# A COOPERATIVE POWER TRADING SYSTEM BASED ON SATISFACTION SPACE TECHNOLOGY

**Keinosuke Matsumoto, Tomoaki Maruo, Naoki Mori**

*Department of Computer Science and Intelligent Systems,*
*Graduate School of Engineering, Osaka Prefecture University*
*1-1 Gakuen-cho, Nakaku, Sakai, Osaka 599-8531, Japan*

Abstract: Various power trading system models have been proposed, but many of them will not aim at load reduction by making customers cooperate with power suppliers in a power trading market. Some researches tried to solve the problem by introducing reward in the power market. This approach was developed on an evaluation function, but it must estimate customers' evaluation functions beforehand. Then, this paper proposes a new approach to cope with various kinds of customers by modeling a power market on a satisfaction space. In addition, we have built the proposed system as a Web application on the Internet. 

Keywords: Power systems, Economics, Energy management, Intelligent systems, Modelling, Communications systems, Utility functions

## 1. INTRODUCTION

Many power trading system models have been proposed to deregulate key elements of the electric industry worldwide (Stoft, 2002; Dy-Liacco, 2002; Vaahedi, 2004). These systems depend on market mechanisms and they would cause a problem that electric power price fluctuates greatly with demand-and-supply imbalance. In order to solve this problem, a research (Matsumoto, *et al*., 2001) has tried to make a cooperative power trading system that keeps a proper balance between demand and supply of electric power by making customers and suppliers have cooperative relations mutually. This approach has been developed on an evaluation function of satisfaction, and there is a problem that can handle only customers that fulfill a specific condition. Then, this paper describes a new cooperative power trading system that can deal with various kinds of customers by modeling a power market on a satisfaction space.

Satisfaction space technology can deal with customers without evaluation functions. In addition, this paper proposes a power reducing method using a combinatorial optimization technique. The method can be applied to a situation that the degree of customer's satisfaction cannot be correctly estimated beforehand.

To make this business model fit for practical use, it is indispensable to develop a communication network model (Vojdani, 2003; Matsumoto, *et al*., 2003) in data communication level. This paper also proposes a network model of the electric power trading systems using Web site as a platform of this network model. Building a network model using Web site enables us to create a communication network system that can flexibly correspond to each communication environment.

## 2. PREVIOUS COOPERATIVE POWER TRADING SYSTEM

A power trading market consists of three kinds of agents: supplier, customer, and auctioneer. They act independently according to the intention of themselves. A supplier tries to sell electric power and make a profit to maximize the degree of satisfaction. A customer is an agent aiming at purchasing electric power to raise the degree of satisfaction. An auctioneer is an agent that conducts market trading impartially and controls the market stability. Configuration of the trading system model is shown in Fig. 1.

If demand exceeds supply, the auctioneer in the cooperative trading system asks customers for power reduction. Reward is paid in compensation for the reduction to maintain the degree of satisfaction of the customers.

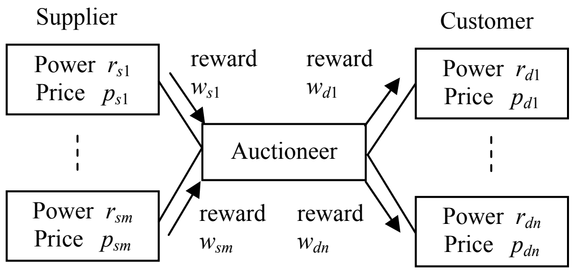


Fig. 1. Cooperative trading system model

In the cooperative trading model, supplier's evaluation function $u_{si}$ is defied as a function of market price $p$ and power supply $r$ :

$$u_{si} = u_{si}(p, r) \quad (1)$$

Customer's evaluation function $u_{dj}$ is also defied as a function of market price $p$ and power consumption $r$ :

$$u_{dj} = u_{dj}(p, r) \quad (2)$$

Taking into account of reward, supplier's evaluation function $v_{si}(p,r,w)$ after introducing reward and customer's function $v_{dj}(p,r,w)$ are shown in (3), (4) respectively. Where $w$ is reward.

