an optimal way that allows them to operate in the multimarket

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environment without incurring any negative profits. In the daily operation, GENCOs have to decide the usage of their fuel according to the production with consideration of different fuel prices taken into account.

The problem addressed in this paper is that separate and evolving public policy debates are currently shaping EM, CM and FM without paying adequate attentions to how each market affects the others, yet GENCOs are subject to the influences from the three interactive markets. Without a better understanding of how a GENCO would react to these three markets, it is difficult to design policies which can achieve the environmental and economic societal goals. To address the value of different market mechanisms, this paper proposes a dynamic decision making model for GENCOs to deal with the multimarket trading problems in each trading interval. The rest of the paper is organized as follows: in Section 2, some important issues relating to the proposed model are explained, followed by the model formulation described in Section 3. Section 4 describes the solution of the proposed model. In Section 5, case studies are presented to compare the multimarket performances under different scenarios. Finally, Section 6 concludes the paper.

2. Problem formulation

To take the uncertainties in EM, CM and FM into account, this paper proposes a two-stage decision making model to give the optimal results in both production process and trading process. Furthermore, another major motivation of the paper is to investigate how different market mechanisms affect decisions of a GENCO. The reason is that a GENCO's decision on how to make use of the generators, the corresponding fuels as well as the allocated emission allowances would be different under different market environments.

A multi-time period electricity network optimization model was presented in [3], which took gas flows, price and storage problem in FM into account, for GENCOs. Reference [4] presented a dynamic economic emission dispatch model of power systems, including a handling scheme to deal with emission constraints. A typical environmental/economic power dispatch optimization problem including fuel cost minimization and emission constraints was described in [5]. With the uncertainties of price forecasting and fuel availability taken into account, Kazempour et al. [6] developed a risk-constrained framework for self-scheduling. However, these studies did not consider the effects of ETS which play an important role in reducing emission. Recently, research efforts have been put into the development of electricity market optimization models with ETS taken into account. Impacts of both emission trading and renewable energy support schemes on EM operation were analyzed in [7]. Reference [8] investigated how different emission caps would affect generation scheduling. A global simulation model was developed in [9] to investigate the operation of the Iberian power market with the incorporation of ETS. However, emission allowance was treated as a fixed cost so that the trading value had been ignored in constructing the decision making models. So far no literature addresses the optimal decision making of GENCOs with the effects of EM, FM and CM taken into account. In contrast to the works that consider only caps on emission, the model proposed in this paper solves the decision making problem by maximizing the total profit of a GENCO in the entire planning period. This is a complex decision making problem in which all units have to be scheduled to satisfy not only the power demand of bilateral trades and power pool but also spinning reserve of the system. Furthermore, the trading in the three interactive markets has to be coordinated with environmental constraints.

2.1. Hierarchical decision making model

The proposed decision making model enables a GENCO to maximize its profit through proper decision making in a hierarchical structure as shown in Fig. 1. Without loss of generalities, all units of a GENCO are assumed online during the planning period. However, the unit commitment that actually determines the on–off status of units can be integrated into the proposed model easily. At each planning level, a GENCO's total expected output is forecasted based on the corresponding historical data [10]. Then the forecast output can be equally spread to each time span of its sublevel (termed as average dispatch). As a result, necessary information of the sublevel including fuel consumptions and emissions can be obtained. On one hand, the average dispatch at the higher levels helps a GENCO to

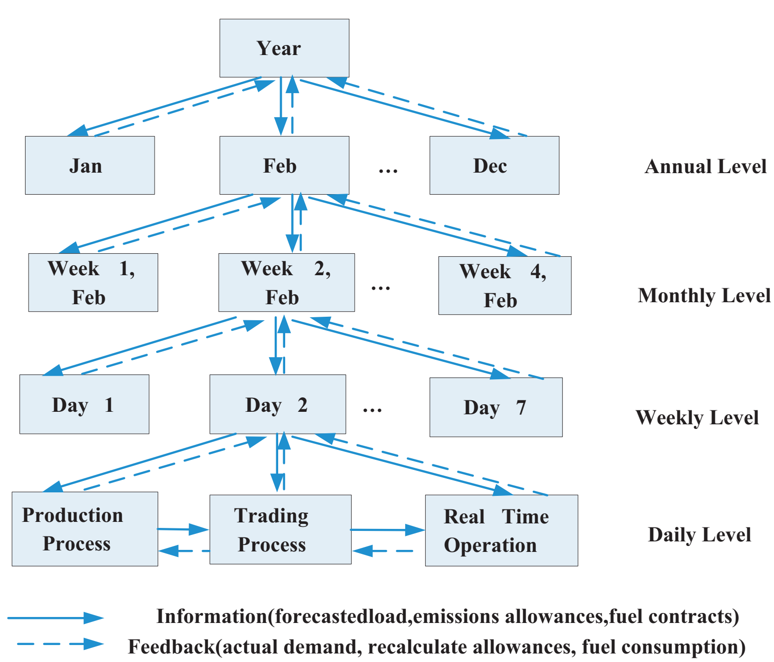

Fig. 1. Hierarchical decision making model.