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Independent operation by subsystems: Strategic behavior for the Brazilian electricity sector

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Abstract

This article describes the competitive strategies of the subsystems in the Brazilian electricity sector. The objective is to present a model in which the operation of each subsystem is managed independently. As the subsystems correspond to the country's geographic regions, the adoption of this model creates conditions for each region to develop according to its own peculiarities. The decision-making process is described based Game Theory. As such, the players or operators of each subsystem carry out their strategies based on the quantities produced, which results in Nash–Cournot equilibrium. In this model, the importance of the proper transmission line dimensioning is highlighted. It determines the competition level among subsystems and allows for optimization of the whole system without requiring arrangements for managing the congestion of the energy transportation grid. The model was programmed in FORTRAN, using IBM's optimization subroutine library (OSL) package.

Keywords: Energy system management; Game theory; Dynamic dual programming

1. Introduction

Brazil disposes of a sophisticated and efficient power supply structure. Due to the country's territorial dimensions and, consequently, the restrictions on electricity transmission, the electricity sector is segmented in four main subsystems: South, Southeast/Center-West, North and Northeast. Also representing the country's geographic divisions, these are the four integrated subsystems forming the National Interconnected System (SIN, abbreviation in Portuguese). Over 85% of electricity generation capacity comes from hydro power plants with large reservoirs of pluriannual regularization. The power plants are located in different hydrological basins and interconnected by extensive transmission lines. Conventional and nuclear thermal plants complement the remaining power supply.

The Southeast/Center-West subsystem concentrates the largest part of the installed capacity, which amounts to roughly 43 GW. It consists of hydroelectric and thermoelectric plants using natural gas, diesel, combustible oil, and two nuclear plants. In addition, this subsystem owns 50% of the installed capacity of Itaipu, the binational (Brazil–Paraguay) hydroelectric plant with a power capacity of 12.6 GW. The South is second with an installed capacity of 14.13 GW. This subsystem consists of hydroelectric plants and thermoelectric plants using natural gas, coal, diesel and combustible oil. The installed capacity of the Northeast subsystem is slightly lower, 14.07 GW. It consists of both hydroelectric and thermoelectric plants using natural gas, diesel, combustible fuel and sugar cane. Finally, the North subsystem, with installed capacity of 5.4 GW, consists only of hydroelectric plants. Fig. 1 below shows the localization of the main plants of the Brazilian electricity system.

The Southeast/Center-West subsystem is also the largest consumer center, representing 61.6% of the SIN load. The South, Northeast and North systems

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Fig. 1. Main plants in operation. *Source*: ONS (www.ons.org.br/ons/sin/index.htm).