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Influence of the Emissions Trading Scheme on generation scheduling

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ABSTRACT

The paper investigates the effects of emissions constraints and Emissions Trading Scheme (ETS) on the generation scheduling outcome. ETS is a cap-and-trade market mechanism that has been introduced in European Union in order to facilitate CO_2 emissions management. This scheme gives generators certain amount of CO_2 allowances which they can use to cover emissions produced during energy generation. In a current setting, most of the allowances are given for free. However, under ETS generators also have an opportunity to buy and sell CO_2 allowances on the market. Since generation power outputs are bounded by the amount of CO_2 emissions that they are allowed to produce over time, it is becoming increasingly important for generating units to manage their allocations in the most profitable way and decide when and how much of permissions to spent to produce electricity. The method proposed here allows for modeling of this new limitation by including costs of buying and selling of CO_2 allowance in the generation scheduling procedure. It also introduces additional emissions constraints in the problem formulation. Although CO_2 permissions and energy are traded in separate markets, the proposed formulation permits analysis on how emission caps and emission market prices can influence market outcome. The method is illustrated on a 5-unit system. Given examples compare (i) a base-case when all generators have made a decision to use portions of their total free allocations that do not cause any shortfall during the investigated time period; (ii) two cases when the least expensive generators' decisions on the amount of free allowances they are willing to use during the considered period are insufficient. In all cases generators also submit prices at which they expect to be able to "top-up" or sell allowances on the market, however, only in the second and third case the "buying" option becomes active and affects generation scheduling and total costs.

In addition, the paper investigates how aggregation of emissions allowances of generators belonging to the same company can affect market clearing.

1. Introduction

The Kyoto protocol is one of the major international instruments to address the problem of a climate change by means of stabilizing the greenhouse concentration in the atmosphere. To help developed countries achieve parts of their emission reduction commitments, Kyoto protocol proposes three flexible market-based mechanisms:

- *Emissions trading* – which is a scheme that allows participating developed countries to establish limits on pollution in a form of allowances. These allowances can then be either used or traded in emissions markets.
- *Joint implementation (JI)* – represents an investment in an emission reduction project which is based in another industrialized country. By financing such a project a company and/or country can earn additional emission allowances.
- *Clean Development Mechanism (CDM)* – represent investments made by industrialized countries in projects based in a developing country which is not subject to Kyoto targets. Again, these emission reduction projects earn their investors additional emission credits.

The above mechanisms essentially permit industrialized countries to control emissions by introducing a limited number of emission allowances that can be traded on the market. They also enable gaining of additional credits from investments in emission reduction projects.

A response of the European Union (EU) to the Kyoto protocol was to introduce Emissions Trading Scheme (ETS). It includes allocation of specified amounts of emission allowances to various industrial installations, including generators [1]. These allowances can be used either for producing corresponding amounts of CO_2 or traded in the market. In the case that the total emission over a monitored period exceeds defined emission allowances, the owner of the installation has to either buy additional allowances on the market or pay a penalty.

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The scheme is divided in two phases. The first phase was from 1st January 2005 till 31st December 2007, while the second phase started in 2008 and will end in 2012. During each phase, installations have to measure and report their emissions at the end of each year, however, compliance periods have been set to 3 and 5 years, respectively. This means that if a company under-uses its allowances in one year, it can save, i.e. *bank*, them and use in the future (either to emit CO_2 or to sell then on the market). The banked allowances, however, have to be used within the baking i.e. compliance period. If the company has over-used its annual quota during a year, it can balance it either by reducing emissions during other years in the banking periods, or by buying them on the market. The purpose of the banking periods is to enable companies to smooth out eventual annual imbalances due to weather, maintenance, and other factors. There is no possibility to carry over unused allowance from one to another banking period, or to borrow them from a future banking period.

Currently, each member state in the EU decides on its allocation policy through its National Allocation Plan. This means that each country can decide which of its industry sectors will have to curtail emissions and by what amount. For example, in the UK, electricity generation sector is affected the most, with majority of curtailments coming from these installations. So far, under EU ETS initial CO_2 allocations are given for free. However there are indications that in the next phase (after 2012) this may change and that all allocations will be auctioned. There are also discussions to introduce central EU allocation instead of National Allocation Plans.

