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Demand Response Effect on Deregulated Power Market

Master Thesis
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List of Abbreviation

EPACT	U.S. energy policy act
DOE	U.S. department of energy
I.L.M	interruptible load management
D.S.M	demand side management
GARCH	generalized autoregressive conditional heteroskedasticity
RBF-NNS	radial basis function neural networks
ANN	artificial neural networks
PJM	Pennsylvania- new jersey-maryland
MCP	market clearing price
LMP	locational marginal price
GENCOs	generation companies
LSEs	load surface entities
MAPE	mean absolute percentage error
MAE	mean absolute error
FMSE	forecast mean square error
DLC	direct load control
ECS	energy consumption scheduler
ARMA	auto regressive moving average
ARIMA	auto regressive integrated moving average
SVM	support vector machine
SVR	support vector regression
RTP	real time price
ISO	independent system operator

IBP	incentive based programs
PBP	price based programs

List of Symbols

P(n)	Price at time step n
L(n)	Load at time step n
a	Slope of the least-squares estimation on load and logarithmic price "ln(P)"
σ	Volatility, error degree of the liner regression on loads and logarithmic price
Δt	Interval of the time step (1 hour)
α	Mean reversion rate
η	Indicator variable on price spike (1:spike, 0:not spike)
κ	Multiplier of 'mean-of-spike-size' with respect to average non-spike price size
δ	Standard deviation of price spike size
k	Time on day ahead market (unit:1hour)
t	Time on real time market (unit: 5 minutes)
dj	Index for a critical peak pricing customer (demand)
Q_{mkt}	Quantity an ESP bought from a market
Q_{dj}	Quantity of electricity demand by customer dj
R_{dj}	Revenue from customer dj
$\mathbf{N_{cpp}}$	Number of critical peak pricing customers
$\mathbf{P^{DA}}(k)$	Electricity price of day-ahead market
$P^{RT}(t)$	Electricity price of real-time market
P^{cp}	Price of critical peak pricing for critical peak times
$P^{non\text{-}cp}$	Price of critical peak pricing for non-critical peak times
N	set of users
n or m	each customer
H	24 hours
h	each hour

$\mathbf{l_n}$	The daily load for user n
$\mathbf{L_h}$	Total load across all users at each hour of the day
$\mathbf{L_{peak}}$	Daily peak load level
$\mathbf{L_{avg}}$	Average load level
$\boldsymbol{l_n^h}$	Total load at hour h by user n
PAR	Peak to average ratio
$\mathbf{C_h\ (L_h)}$	Cost of generating or distributing electricity by the energy source at each hour $h \epsilon H$
$\mathbf{Y_n}$	Set of household appliances
y	Each appliance
$\boldsymbol{x_{n,y}^h}$	One-hour energy consumption that is scheduled for appliance a by user n at hour h
$\mathbf{X_{n,y}}$	Energy consumption scheduling vector
$\mathbf{X_{-n}}$	The vector containing the energy consumption schedules of all users other than user n
$\mathbf{b_n}$	daily billing amount in dollars for user n charged to him by the utility at the end of each day

Abstract

The most important incentive for electricity users to participate in a demand-side management program is the maximization of the user payoff and this can be done by rescheduling his energy consumption. Without customer participation demand response program will certainly fail to achieve their goal of reducing peak demand so customer acceptance and enrolment in the demand response program is an urgent need.

A distributed demand-side management system among users will be presented with a two way digital communication infrastructure. Then by using game theory an optimization equation is formulated. It deals with the total hourly load for each user. The players in this game are the users and their strategies are the daily schedules of their appliances and loads.

The reality of this program is proved by implementing it on a real data taken from ISO market and by using genetic algorithm with a constrain that the total daily energy consumption of each user remain approximately constant

The result show the success of this program that lead to reduce the billing tariff paid by each user and consequently the total energy cost.

Many factors affect on load forecasting studies such as previous loading temperature, weather condition, prices.

In deregulated market the price has a big influence on the load so it is useful to build a load-price forecasting models that depend on load and price time series.

Support vector machine is one of the novel machine learning techniques which enter recently power system study.

