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Outages Cost Estimation for Residential Sector

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ABSTRACT. This paper investigates and analyzes the effects of electric service interruptions resulting from severe power outages. The residential sector in the city of Riyadh has been selected as a practical case to conduct this study. It has been found that this sector – which constitutes about 70% of the Saudi Electric Company in the central region (SECO) energy consumers – will suffer tangible and intangible losses should outages occur in specific times, seasons and last for long durations

1. Introduction

Electric service interruptions occur when system capacity, due to severe power outages, is insufficient to meet the system load levels. During these periods of inadequacy, outage costs will be borne by the utility, its customers and perhaps, by the entire society. The utility outage costs include loss of revenue, loss of future sales and increased repair expenditure and maintenance. These costs usually form only a small part of the total outages costs. The greater part is that borne by the consumers. The outage costs depend on many factors and situations, some of which are discussed in the following sections.

The problem of estimating outage costs is affected by the perceived costs of an electric outage and the point in time when a consumer would like to buy electric energy but is unable to do so. Since there are different classes of consumers, each will tolerate loss of service differently. A residential consumer may suffer a great deal of hardship if an outage occurs during a hot summer day or while he is engaged in domestic activity but it may be of little inconvenience to a commercial user who is forced to close until power is restored. Also an outage may cause a great loss to an industrial user if it occurs during the time of the production process. Therefore, consumers do not perceive service interruption to the same degree of hardship.

2. Literature Review

A review of the literature reveals numerous studies directed to estimate residential outages cost. Krohm[1] considered that the impacts of outages upon residential consumer can be measured as the disruption of household preferred consumption pattern by time-of-day. A measure of the resultant reduction in the household welfare level due to inconvenience, lost leisure, etc. is its willingness-to pay to avoid the outages. Koval *et al.*[2] developed a statistical method and showed that the outage costs vary in a non-linear way with durations. Munasinghe[3] considered that the main outage costs is the loss of evening leisure time which can be evaluated at the household income. The Swedish study[4] was obtained by direct questioning to the customers and through worked examples based on actual losses, household activities, and leisure time. Wacker *et al.* [5,6] and Billinton *et al.*[7] used three survey approaches. Two of these approaches were considered with tariff changes that would be commensurate with specified changes in system reliability, while the third approach was concerned with the type of preparatory actions that consumers may take during outages periods. Also Billinton *et al.*[8] relate the costs to the expected energy not served by using a frequency and duration approach and Mont Carlo simulation. Shaalan[9] used a customer survey to estimate the outages costs for major customer`s categories (*i.e.* residential, commercial, industrial). The method adopted was based on the customer`s survey to assess damage that may result due to power outages.

The data extracted from these studies are of significant contribution to the reliability-based power system planning[10,11]. These approaches, however, are not strictly comparable, the major reason being that the cases, scenarios, data, and modelling techniques are not identical.

3. Study Procedures, Results and Discussions

The objective of this study was to explore the impact of outages upon the residential sector in the city of Riyadh. Riyadh is the capital of Saudi Arabia and the largest city within the Saudi Electric Company (SECO) in the central region. The data used in this study is based on 354 responses from a residential survey resulting from 730 questionnaires[12]. The survey involved selected samples of residential consumers in Riyadh. The respondents were asked to provide information concerning their monthly energy consumption and payment bill. These enable the cost estimation and other results to be correlated and analyzed for their relationship with household activities and type of dwelling. The breakdown of the respondents by dwelling type and their average monthly energy consumption and bill payments are shown in Table 1.

TABLE 1. Respondents proportions, consumption and payments by dwelling types.

Type of residence	% of respondents	Av. consumption (kWh / mo)	Av. bill (SR / mo)
Villa	67	4500	458
Duplex	12	2720	190
Apartment	21	2143	150

3.1 Opinions Regarding Service Quality and Outages

In response to the questions of attitude towards the service quality, there was an unanimity among the respondents that the system offered a good and reliable service (the scale varies from 0 "intolerable" to 5 "excellent") and the rate of outages during the past two years had been rather low. These opinions are depicted in Figure 1.

