IMPACT OF DEMAND-RESPONSE PROGRAM ON ELECTRICITY DEMAND IN POWER MARKET

Rekha Swami,

Engineering College Bikaner, Raj., INDIA

Abstract: The global electricity demand is increasing day by day, whereas power generation sources are limited. Therefore, in recent years, world has moved towards the use of distributed generation (including both renewable and non-renewable energy sources) for power generation. However, the variable nature of renewable sources especially solar and wind created problem in power system operation. One way to handle this, is the use of demand response program in power system operation. In the presented work, impact of demand response program on electricity demand is analysed. Simulation is performed using General Algebric Modelling System (GAMS) software.

Index Terms- Classification, Demand Response Program, Elasticity, Demand.

I. INTRODUCTION

Recently, to meet the world's increased electricity demand, distributed generations such as solar, wind, fuel cells, microturbines are widely used in power systems. These distributed generation sources are placed near to consumers and results in lower electricity cost, increased energy efficiency and reliable power supply. Besides having so many advantages they create some difficult challenge in power system operation. This happens because of the variable nature of these sources especially solar and wind. Sometimes generation may be higher than load and sometimes load is higher. When load is higher than generation then system may collapse [1-3].

One remedy is to use Battery Energy Storage, that stores energy when generation is higher or releases stored energy whenever it is required [4]. One more solution for the error produced by renewable energy prediction is the use of Demand Response Program [5].

Demand Response Program is defined as the change in the electricity usage by the end-term users from their normal consumption pattern in response to the change in electricity prices over time or incentive given them to reduce electricity use when the market price is high [6-7]. The Demand Response Program reduces the power demand in peak period thereby reducing the operation cost [8-9].

Demand Response Programs are categorized into price-based and incentive-based. In price-based, consumers vary their electricity usage patterns depending on prices, and in incentive-based, changes are made depending on incentives given to consumers during peak periods [10]. A Demand Response Program model based on price elasticity is presented in [11].

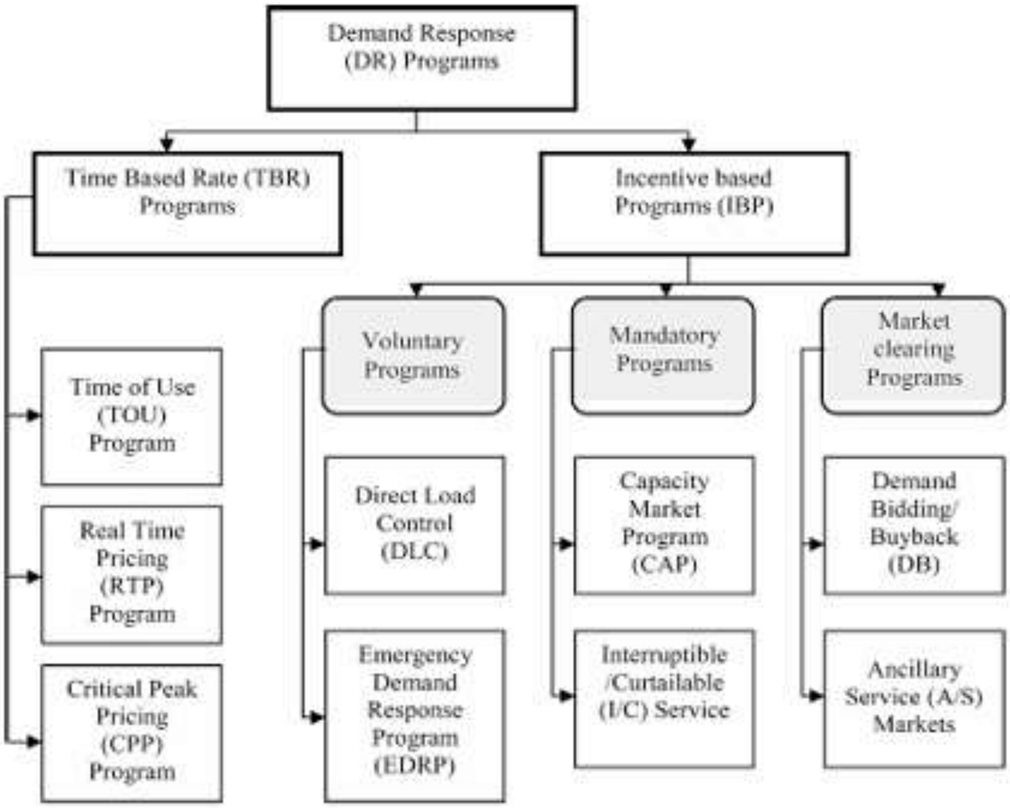


Fig (1): Demand Response Classification

2. Demand Response Program Modeling

In the power market, electricity demand decreases with an increase in electricity prices, and vice versa. This relationship between demand and price is modeled in terms of elasticity (E), interpreted as the demand sensitivity toward the electricity price.