$$v_{si}(p,r,w) = u_{si}(p,r) - w \quad (3)$$

$$v_{dj}(p,r,w) = u_{dj}(p,r) + w \quad (4)$$

If market price is $p$, initial power demand $r_{dj1}$ and reduced power demand $r_{dj2}$, then the reward $w_{dj}$ given to customer $j$ is defined as (5) in this model.

$$w_{dj} = u_{dj}(p, r_{dj1}) - u_{dj}(p, r_{dj2}) \quad (5)$$

We define a degree of satisfaction of customer $j$ as $V_{dj}$ $(p,r,w)$, and also define $g_p$ as a satisfaction function of the reward at a market price p. In this case,

$$g_p(w) = V_{dj}(p, 0, w) \quad (6)$$

$$v_{dj}(p,r,w) = g_p^{-1}(V_{dj}(p,r,w)) \quad (7)$$

Where, $g_p^{-1}$ is an inverse function of $g_p$, $U_{dj}(p,r)$ is a satisfaction function with regards to the power quantity $r$ under the conditions of the market price $p$, which is defined as (8).

$$U_{dj}(p,r) = V_{dj}(p,r,0) \quad (8)$$

The following equation is derived in the same way:

$$u_{dj}(p,r) = g_p^{-1}(U_{dj}(p,r)) \quad (9)$$

Substituting (7) and (9) for (4), we get (10):

$$g_p^{-1}(V_{dj}(p,r,w)) = g_p^{-1}(U_{dj}(p,r)) + w \quad (10)$$

Mapping (10) using $g_p$, (11) is derived as a constraint of this model.

$$V_{dj}(p,r,w) = g_p(g_p^{-1}(U_{dj}(p,r)) + w) \quad (11)$$

The left hand side of (11) expresses the degree of customer $j$'s satisfaction. On the other hand, right hand side of the equation shows the degree of customer $j$'s satisfaction that an auctioneer estimates. This type of customer's $g_p$ is a linear function, so that reward is correctly paid to the customer because both hand sides of (11) are equal.

If another customer's $g_p$ is an upward convex function, then (12) is satisfied:

$$V_{dj}(p,r,w) > g_p(g_p^{-1}(U_{dj}(p,r)) + w) \quad (12)$$

For this type of customers, the auctioneer estimates their satisfaction less than real values. Therefore, they get reward more than necessary to be paid to them.

If the other customer's $g_p$ is a downward convex function, then (13) is satisfied:

$$V_{dj}(p,r,w) < g_p(g_p^{-1}(U_{dj}(p,r)) + w) \quad (13)$$

For this type of customers, the auctioneer estimates their satisfaction more than real values. Therefore, they will not get enough reward to maintain the degree of satisfaction.

## 3. SATISFACTION SPACE

We have developed a satisfaction space technology that solves the problem stated in the previous chapter.

### *3.1 Definition of Evaluation Function*

Supplier's and consumer's evaluation functions are defined as satisfaction functions like (14) and (15) respectively.

$$V_{si} = V_{si}(p, r_{si}, w_{si}) \quad (14)$$

$$V_{dj} = V_{dj}(p, r_{dj}, w_{dj}) \quad (15)$$

Where, $p$ is a market price, $r_{si}$ supplier $i$'s power supply, and $w_{si}$ the amount of reward to pay. On the other hand, $r_{dj}$ is customer $j$'s power demand, and $w_{dj}$ the amount of reward to be paid.

Moreover, a total evaluation function of the cooperative power trading system is defined as (16),

$$f = \sum_{i=1}^{m} \alpha_i V_{si}(p, r_{si}, w_{si}) + \sum_{j=1}^{n} \beta_j V_{dj}(p, r_{dj}, w_{dj}) \quad (16)$$

Where $\alpha_i$ and $\beta_j$ are weights of suppliers and consumers respectively.