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F. Elkarmi
Director., Energy Sector., Higher Council for Science & Technology, Amman., Jordan.

H. El-Zayyat
Associate Professor., Electrical Engineering Department., University of Jordan., Amman., Jordan.

Z. Tahboub
Assistant Professor., Industrial Engineering Department., University of Jordan., Amman., Jordan.

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F. Z. ElKarmi
Director, Energy Sector
Higher Council for Science & Technology, Amman, Jordan

H. M. EL-Zayyat
Associate Professor, Electrical Engineering Dept.
University of Jordan, Amman, Jordan

Z. A. Tahboub
Assistant Professor, Industrial Engineering Dept.
University of Jordan, Amman, Jordan

تكلفة انقطاع التيار الكهربائي في الأردن

ان وثوقية نظام القدرة الكهربائي امر مهم للمنتجين والمستهلكين للطاقة الكهربائية على حد سواء، فللمنتج تعود الاهمية في مرحلة تصميم نظام كهربائي موثوق به بينما للمستهلك ترجع الأهمية في عملية استخدام الكهرباء اقتصاديا في النواحي الإنتاجية وفي الخدمات المختلفة. وبدمج العاملين السابقين معا فإن اهمية وثوقية النظام الكهربائي تنعكس على الإقتصاد الوطني. ومن الجدير بالذكر أن احد المؤشرات الهامة في تحديد مستوى هذه الوثوقية هو تكلفة انقطاع التيار الكهربائي عن المستهلك. ففي هذا البحث يقدم الباحثون تقديرا لتكلفة انقطاع الكهرباء في الاردن باستخدام ثلاث طرق. وقد تم تقدير معدل تكلفة انقطاع التيار الكهربائي بحوالي ٦٣ر٠ دينارا لكل كيلو واط ساعة (اي حوالي دولار امريكي واحد لكل كيلو واط ساعة) بينما تم حساب تكلفة انقطاع الكهرباء في القطاعات المنزلية والصناعية والتجارية على التوالي كما يلي:-
٢٨ر٠ دينارا، ٣٢ر٠ دينارا و ١ر٤ دينارا لكل كيلو واط ساعة.

ABSTRACT

Electric power system reliability is a very important aspect for both producers and consumers. For the former it is important to design an optimally reliable system while for the latter it is important for the economic use of electricity for production and services. Combining the two sides one sets the importance of system reliability to the national economy. One important indicator for determining optimum reliability level is the cost of outage to consumers. The authors in this paper present an estimation for the cost of outage using three methodologies. The overall average cost of outage is estimated at JD 0.63/Kwh (U.S.$ 1/Kwh) while the specific outage costs are: JD 0.28/kwh, JD 0.32/Kwh and JD 1.4/Kwh for domestic, industrial and commercial consumers respectively.

1. INTRODUCTION

It is a known fact that electricity plays a major role in the development of nations. This role is, in a way, more vital to the development process than other services or commodities, because electricity is essential for the provision of these services and production of these commodities in the first place. The projected demand for electricity of the economic sectors in any country, especially the developing ones, for increased modernization, high rates of economic growth and better standard of living will add to the importance of the role of electricity in the development process. Moreover, once electricity service is extended to consumers it may be impossible to do without it, or even to some extent to replace it. This is true because electricity is the only energy source for certain applications, such as lighting, electromotive power, telecommunications and data processing. Furthermore, it is a clean energy source which is, in most cases, reliable and very competitively cheap. However, once electricity supply to consumers becomes, for any reason, less reliable or of inferior quality beyond an acceptable level, an associated detrimental economic effect must be attached to the supply of electricity in its role in the development. This becomes an important decision factor in the work of electricity planners. "How reliable a power system should be?", "what could be done to improve reliability and quality of supply and at what associated costs?" are questions to be answered by the planners. This paper provides an estimate for the cost of electricity outage in Jordan to help planners in addressing these questions.

An electric power system is adequate only if it is capable of meeting the demand of consumers at all times and with an optimum level of reliability. This optimum level depends on the inherent technical features of the components of the power system and the investment policy for expansion and enhancement of the power system. However, it is determined by the economic worth of electricity to various consumers, i.e., negative economic impact of the absence of electricity service.

