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Dynamic simulation model of a coal thermoelectric plant with a flue gas desulphurisation system

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Abstract

In this paper a Dynamic Simulation Model has been used to present the likely responses of the electricity industries' latest perturbations such as: changes in environmental regulations, international fuel market evolution, restriction on fuel supply and increase on fuel prices, liberalisation of the European Electricity Market, and the results of applying energy policies and official tools such as taxes and emission allowances.

The case under study refers to the Teruel Power Plant, built after the 1970s oil crisis to ensure national electricity supply; burning domestically produced coal in order to ensure local mining activity. The Teruel Power Plant has made relevant investments in order to meet emission limits, such as a Flue Gas Desulphurisation Plant. The economic viability of the power stations has to be analysed after environmental costs have been internalised.

A system is defined that studies the coal-firing Electric Power Plant selling energy to the free electricity market, whenever the generation cost is competitive. A Dynamic Simulation Model would appear to be an accurate tool to optimise power station management within different frameworks.

Keywords: Dynamic simulation model; Coal thermoelectric plant; Environmental costs

1. Background

This paper presents a Dynamic Simulation Model that intends to provide a representation of the economic viability of power plants operating in the recently restructured Spanish Electricity Sector. The simulation results show how clean technology costs and CO_2 emission penalisations modify the electricity production costs; and how techno-economic tools, regulatory intervention and energy policies may bring stability to the new competitive market, even to the future European Electricity Market.

The computer model represents the production costs of a Coal-Burning Power Plant. The facility reduces combustion emissions by a Flue Gas Desulphurisation Plant, in order to be able to sell electricity to the now running Spanish Electricity Pool. A series of scenarios are herein presented to illustrate different situations, such as an increase of imported fuel prices or taxes, variations of environmental costs and criteria for public incentives and taxation, new restrictive emission limits enforced, etc.

The process simulation has been carried out with the software package SIGEM (Intelligent Model Generator System) introduced by Caselles in 1988.

1.1. Coal-based power generation

After the 1970s oil crisis, the main goal of Spanish Energy Policy was to minimise dependence on the international fuel market. An important project promoting coal-based power generation was developed. On 20th June 1974, the National Energy Authority authorised ENDESA (the largest National Electric Company in Spain at the time) to install a Thermoelectric Power Plant in Andorra, the Teruel Power Plant.

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The subituminous coal of Andorra and the surrounding area is the principal fuel burned at the three groups of generators of 350 MW each. In this way, the government ensured the main economic activity in this particularly depressed area: local mining. This facility is still one of the most important Power Plants burning national fuel in Spain; and it contributes to diminish the direct repercussion that petroleum import conditions might have on the national economy.

Under the initially designed conditions, the Teruel Power Plant has had a negative impact on the natural environment in that area; in spite of the fact that the Plant fulfils the emission limits established by the legislation in force at the time of its opening. A standard legal procedure for Ecological Offence was initiated against the operating company and its responsible general manager. The company has actively participated in studies, and it has developed projects to improve the adverse environmental conditions: a Coal-Washing Project, which has managed to eliminate 40% of the Sulphur content in coal since 1988; the use of natural gas as a support fuel. In order to allow sulphur dioxide emissions to remain below the increasingly restrictive limits, and those established by legislation for forthcoming years, a Desulphurisation Plant was projected to ensure that the Power Plant activity continued.

The process chosen for the Desulphurisation Plant, that of lime stone-forced oxidation (LSFO), reaches performance levels of over 90%. The Teruel Power Plant estimates that it shall reach emission values of 1170 mg/m^3 N (Ministerio de Industria y Energía—Ministry of Industry and Energy, 1992).

The LSFO system process generates significant amounts of desulphurisation gypsum that have to be managed, and it also increases carbon dioxide generation. Research studies on the characterisation of the desulphurisation gypsum and its market research were undertaken (Peris-Mora, 1996), and they reveal the possibilities of using this gypsum as a by-product, thus minimising environmental costs.

The Power Plant has been able to commercialise the total amount of fly ashes and approximately half the scoria generated in combustion. The remaining scoria and the desulphurisation gypsum are presently being used as filling material, for mining purposes, in the company coal mines themselves. The restoration costs avoided through the use of these by-products have not been clearly calculated (Ministerio de Industria y Energía, 1992; Legarreta-Fernández, 1986; ENDESA, 1998; Geocisa–Urbaser, 1999; Labandeira–Villot, 1996; Higgins, 1993).

1.2. The Spanish electric sector

Traditionally, the Spanish Government had been administering the generation and supply of energy through an integrated exploitation of the generation resources. The regulated generation activities were planned in order to not only meet the forecasted electricity demand at minimum overall costs, but also to optimise the resources to provide this public service (Legislación Española, 1987; Ministerio de Industria y Energía, 1970–1993). Distributing the income produced for the electricity sold, covered the total costs involved in the regulated generation activities. This was carried out proportionally to the produced energy and the production costs of each Power Plant. Companies in the electric sector always recovered investments and production costs, and the energy supply was guaranteed. The transposition of the European Parliament and Council Guideline 96/92/EC (regarding common regulations for the Domestic Electricity Market) to Spanish legislation gave rise to a restructuring protocol of the national electric system.

The Spanish Electric Power Act (Legislación Española, 1997) established a new regulatory framework to organise energy markets on a day-to-day basis. Qualified buyers and sellers of electricity present their offers in the wholesale pool for the following day. A process of bids with an algorithm matching each of the 24 h of the following day according to the buyers demand, is developed for the pool administrator. The pool administrator consolidates the bids for each hourly period. An aggregate price supply curve determines the marginal price, that is, the price applied to the total amount of the hourly energy bought.

The system operator evaluates the technical viability of the operating schedule of the production units in order to guarantee the safety and reliability of supply on the transmission network. The required adjustments between demand and production are made in the intraday market. To be able to participate in the intraday market, the agents must have participated in the corresponding daily market. The pool administrator evaluates the technical feasibility of the assignment by taking into account the technical constrain and the regulatory and ancillary services assignment procedure, and any other necessary adjustments between demand and supply, a final hourly generation schedule is determined.

The purpose of deviation management and ancillary services is to ensure that energy is supplied under established conditions of security, reliability and quality. The system operator incorporates regulating band ancillary services in the viable daily schedule after the daily market sessions have been held. After every intraday market session, the system operator manages any deviations in real time using ancillary services and the deviation management procedure.

The Spanish Electric Power Act established some economical instruments, which allowed National and European Energy Policies criteria to be applied. Examples of such incentive are: the premium for the consumption of domestically produced coal (RD 2017/1997), capacity payment (Legislación Española (Spanish Legislation), 1998b), for diversification and security of supply incentive, or cogeneration compensations until 2007. (Legislación Española, 1998a), or the electric system directly purchasing the energy generated in special regime power stations at a higher price.