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A system dynamics conceptual model on retail electricity supply and demand system to minimize retailer's cost in eastern Australia

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Abstract

In eastern Australia's electricity market, the retailers have to purchase a certain amount of power to fulfill their customers' demand. When the purchased power through forward contracts exceeds the electricity demanded by customers it leads to retailer's loss. On the other hand, the demand is higher than the purchased power which urges the company to buy extra power from a peaking power generator at electricity market with volatile price. This research studies power supply and demand systems at electricity retail market. System Dynamics (SD) methodology is used to investigate the influence of weather and forward contract conditions on the fluctuation of energy supply and demand in order to minimize energy retailer's cost. A respective conceptual model has been built by using qualitative phase in SD approach which enables further development in the SD's quantitative phase.

Keywords: Conceptual model; energy retail market; retailer's cost; system dynamics

Nomenclature

a	retailer's cost
b	retailer's market share
c	long-term demand forecast
d	regular procurement at financial market
e	procurement cost for forward contract
f	short-term demand forecast
g	supply shortage
h	irregular procurement at spot market
i	procurement cost for spot contract
j	forward contract price
k	forward contract volume
l	extreme weather conditions
m	supply availability

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n	spot market price volatility
B	balancing loop
R	reinforcing loop

1. Introduction

In eastern Australia's electricity market covering the Australian Capital Territory, New South Wales, Queensland, South Australia, Victoria and Tasmania, customer demand is not supplied directly by power generators. Instead, the demand is fulfilled by energy retailers who purchase electricity from the generators or sellers and package it with transportation services before distributing to consumers. The electricity purchases could be made on regular basis for long or medium term periods called forward contracts at financial markets or irregular basis at an electricity spot market, namely the National Electricity Market (NEM). If the forward contract volume is not sufficient at a certain trading interval, then the spot contract is required to meet the demand [1]. However, the spot market price is so volatile which might lead to retailer's financial loss in substantial amounts [2]. Moreover, it could result in bankruptcy as it happened at Texas Commercial Energy (TCE), a US electricity retailer in February 2004 [3].

The demand of electricity fluctuates over time caused by some important factors, particularly weather conditions. Therefore, how the dynamic behavior of retail electricity market system under forward contract volume and weather condition changes is the question in this research. The aim of this research is to support electricity retailers in managing their forward contract with power generators in a financial market under weather change and power market environment in eastern Australia in order to minimize their cost. The research objective is to develop a system dynamics conceptual model to evaluate the effects of forward contract volume and weather conditions on retailer's cost.

2. Methodology

A system-oriented approach based on system dynamics is employed to develop the model. The notion of using SD method to study the electricity market systems is largely due to the dynamic features resulting from the feedbacks in the systems [4]. Similarly, the system dynamics method has been utilized in the prior studies of reverse logistics to maximize manufacturer's profitability in computer industry [5-6].

The entire process is divided into two analyzing phases, namely qualitative and quantitative. In the qualitative phase, it starts with the observation of the systems under consideration before identifying the model objectives. Then, systems approach and analysis are applied to the observed systems by selecting properly all relevant entities and variables to the objectives in order to have a simplified and well-defined system. In the next step, a causal loop diagram is developed which is then transformed into a stock and flow diagram. During the quantitative phase, the stock and flow diagram is translated to a simulation program using SD software for developing dynamic models. Once the initial models are gathered, they are iteratively verified and validated to obtain sufficient models. The program executions are performed under alternative what-if scenarios followed by analyzing the results [7].

In this research, simply the qualitative phase is utilized to design a conceptual model regarding the retail electricity market systems. Similar approach is also utilized in the previous study regarding environment sustainability performance of reverse logistics operations in computer industry [8]. Accordingly, the system dynamics methodology from Georgiadis & Vlachos is modified as can be seen in Fig 1 [7]. The conceptual model consisting of a causal diagram and a stock-and-flow diagram is developed by means of a system dynamics software, Vensim PLE for Windows version 6.00 Beta.

3. Systems description

3.1. Electricity market structure in eastern Australia

Industry reforms that initiated in the early 1990s had formed the existing structure of electricity market in Eastern Australia covering the Australian Capital Territory, New South Wales, Queensland, South Australia, Victoria and Tasmania. As a key element of the reforms, the National Electricity Market (NEM) which began operation in 1998 allows power flows across the area. It operates as a wholesale spot market for electricity trading between generators and retailers through a gross pool which is managed by the Australian Energy Market Operator (AEMO).

The electricity supplies from the generators are aggregated and dispatched by the AEMO to meet the demand of retail consumers intermediated by the retailers. Additionally, the retailers might reduce any price risk at the spot market by contracting with generators at financial markets. Meanwhile, industrial consumer demand is fulfilled directly by the generators. The industry structure is illustrated in Fig 2 [1].