This last factor stems from the fact that an unreliable supply results in both short and long terms consequence to the economy. In the short term the customers may be forced to affect changes in their operating regime while in the long term they may take decisions to acquire standby sources or ultimately to become self-reliant. To these are added the cost of idle time, spoilage of raw materials, possible damage to equipment and lost revenues.

This paper sheds light on the electricity outage costs to various consumers in Jordan and compares three different methods for the evaluation of these costs.

2. DEFINITION OF THE PROBLEM

In Jordan, as in many developing countries, an accurate assessment of the true economic value of electricity outage to consumers, utility and the national economy are not existent to date. This information is valuable for any planning study leading to decisions regarding tariff, optimum reliability level of the power system or its expansion.

At the consumer level the electricity worth is measured by the willingness to pay for the service. However, this subjective measure must be appropriately qualified to arrive at a reasonable value. Moreover, additional adjustments must be incorporated to reflect the cost of damage or loss, if any, due to any outage.

The cost of outage to the utility must be equal to the cost of outage to the consumer plus all costs incurred to maintain a given reliability criterion. This last factor may entail the capital, operation and maintenance costs needed to maintain the required level of reliability of the power system.

As for the cost to the national economy, the cost of securing foreign exchange for financing the expansion of the power system and its operation must be added to the utility cost. This cost to the national economy must be adjusted using shadow prices [1] to reflect any distortions in prices in the local market. However, for the case of Jordan the corrections using shadow prices are not necessary due to the recent measures taken by the government which are believed to be adequate to eliminate any distortions in the economic value of foreign exchange. Furthermore, the value of fuel and capital equipment in Jordan is equal to the international prices.

The cost of energy shortage to the utility was studied by Billinton, Oteng-Adjei and Chajar [2]. They compared two different methods, namely; customer damage function and simulation, where the difference between the results of the two methods was negligible.

3. CALCULATION OF OUTAGE COST BASED ON THEORETICAL APPROACHES

There are basically two approaches for the calculation of outage costs. A simplistic approach[3] and a more detailed approach[4]. In the former a single value for each Kwh unmet is calculated regardless of the type of consumer while in the latter the cost for each type of consumer is calculated.

In the remainder of this section the results of the outage cost for Jordan using the two approaches are presented.

A measure of the economic activity of any country is the Gross Domestic Product (GDP) which is basically the sum of the value added by productive sectors of the economy. In the following table the GDP (at constant 1980 prices) and the electrical energy consumption for the period (1980 - 1990) are presented:

Table 1: GDP and Electrical Energy Consumption in Jordan (1980 - 1990):-

Year	GDP	GDP	Electricity Consumption Gwh	
	(in million JD)*	(in million U.S.$	Total	Economic Sectors
1980	984	3303	877	535
1981	1078	3292	1028	623
1982	1139	3231	1274	794
1983	1166	3211	1623	1056
1984	1189	3092	1944	1304
1985	1235	3130	2151	1457
1986	1261	3603	2323	1576
1987	1297	3832	2655	1849
1988	1252	2813	2761	1880
1989	1343**	2005**	2920	1990
1990	1316**	1964**	3089	3100

* 1980 constant prices
** Estimate
(Sources: Central Bank of Jordan Statistical Bulletins and Jordan Electricity Authority Reports).

Several comments are in order for Table 1 as follows:-

1. Average annual growth rate for GDP during the period is 4.1% for the values in JD.
2. Average annual growth rate for GDP during the period (except 1990) is 2.1% for the values in U.S.$ which indicates that the exchange rate of the U.S.$ versus JD has doubled during the period.
3. Average annual growth rate for total electricity consumption is 15.4%
4. Average annual growth rate for consumption of economic sectors is 17%.
5. The average yearly exchange rate for each year is used to convert GDP figures into U.S.$.

Since electricity is one essential element in the economic development of any country then each Kwh consumed is directly proportional to certain JD value of GDP. Thus the ratio "GDP / electricity consumption" is a representation of the value of electricity to the economy. In other words it is a measure of the cost of outage.