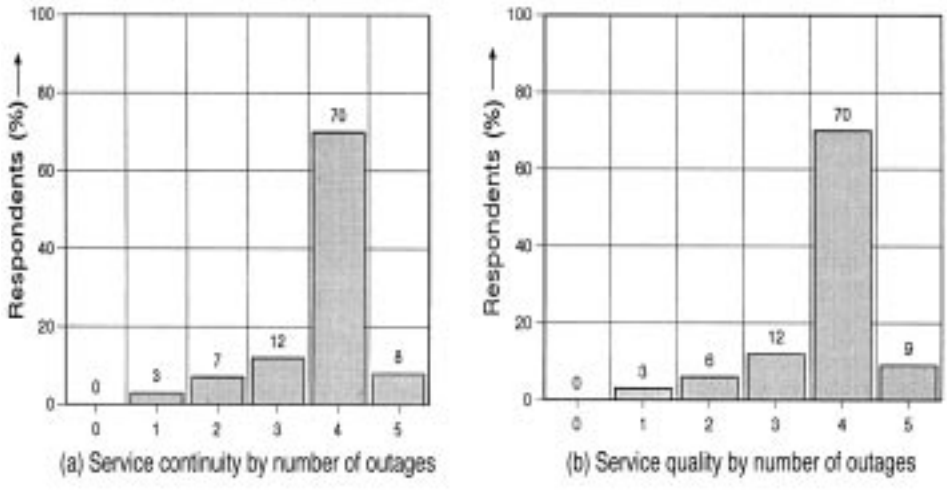

FIG. 1. Attitude towards service quality and continuity.

3.2 Levels of Hardship with Outages

To explore the extent of respondents' discomforts, anxieties and adversities during service interruptions, they were asked to give, based on a scale varying from 0 (no hardship) to 5 (extreme hardship) their level of hardship of not being able to use major electrical appliances such as kitchen devices, washing machines, air conditioners, lights. Their responses are depicted in Figure 2. It is noticed from the figure that the most critical devices that the residential consumers will not be able to use should an outage occur, are mainly air conditioners followed closely by loss of lighting and less closely by kitchen facilities and washing machines.

