

Chapter 90

Demand–Side Response Smart Grid Technique for Optimized Energy Use

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ABSTRACT

The chapter describes a dynamic smart grid concept that enables electricity end-users to be acting on controlling, shifting, or curtailing own demand to avoid peak-demand conditions according to information received about electricity market conditions over the Internet. Computer-controlled switches are used to give users the ability to control and curtail demand on a user's premises as necessary, following a preset user's preferences. The computerized switching provides the ability to accommodate local renewable energy sources as available. The concept offers further the ability to integrate charging electrical vehicles during off-peak periods, helping thus substantially improving the utilization of the whole electricity system. The approach is pursuing improved use of electrical energy associated with improved energy management, reduced electricity prices and reduced pollution caused by excessive use of combustion engine in transport. The technique is inherently restricted to take effect in frame of energy tariff regimes based on real-time price made to encourage and reward conscious users being proactively participating in holistic energy management strategies.

INTRODUCTION

The traditional user-supplier rapport in the electrical energy market has historically evolved following a strategy implying whenever a load is switched on it is expected to be fulfilled by the

supplier at the expected time and quality. Growing electrical demands followed by constantly growing supply led to troubled electrical services manifested mainly by daily and seasonal excessive peak and low demands. Those chronic peaks on electrical networks are usually associated with compromised quality, risk of forced outages and

DOI: 10.4018/978-1-4666-4852-4.ch090

high-priced energy supply; while low-demands on the other side might be driving some power plants to be operating at critical economic viability. Demand-side-response techniques are helping electricity users to become proactively participating in averting detrimental conditions presently prevailing in the electricity sector (Kamel, 2009b). Coordinated strategies shall help achieving improved use of electrical power plants and electricity infrastructure, besides integrated use of different types of energy sources. (Chua-Liang Su & Kirschen, 2009) proposed a day-ahead market-clearing mechanism that allows consumers to submit complex bids. Those bids are expected to give consumers the opportunity to specify constraints on their hourly and daily consumptions in the same way as generators can specify the operating constraints on their generating units. It is a day-ahead market with complex bids and offers whose objective is to maximize the social welfare. The social welfare is described as the difference between the value that consumers attach to the electrical energy that they buy and the cost of producing this energy. Not all consumers have the ability or the motivation to adjust their demand as a function of price. Part of the demand will therefore remain perfectly inelastic. Therefore, consumers were classified into two types, price-taking and price-sensitive. Price-taking is those consumers who have, in theory, an infinite marginal value as otherwise the consumers would have placed price responsive bids with a finite marginal value attached.

Plant Capacity Factor

The plant capacity factor (PCF) or the so also called utilization factor of a power plant is, by definition, the proportion of the actual electrical energy generated yearly by the plant to the quantity of electrical energy, which would be generated if the plant was operated at rated power for full year's time (8760 hours) as reported by Brinkmann (1980). The factor has a direct influence on the

energy cost as can be deduced from the following equation of the fixed charge method according to De-Meo (1978), Leonard (1977), Chobotov (1978) and Clorefeine (1980):

$$c_E = c_{tr} \text{FCR}/(T_o \text{PCF}) + c_{op} \quad (1)$$

where c_E is the cost of energy generated, c_{tr} cost of installed power including taxes during the installation period, FCR fixed charge rate of the capital, normally 15...18% a year according to Leonard (1977) and Leonard (1978), $T_o = 8760$ (h) the hours per year, PCF plant capacity factor and c_{op} the operation and maintenance cost of the plant. For plants operating 24 hour/day, 7 days a week, i.e. 8760 hour/year PCF is a unity, which produces the least possible energy cost and best economic conditions. For power plants operating any less than 8760 hour/year the PCF will respectively be lower (below unity) what drives the cost of the produced energy to be accordingly higher, Equation (1).

Figure 1 illustrates the impact of the plant capacity factor on the cost of the produced energy. The calculation is made on the basis of the cost of the installed power $c_{tr} = \$1000/\text{kW}$, capital fixed charge rate $\text{FCR} = 0.17$ and the operation and maintenance cost of the plant $c_{op} = \$0.02/\text{kWh}$. It is evident that a power plant operated at low plant capacity factor e.g. $\text{PCF} = 0.1$ (this is 2.4 hour/day) will be producing energy at \$150/MWh, while operated continuously for 24 hour will produce energy at a cost of \$25/MWh.

Figure 1 depicts the importance of operating power plants and electrical network infrastructure at elevated plant capacity factor, close to the unity, in order to verify best economic performance. Various efforts on avoiding peak demands on the electrical network are mainly aiming at leveling demand throughout the year in order to achieve as high plant capacity factors as possible for all electrical power components. Additionally, leveling demands is pursued to avert or delay the urgency to expand generation capacity and network

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