The cost of outage based on the values in Table (1) varies from JD 0.5 to JD 1.12/Kwh for the total consumption and from JD 0.7 to JD 1.8/Kwh for the consumption of economic sectors only. As for the values in U.S.$, the ranges are U.S.$ 1.44 to U.S.$ 3.77/Kwh and U.S.$ 2.07 to U.S.$ 6.17/Kwh, respectively. Therefore, the average outage costs for the period of study can be summarized as follows:

Outage Cost based on total consumption		Outage Cost based on consumption of economic sectors	
JD/Kwh	= U.S.$ /Kwh	JD/Kwh	= U.S.$ / Kwh
0.75	2.19	1.17	3.43

It should be noted that the outage costs in U.S.$ /Kwh using the current exchange rate would be U.S.$ 1.25/Kwh for total consumption and U.S.$ 1.95/Kwh for the consumption of the economic sectors only. Interestingly enough, a recent expansion study[5] has estimated the outage cost (or cost of unmet energy) in Jordan to be U.S.$ 1/Kwh which is not far from the above calculations. In this latter study, the calculations were based on the average marginal cost of electricity production where the cost of outage was taken as twice the

marginal cost. In this approach, the outage cost is divided into outage due to capacity shortage and outage due to energy shortage. The capacity portion is based on the Long Run Marginal Cost (LRMC) while the energy portion is based on the Short Run Marginal Cost (SRMC). The average marginal cost is a combination of the two marginal cost components.

A previous load management study[6] has attempted to estimate the outage cost in Jordan whereby it used the Minimum Cost of Outage Method (MCOM). This approach is simply, to estimate the expected value of the annual outage costs assuming a functional relationship between outage costs and the annual total number of service hours lost due to outage. In this study the outage cost for domestic consumers is estimated at JD 0.24/Kwh. As for the services (commercial) and industrial sectors the approach is based on the regression of the value added of these sectors and the electricity consumption. A recalculation of outage cost based on value added for the period (1980 - 1987) is as follows:

Year	Value added (million JD)			
	Services sector		Industrial sector	
	Current Prices	Constant 1980 Prices	Current Prices	Constant 1980 Prices
1980	567	567	167	167
1981	758	752	208	193
1982	858	740	230	199
1983	918	752	215	176
1984	966	767	251	199
1985	1019	784	253	195
1986	1048	806	242	186
1987	1068	822	252	194

The outage cost for the services sector varies during the period (1980 - 1987) from JD 0.98 to JD 2.27/Kwh while for the industrial sector it varies from JD 0.2 to JD 0.55/Kwh. The average outage cost is JD 1.53/Kwh for the services sector and JD 0.33/Kwh for the industrial sector. Thus the calculations of outage costs according to the methodology of this previous study[5] yield the following average values:

Domestic Sector	Services Sector	Industrial Sector
JD/Kwh 0.24	1.53	0.33

Therefore, the weighted average outage cost (based on sectorial share of electricity consumption according to 1988 consumption figures) is JD 0.7/Kwh which is very close to the JD 0.75/Kwh calculated by the authors using the simplified method.

It is worthwhile to state that the above mentioned two studies [5,6] were not primarily directed to calculate the cost of outage, rather the cost of outage was estimated for the purposes of system expansion and load management.

4. CALCULATION OF OUTAGE COST BASED ON FIELD SURVEY

Field study of shortage cost to different customers has been used. Subramaniam, Billinton and Wacker [7] report on a field study of industrial customer damage function. Wacker, Wojezynski and Billinton [8] also report on a Canadian residential survey.

The authors designed two questionnaire forms; one for domestic consumers and the other for industrial and commercial consumers. The questions were carefully prepared in order to be able to estimate, from the responses, the value of consumers willingness to pay for electricity service or in other words: what extra payment they are willing to give to avoid an outage? The factors stressed in previous studies, e.g. [7,8] were included in the questionnaire * . However, the results derived from such field studies are only typical to the particular case.