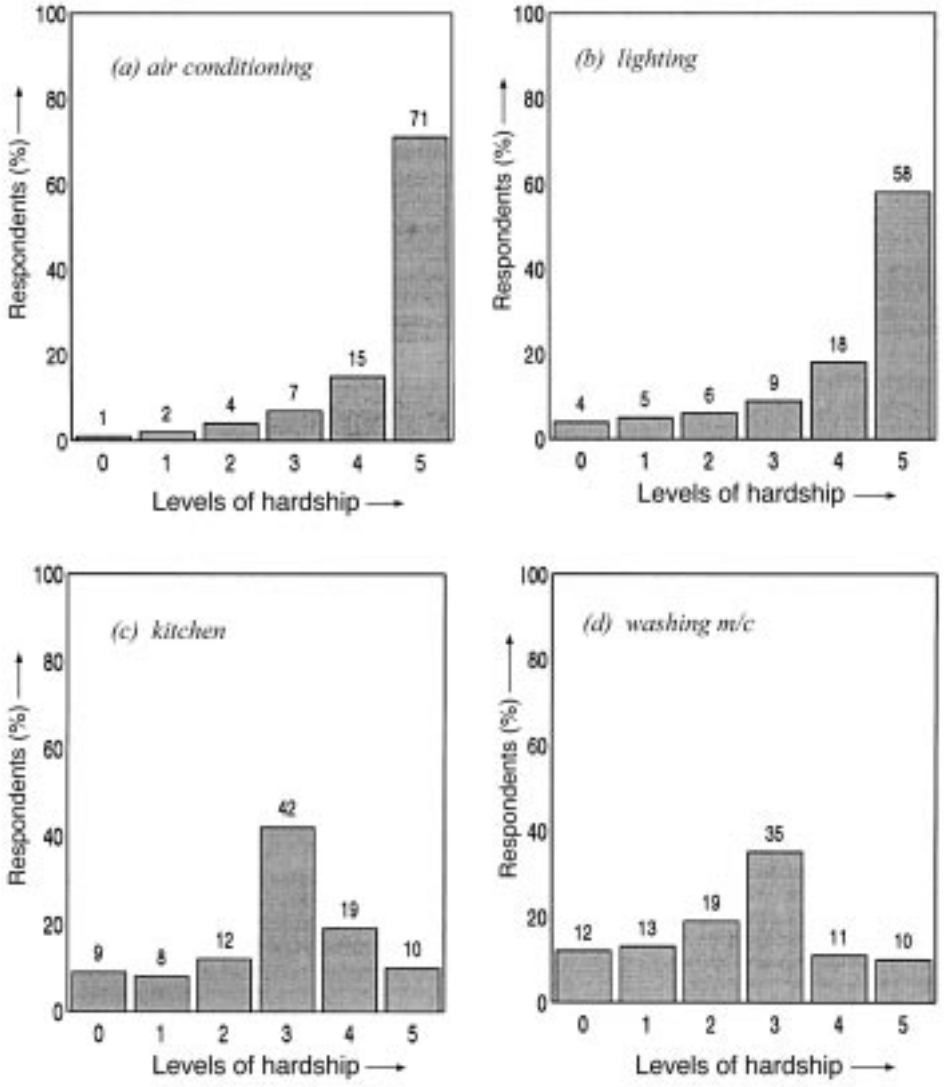

FIG. 2. Variation of household hardship during outages.

3.3 Hardship vs. Frequency and Duration of Outages

The survey suggests some hypothetical scenarios of power outages in summer time for 4 hours between 12 noon and 6 pm. These outages may occur once per day, week or year. Their opinions are displayed in Figure 3. From the Figure, it is clear that the severity of hardship will increase with the frequency of the outages.

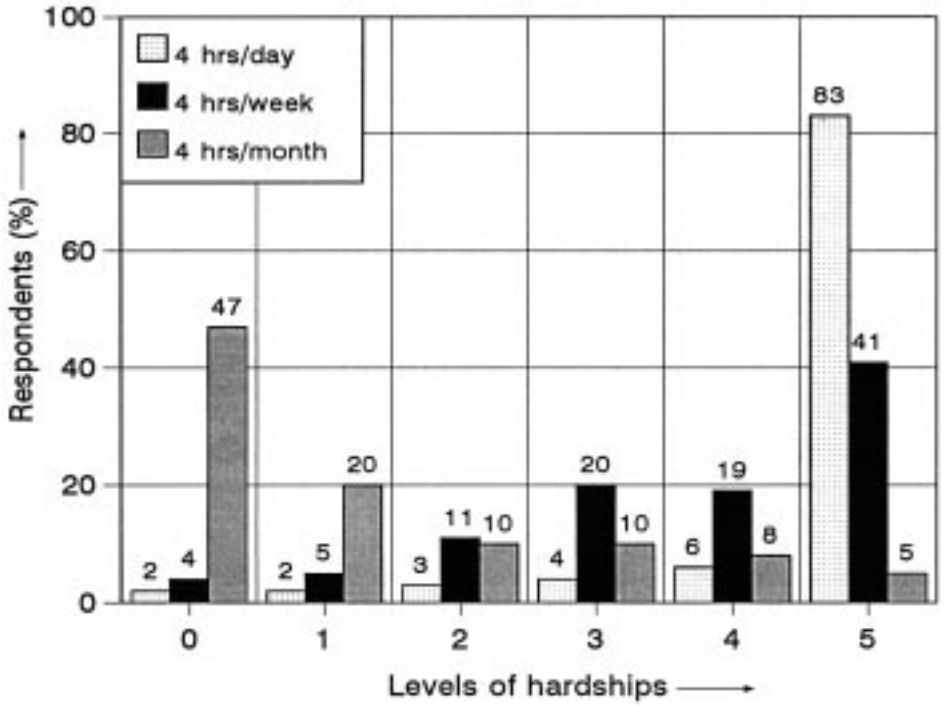

FIG. 3. Variation of hardship with frequent outages.

The respondents' reactions towards duration and occurrence time of interruptions were also sought. These occurrences were suggested to be in the summer season and after midday where the use of air conditioners is mostly needed. The duration of these interruptions were suggested to be 20 minutes, 1 hour, 4 hours, and 8 hours. These results are shown in Figure 4 which depicts the respondents irritation rapidly increasing with the length of service interruptions.

