Energy 109 (2016) 310–325

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Is real-time electricity pricing suitable for residential users without demand-side management?

Javier Campillo*, Erik Dahlquist, Fredrik Wallin, Iana Vassileva

School of Business, Society and Engineering, Mälardalen University, Sweden

ARTICLE INFO

Article history:
Received 19 November 2015
Received in revised form
15 March 2016
Accepted 24 April 2016

Keywords:
Smart metering
Dynamic pricing
Electricity market
Real-time pricing
Power systems

ABSTRACT

The smart metering infrastructure in Sweden allows electricity providers to offer electricity RTP (real time pricing) to homeowners, together with other dynamic pricing contracts across the country. These contracts are supposed to encourage users to shift power consumption during peak hours to help balance the load in the power system. Of all the available contracts in Sweden, monthly-average price holds the largest share, in response to the low electricity prices during the last three years. It is not clear if RTP will become a popular dynamic pricing scheme since daily price fluctuations might keep customers away from this type of contract. Literature review suggests that RTP adoption is only beneficial when combined with the use of customer demand flexibility, but it does not provide enough information about users adopting RTP without changing their electricity usage profile. This paper studies the economic impact if customers would shift to RTP contracts without adopting demand-side management. To achieve this, electricity costs from a large group of households were calculated and compared between both pricing schemes using the hourly consumption data of a 7-year period. Results suggest that the RTP electricity contract offer a considerable economic savings potential even without enabling consumer demand-side management.

1. Introduction

In power systems, the produced power has to equal the consumed one plus the losses in the transmission and distribution systems at all times. Energy storage can be used as a buffer, to help keep the system balanced under unexpected rapid changes between supply and demand, but current technologies provide with limited storage capacity and financial benefits are yet not fully understood [1].

Different power sources have to be dispatched according to demand fluctuations in order to maintain the balance between load and supply at all times. Each power source has a different cost structure and it runs under different operation conditions; the TSOs (transmission system operators) and balance providers decide which power sources to include in the system at any given time, based on several parameters, for instance: running costs, electricity demand forecast, weather conditions and reservoir capacities.

These power production costs are highly variable and thus, effective ways to charge end-users for a product that is highly variable in nature, has been debated since the beginning of the electric power industry itself. Utilities defined the optimal pricing regime for this service as Hopkinson's differentiated rates based on time-of-day use [2] and since then, additional dynamic pricing schemes have been developed. Today, different methods include CPP (critical peak pricing), CPR (critical peak rebate), demand-based tariff and RTP (real time pricing) [3–7].

Lately, large penetration of intermittent renewable energy sources, such as wind and solar power, have introduced larger fluctuations on the supply side, in consequence, existing prime movers have to ramp up and down their production capacity, often operating in derated mode at low efficiency. This operation has led to increased operation costs and in general, added more complexity to the operation and control of the power system [8–10]. This has, in consequence, increased the price fluctuations in the electricity market.

In Scandinavia (Denmark, Finland, Norway and Sweden), the Nordic Power system is based on a mixture of power sources with a total installed capacity of 100,832 MW in 2013 [11]. Over half of the production capacity comes from renewable power sources, mainly

* Corresponding author.
E-mail address: javier.campillo@mdh.se (J. Campillo).

http://dx.doi.org/10.1016/j.energy.2016.04.105
0360-5442/

hydropower. CHP (Combined Heat and Power) makes up for the second largest generation type, followed by nuclear power in Sweden and Finland. Wind power accounts for less than 10% of the total production capacity in Scandinavia, but has increased significantly over the last few years [12].

In Sweden, the installed capacity increased with 890 MW from 2011 to 2012 (2.4%); 1055 MW from new wind power stations plus the small contribution of new solar panels (24 MW) minus the loss of 170 MW in decommissioning of condensing power plants [11].

The electricity market has been deregulated since January 1 1996, meaning that both electricity production and retail have been subject to competition after the reform. The wholesale price of electricity is determined by supply and demand on an hourly basis on NordPool's spot market (Elspot) for the next 24-h period. Due to physical transmission restrictions between countries, the Nordic electricity market is divided into bidding areas (Elspot areas) [13]. The network operation still remains as a regulated monopoly in Sweden. The distribution networks are operated by about 160 different distribution system operators and the transmission network is governed/operated by Svenska Kraftnät, the Swedish TSO.

For each hour of the following day, the players in the spot market specify the amount of electricity they wish to sell or buy. All the bids are aggregated both in price and quantities and the demand curve is built from the sum of all purchase bids. The combination of price and quantities where supply and demand curves match, establish the market price as shown in Fig. 1 [13].