To implement a good Demand Response (DR) program, critical peak pricing (CPP) plan will be studied as an active demand response program. The economic perspective of CPP plan is the incentive of the plan conductor, or the profit of an energy service provider (ESP). The technical perspective is a method to maximize the incentive of CPP plan, or an ESP's profit. If the electricity market price can be predicted properly, generation companies and the load service entities as main market participating entities can reduce their risks and maximize their outcomes further. This will be realized by predicting the market prices then with the help of the Support vector machine (SVM) which is one of the novel machine learning technique. It predicts the overloading conditions to make the critical peak price decision

The suggested models procedure presented in this thesis are as follows:

- Model 1 is the price forecasting model based on the data of the previous day. This model has been tested using real market data from the ISO market data
- Model 2 is the heavy load detection using support vector machine technique
- Model 3 is using game theory technique in the daily energy consumption cost optimization which means the maximization of the pay off of each user by rescheduling energy consumption

Finally comparison of three algorithms is discussed and their effect on reducing the total energy cost:

- The genetic algorithm
- The harmonic search algorithm
- The backtracking search algorithm

The results show a good performance for the three algorithms as the three realize a positive profit. By comparing the profit it indicate that the harmonic search algorithm is better than the genetic because the profit is higher and the backtracking search algorithm is the best algoriyhm

CHAPTER ONE

INTRODUCTION

1.1 General

Old regulated electricity markets are where generation, transmission and distribution systems were owned by monopolies which:

- Were inefficient
- Have no incentive to operate efficiently
- Operate at increasing costs
- Do not care about environmental aspects (emissions)
- Do not face penalties for mistakes
- Perform unnecessary investments

Nowadays electricity tend to Deregulate which means change in government control. Break up of governmental utilities to profitable companies which mean allowing private sectors to invest in generation, transmission and distribution. This leads to introduce competition in the electricity market

Benefits of this competition are:

- Increasing efficiency in the supply of electricity
- Lowering the electricity cost to consumers
- Focusing on customer satisfaction (power quality and service reliability)
- Promoting economic growth

The old classical philosophy applied in monopoly systems was not suitable in deregulated power market as not reasonable to supply all the required demand whenever it occurs but it is more suitable to apply a new philosophy that states that the system will be most efficient if fluctuation in demand is kept as small as possible.

As electricity is distinguished from other commodities by its limited-storable nature so it raised the importance of price forecasting. Price-forecasting tools are essential for all electricity market participants under new deregulated environment so generation companies and consumers of electricity need to meet in a marketplace to decide on the electricity price. Proper electricity price forecast can help to build up cost effective risk management plans for the participating companies in the electricity market. Currently, market participants have to use different instruments to control and minimize the risks as a result of market-clearing price volatility. If the electricity market price can be predicted properly, generation companies (GENCOs) and the load service entities (LSEs) as main market participating entities can reduce their risks and maximize their outcomes further.

Demand response is similar to dynamic demand mechanisms to manage customer consumption of electricity in response to supply condition

It can be described by energy demand management also known as demand side management which is the modification of consumer demand for energy through various methods such as financial incentives and education

The goal of the demand side management is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak time such as night time and weekends

Game theory is one of the utilized techniques to decide the optimum consumption for each participant, it is used when a number of agents are requested to make the decisions in a game this choices that potentially affect the interests of other players if each player is restricted to a simplex in his own strategy space and if the payoff functions are bilinear functions of the strategies then an equilibrium point exist then by studying 4 game theorems some conditions are raised and implemented in the energy rescheduling process .

In this chapter a description of the thesis objectives and outlines are presented

1.2 Thesis Objectives

This thesis illustrates the importance of:

- Demand response with the help of price forecasting and critical peak decision on the market price proving this on real market data and showing the profit an energy system provider can gain from this .
- Implement demand response to reduce customers bill is proven by using game theory and implementing its condition on the algorithm to reschedule each user daily energy consumption and consequently reducing his electricity bill.

1.3 Thesis Outlines

This thesis contains 7 chapters and a list of references:

- Chapter one presents a brief introduction to the thesis, highlights on the thesis objective, and a skeleton of the proposed thesis

- Chapter two reviews the literatures, which concern the price forecasting studies under deregulated electricity markets, the studies of implementing support vector machine for heavy load detection and the studies of using game theories in rescheduling energy consumption as demand response program.

- Chapter three describes the formulation of the price forecasting equation working on three methods for forecasting the price random walk, mean reversion, and jump diffusion and realize it on a real market data.

- Chapter four is divided into two parts, the first part describes the support vector machine and its use in heavy load detection, and the second part shows the calculation of the energy system provider profit

- Chapter five describes game theories and their usage in the algorithm for rescheduling daily energy consumption as a demand response program also the formulation of the energy consumption equation which will be solved.

- Chapter six presents the comparison between three optimization techniques, the genetic algorithm, the harmony search algorithm and the back search tracking

- Chapter seven presents the conclusion, the recommendations, and the future work of the thesis.

- A list of references showing the papers and sites which have been used through the study of the proposed thesis.