Although not without glitches, the ETS proved to be a move in a good direction [2]. Fig. 1 and Ref. [2] illustrates prices of CO_2 emission allowances during the first phase (till the end of 2007). Red curve indicates prices of future contract for delivery in December 2007, i.e. for the phase one, while black curve shows price dynamics for contracts that will be delivered in December 2008, i.e. in the first year of the second phase. Note that there is no banking between phases one and two, and therefore these are prices for two separate products.

It can be observed from Fig. 1 that prices were more volatile during the first phase. There was a significant drop that occurred in April 2006, when results of measurements for the first year were published. It was not an unexpected result as it was in the very beginning of the ETS, and participants did not have sufficient experience with that market.

Electricity sector is one of the major sources of CO_2 emissions and, therefore, generating units are included in the EU ETS mechanism [3]. Although different countries approach allocation of emission allowances to generators in different way, electricity market prices will be affected by the scheme as electricity producers seek to pass their additional costs to consumers. Moreover, emission caps may also affect decisions of generating companies on how much and when to produce, in order to use their allocations effectively. This, in turn, will affect a market clearing outcome that is generation output levels and schedules.

Some of the previous formulations of a unit commitment problem that account for emission constraints have been solved using Lagrange relaxation methods [4–7]. The analysis in [4] looks at the problem of SO_x emissions, with a formulation that incorporates these constraints into an objective function. In [5] an Augmented Lagrange Relaxation is used to solve a unit commitment where transmission and environmental constrains are added to the set of typical system constraints such as power balance, minimum-up, minimum-down and ramp constraints, while a method which combines Lagrange Relaxation and evolutionary programming is used in [7]. Formulations of emission functions for different type of pollutants (such as CO_2, SO_2 and NO_x) are discussed for various generating units in [6]. This work also suggests emission function formulations that account for differences of emission levels during start-up, ramping-up and part-load operations.

In contrast to the above mentioned work that considers only caps on emission allowances, the objective of this paper is to investigate the possible influence of an emissions trading on decisions of generators and, thus, on market clearing. Therefore, the here proposed model solves generation scheduling problem of minimizing generation and start-up costs subject to constraints such as power balance, generation limits, minimum-up and minimum-down time, as well as ramp constraints. To account for the effects of the ETS, the cost function is expanded to include costs and revenues associated with *possible* buying and selling of CO_2 allowances which are sold on separate emissions markets. It is important to note that the model assumes that generators have made decisions on how to use their allocated pool of allowances over time. It is reasonable to expect that when initial allowances are allocated for free (as is currently done in the EU) generation companies will not wish to use all of the allowances indiscriminately. Rather, they will make strategic decisions to use allocations at times that will allow them to maximize their profits. In this paper, we have assumed that generating companies have already decided on the amounts of CO_2 allowances they are planning to use at certain periods of time. Such decision-making process is not subject of this paper.

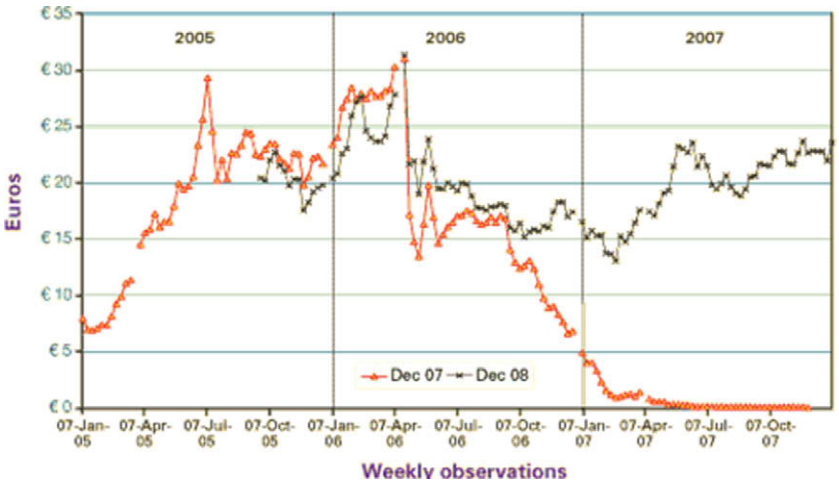

Fig. 1. Prices of future CO_2 allowances [2].