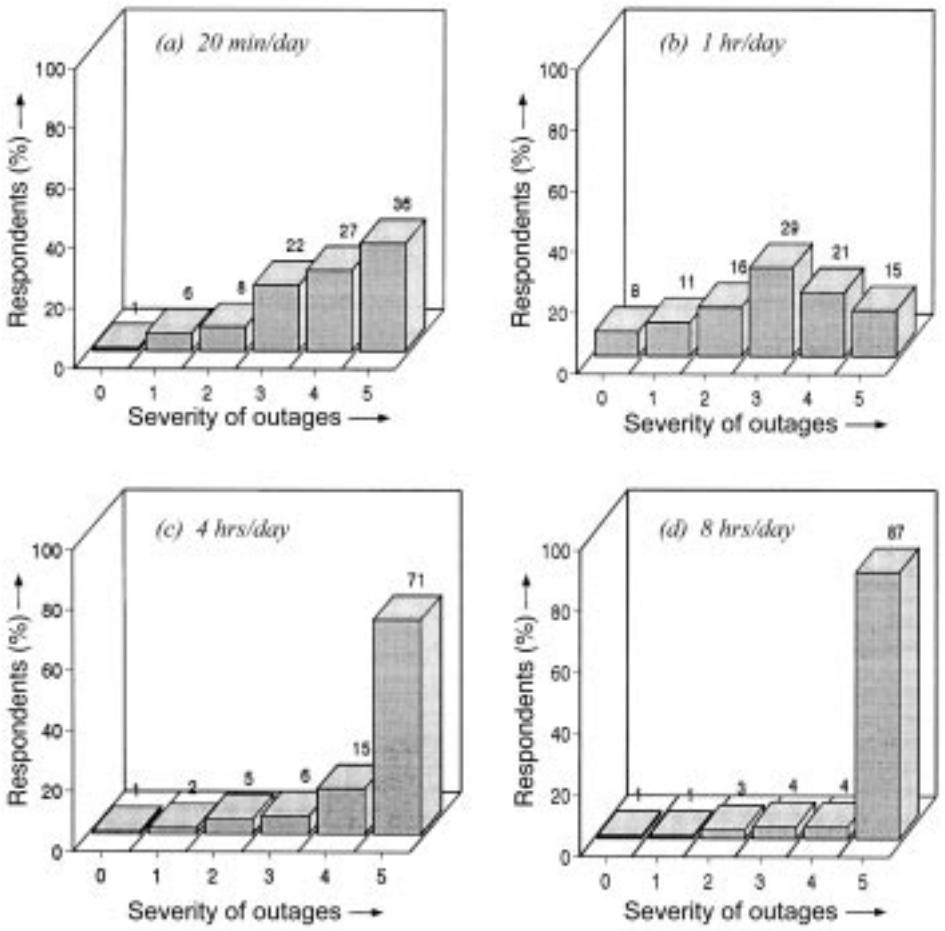

FIG. 4. Variation of hardship with outage duration.

3.4 Hardship vs. Seasons Outages

The survey suggests some hypothetical scenario of service interruptions in different seasons of the year between 12 noon and 6 pm. The results are shown in Figure 5 which indicates that the respondents reactions widely vary with respect to the season where the outages occur. It is quite obvious that the interruption impact is more pronounced in summer time compared with other seasons due to the high temperature and the wide use of air conditioners.