NordPool Spot's market share of all the electricity traded in the Nordic and Baltic area in 2014 was 501 TWh [14], the largest part of all the electricity produced and consumed in the area. In Sweden, the total electricity produced that year was 149.5 TWh, with a net export of 10 TWh, leaving a total of 139.5 TWh of electricity used in the country [15]. Almost all electricity generated and consumed in Sweden was traded through NordPool Spot.

Additionally, Sweden made a strong commitment to deploy an advanced metering infrastructure and by year 2009, reaching full smart metering coverage. With this infrastructure in place, from 1st October of 2012, new regulations for hourly metering came into force. These new regulations gave electricity customers the right to have their electricity consumption metered by the hour and established that electricity suppliers could offer variable-pricing contracts based on hourly meter readings [16].

For household users in Sweden, the total electricity cost comprises the cost of electricity supply itself, electricity transmission, energy taxes and VAT (value-added tax). In 2014, in average, the share of the electricity supply price made up to 33% of the users electricity bill, 24% corresponded to the network tariff and 43% to energy tax and VAT [17].

One of the main advantages for residential users of a deregulated market together with smart metering technology, is the contract flexibility and options provided by electricity retailers [18]. The number of customers that have switched electricity retail companies has been fairly constant over the past four years. In 2014, almost 1.2 million households changed electricity retailers or signed a new contract, corresponding to 24.7% of the total amount of residential users in the Swedish electricity market [17].

Residential customers in Sweden can choose from different pricing contracts from approximately 200 different suppliers. The most common types of contracts are the variable pricing contract, where the cost per kWh is based on NordPool Spot month's average spot price, plus a retailer fee; fixed price contract where the user pays a predetermined electricity price agreed between the retailer and the customer and that remains fixed during the duration of the contract (1, 2 and 3 years); default contract, which is selected by the local network owner, if the customer does not make an active choice; hourly RTP, where the cost per kWh is determined by the spot market price and although it is not common, it is possible to sign for this type of contract with a limited number of providers (ten at the end of 2015); other contracts options include demand-based pricing options and mixed rates (50% fixed, 50% variable) [17].

The overall average low-prices in the Nordpool spot market in the last years, has resulted in a great number of users shifting from fixed price contracts to variable-price ones. In December of 2014, 41.4% of Swedish domestic customers had signed variable-price contracts, about 6% more than the customer base for fixed-price contracts. The small percentage of customers still using default contracts is rapidly declining because due to an increased awareness about the possible flexibility options and due to the high prices offered with this type of contract. Additionally, users choosing

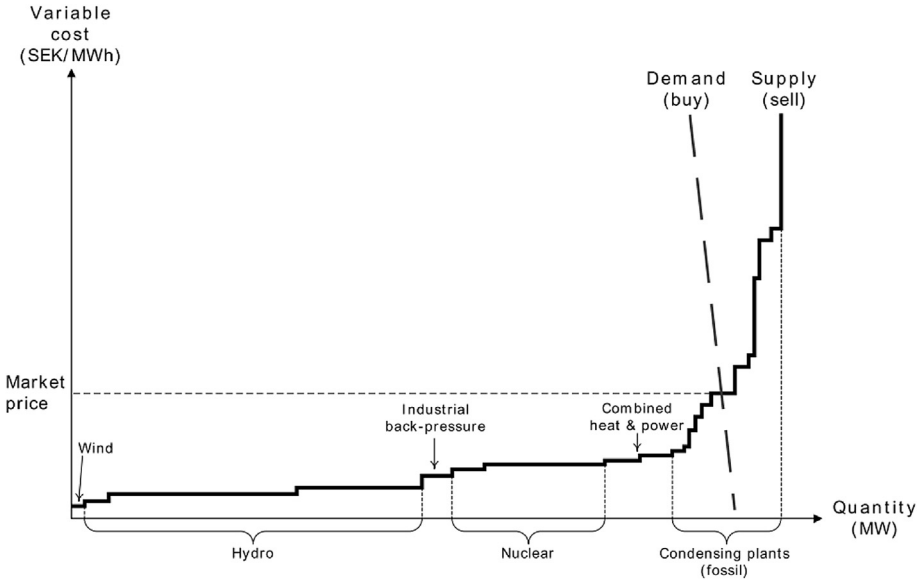

Fig. 1. Price formation in the Nordpool Spot market.