$$E = \frac{\partial q}{\partial \rho} = \frac{\rho_0}{q_0}\frac{dq}{dp}$$

Where ρ_0 and q_0 are the initial cost of electricity (€ct /kWh) and initial demand (kW), When electricity prices vary, demand reacts in two ways:

Some of the loads can only be turned on or off. These loads cannot be transferred from one period to another and have sensitivity in one period measured by self-elasticity. Some loads can be transferred to another period due to price fluctuations in one period. These loads have multi-period sensitivity, measured by cross-elasticity. Some loads can be transferred to another period due to price fluctuations in one period. These loads have multi-period sensitivity, measured by cross-elasticity. As shown in Fig 2 when demand is fixed, then intersection of supply and demand results in high cost but when demand becomes elastic, the electricity cost is reduced.

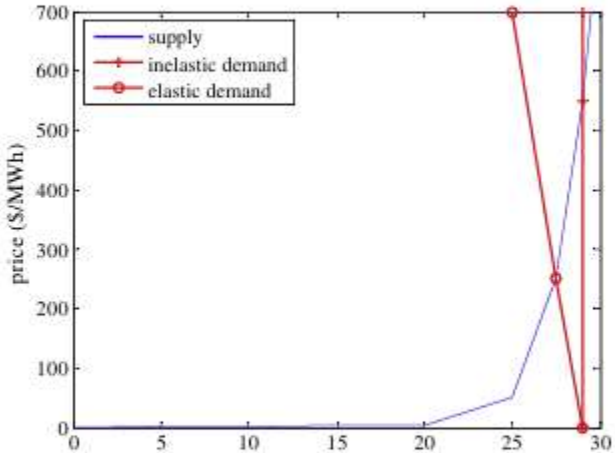


Fig (2): Effect of load change on electricity prices

In DRP, consumers reduce their demand during peak hours and shift it to off-peak hours due to these elasticities. The changed demand after implementing DRP is given by:

$$P_{L,DRP}(t) = P_L(t) \cdot \{1 + E(t,t) \cdot \frac{[P(t) - P_0(t) + A(t)]}{P_0(t)} + \sum_{\substack{t'=1 \\ t' \neq t}}^{24} E(t,t') \cdot \frac{[P(t') - P_0(t') + A(t')]}{P_0(t')}$$

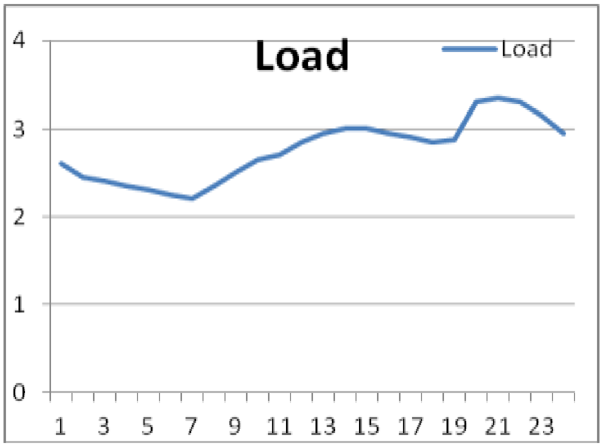
where, A(t)-incentive given to consumers for DRP implementation, P_L-Demand before applying DRP, $P_{L,\,DRP}$ -Changed demand after implementing DRP. In this equation, the second term is due to self-elasticity E(t,t), and the third term is due to cross-elasticity $E(t,t')$ [12-13].