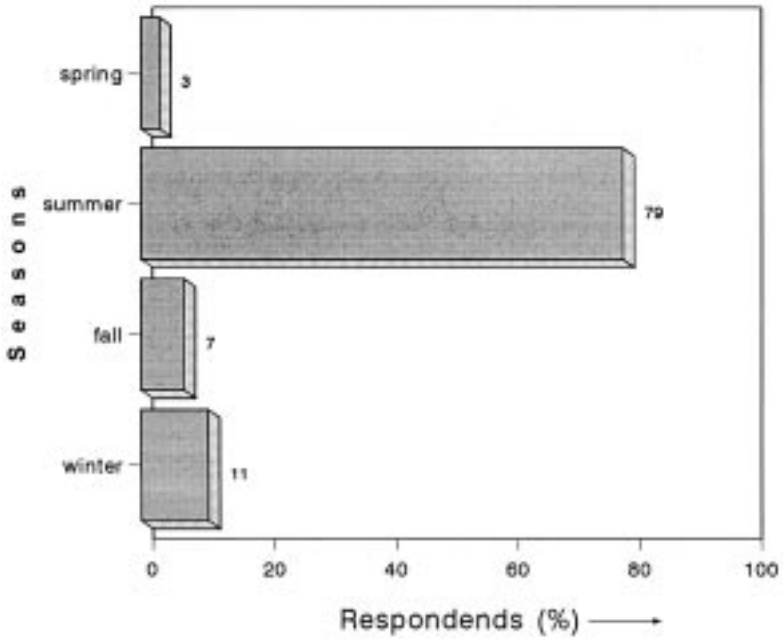

FIG. 5. Severity of outages in different seasons.

4. Outages Cost Estimation

The survey aimed to measure the tendency among customers to accept tariff increase and to realize to what extent they were willing to pay to avert service cessation. It is suggested that the power system has become subject to more frequent power outages. To increase system reliability, the company may add generating units and/or reinforce its network facilities which may result in tariff increase. Hence, the argument postulates daily power outages in summer period for durations of 20 minutes, 1 hour, 4 hours, and 8 hours. A range of possible tariff rate increases were proposed and the respondents were asked to perceive and assess the possible damage resulting from service interruptions and consequently to discern the fair and appropriate rate increases based on the prevailing present tariff structure. The data reported by the customers is exhibited by Fig-

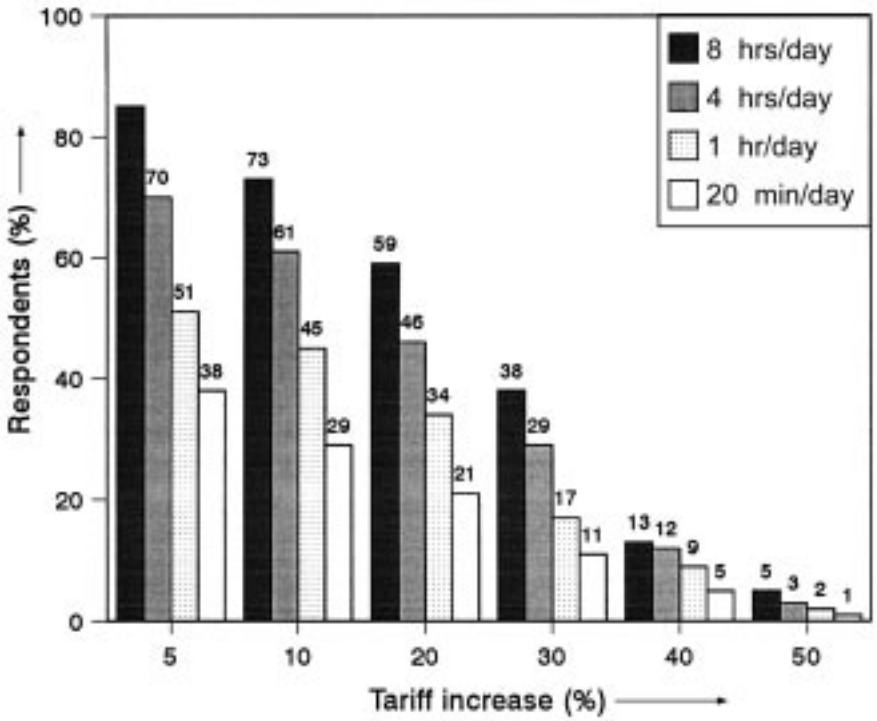

FIG. 6. Suggested tariff rate increase with outage duration.

ure 6. The Figure reveals that the most expected rate increase that customers are willing to pay to maintain acceptable supply quality and avoid the 4 and 8 hours service interruptions per day can reach up to 20% of the present rate level. The willingness-to-pay, however, diminishes as more rate increases are proposed or when less frequent outages are suggested.

The average value of the maximum amount per month that the respondents were willing to pay for more reliable system is based on their average energy consumptions (kWh/mo) and payments (SR/mo) in summer time. The cost per outage estimate for the residential sector as SR/kWh was evaluated for the purpose of this study. This estimate is presented in Table 2 and depicted in Figure 7 which evidences clearly the time-dependent non-linear nature of outages cost that could be prohibitive should interruptions last for longer periods. The SR/kWh estimates are weighted by the customer's monthly consumption and payment and converted to a per unit interruption basis to make the estimate consistent.

TABLE 2. Variations of residential cost with durations of outages.

Outages durations	SR / kWh
20 min	0.2146
1 hour	0.8048
4 hours	4.3820
9 hours	97.3200

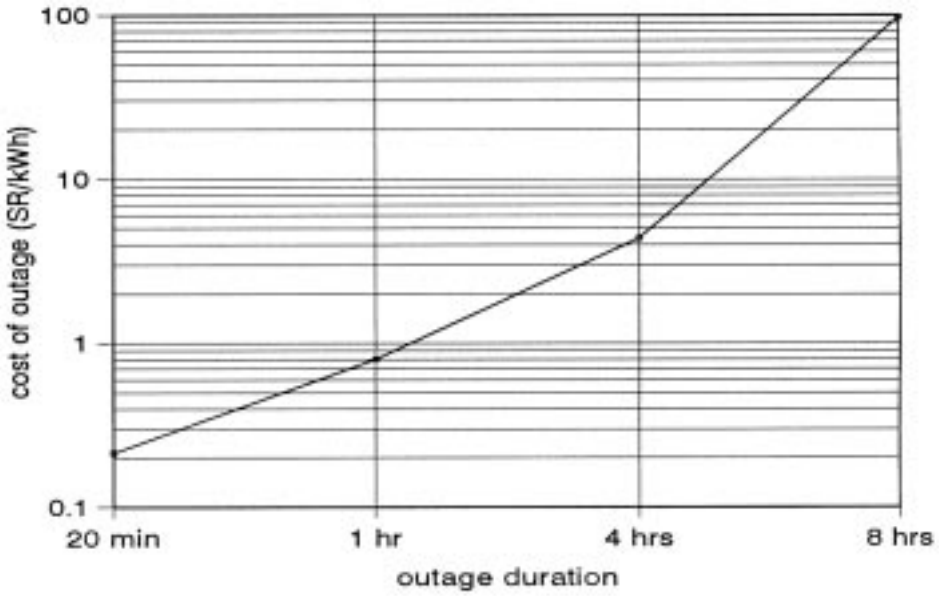

FIG. 7. Variations of cost with outage duration.

5. Conclusions

This paper presents results of research conducted to assess the perceived losses incurred by the residential sector in Riyadh due to severe electric power outages. The results reveal that these outages result in customer's deprivation from social activities, usage of certain essential appliances, and food spoilage. This causes customer's discomfort and anxiety which are intangible losses and cannot be quantified in monetary values. An approach, based on customer's losses incurred during outages and his willingness-to-pay to avert these outages, has been used to estimate the customer's perceived costs should outages occur in specific periods and last for longer durations. The major contribution of this study is the compilation of residential cost of outages data which can be used as a key input to reliability/worth assessment in power system planning and operation.

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تقدير تكاليف انقطاعات الخدمة الكهربائية للقطاع السكني

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المستخلص . في هذه الورقة تم تحري وتحليل آثار انقطاعات الخدمة الكهربائية الناجمة عن أعطال كبيرة في إمدادات القدرة . ولقد تم اختيار المستهلك السكني بمدينة الرياض كحالة عملية لإجراء هذه الدراسة . ولقد تبين من نتائج هذه الدراسة أن هذا القطاع الذي يشكل حوالي ٧٠٪ من مجمل الاستهلاك بمنطقة امتياز الشركة السعودية للكهرباء (فرع المنطقة الوسطى) سيعاني من خسائر معنوية ومادية من جراء تلك الانقطاعات ، وستتفاوت تلك الخسائر تبعا للأوقات والفصول وطول الفترات التي تستغرقها تلك الانقطاعات .