3. DEMAND RESPONSE IMPACT ON ELECTRIC DEMAND

To analyse the impact of Demand response program on electric demand, A data set from Ref. [14] is taken to demonstrate how demand varies depending on electricity prices and elasticity. The load is divided into three parts: low-load hours (1-8), off-peak hours (9-18), and peak hours (19-24). The cost of

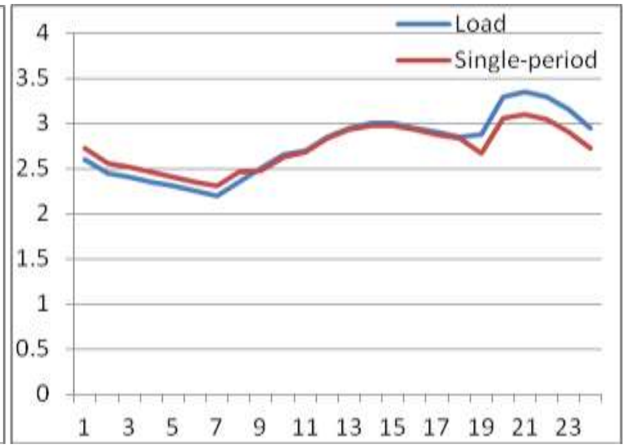
Table 1: Self & Cross Elasticity

	Low load	Off-peak load	Peak load
Low load	-0.10	0.016	0.012
Off-peak load	0.016	-0.10	0.01
Peak load	0.012	0.01	-0.10



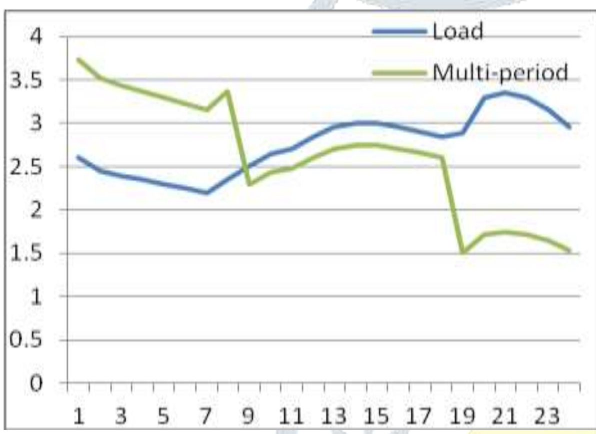
Time (hr)

(a) Demand



Time (hr)

(b) Modified Demand due to Single-Period Elasticity



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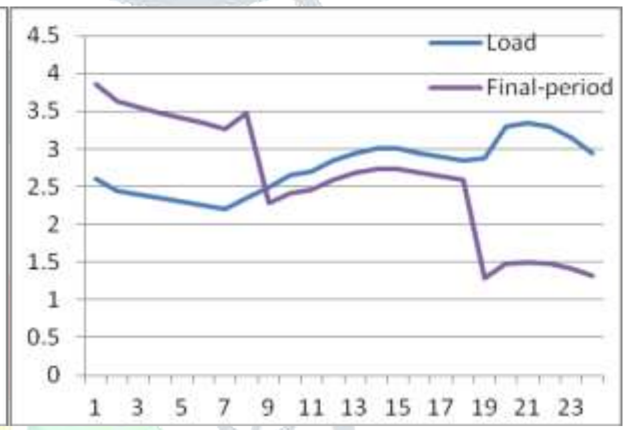
(c) Modified demand due to multi-period Elasticity



Time (hr)

(d) Modified demand due to Final-period Elasticity

Fig (3): Changed Demand using Elasticity

electricity has been 36 €ct/kWh on average. To implement DRP, prices for peak, off-peak, and low-load periods are assumed to be 62.4, 38.4, and 19.2 €ct/kWh respectively. Self and cross-elasticity are provided in Table 3.1.

It is clear from Figure 3 that elasticity reduces demand in peak hours and shift it to low load hours. The reduction in peak demand is more in multi-period elasticity rather than single-period elasticity. The maximum peak reductions and shifting in low-load hours occur in final-period elasticity.

IV. CONCLUSION

This paper provides the basic detail of demand response program including its classification. It also presents the load demand economic model. A load data set from Iranian power grid is considered and results are verified in order to check the correct implementation of demand response program. Simulation is performed in GAMS environment. It is concluded that in final-period elasticity, maximum peak reductions and shifting in low-load hours occurs.

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