The questionnaires were completed by the respondents by interview. About one hundred domestic consumers, and thirty industrial and commercial consumers were interviewed. The data was statistically then analyzed using the SPSS computer package ** . In the remainder of this section the analysis of the survey results is presented.

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* The questionaire forms are available upon request from the authors

** The SPSS is a collection of statistical analysis tools that can be used either on a PC or mainframe computers.

4.1 Domestic Consumers

About 80% of the respondents had experienced at least one outage during the past three years while the remaining 20% were either do not remember or do not know or were sure they did not have any outage. Thus, 80% is a good percentage, to give enough confidence in the responses, which indicates that the large majority of respondents responded from experience.

As for the preferred time for an outage, if any, about 50% prefers the period 12-18 hrs., while about 25% prefers 0-4 hrs.. Only 2% does not mind an outage in the period 18-24 hrs., and 15% in the period 6-12 hrs. This means that the majority of respondents prefers the afternoon period (6 hrs.).

Several questions were designed to estimate the consumers willingness to pay to avoid an outage. The average value of willingness to pay is JD 1.35 (the choices given to consumers in the questionnaire were: JD 0.5, JD 1, JD 2, and JD 5 as extra payment to avoid an outage). Furthermore, 52% and 29% of respondents prefer one outage per year and one outage every six months, if they must have any, respectively. Moreover, the value of average monthly bill of the respondents was JD 10.7 which is roughly equivalent to about 200 Kwh/month consumption.

As only 6.5% indicated that there was food or equipment damage due to outage, it is safe to state that the cost of outage is equivalent to the direct value of willingness to pay only. However, since the JD 1.35 is for one outage and the duration of the preferred outage is six hours, as mentioned earlier, the willingness to pay is 1.35/6 = JD 0.225/hr.

From the responses to several questions, the average instantaneous connected electrical load for a typical household can be estimated as follows :

3 x 0.06 Kw (Lighting)
+ 1 x 0.2 Kw (T.V)
+ 1 x 0.25 Kw (Refrigerator)
+ 1 x 0.1 Kw (Miscellaneous)
= 0.73 Kw

So the cost of an outage becomes

0.225/0.73 = JD 0.31/Kwh.

This is in close agreement with the result indicated in section 3 above (JD 0.24/Kwh)

4.2 Industrial and Commercial Consumers

About 90% of the respondents have had an electricity outage to their premises within the past three years. The majority of respondents (75%) had a frequency of outage between three to six months. As for the duration of outage 75% of the respondents estimated a period of 30 minutes to 2 hours for the outages they experienced.

All of the respondents that have standby generators indicated that they operate them during outages while none uses the generators to reduce their electricity bill. Moreover, about two thirds of the respondents employ their work force in other activities; such as material handling, maintenance, calibration, storage, etc., during outages. This finding leads one to conclude that there is very little idle time cost for workers during an outage.

Theoretically the cost components of electricity outage to an industrial or commercial outfit are as follows[11]:

Cost of electricity outage = SPC + IFC + OPC

where,

SPC : Spoiled production cost
IFC : idle factor cost
OPC : overtime production cost

As for the first cost component all the respondents indicated that for material damage to occur the outage duration should be longer than two hours. Since most of them responded that they experienced outages in the range of 30 minutes to two hours, thus this cost component will be the loss of expected revenue. This is estimated in the following analysis:

Average electricity cost to industrial and commercial consumers is JD .030/Kwh and JD .05/Kwh, respectively, which all respondents indicated that it constitutes not more than 5% of production cost for the industrial sector and 3% for the commercial sector.

So, at the utmost, the outage of electricity in an industrial firm will cause a complete production stoppage which will cause about 100% loss of production revenue. However, this production loss can be overcome or compensated through overtime work keeping in mind that this has an added associated cost which is overtime pay and production rescheduling. Hence, the net SPC can be estimated at 50% of the total production cost;

$$\frac{.030}{.05} \times .50 = \text{JD } 0.30 \text{ /Kwh}$$

On the other hand, the commercial sector can be classified into two groups. The first comprises firms which are tied to other enterprises to facilitate their operations. In this case an outage will cause partial loss of productivity since such firms are not totally dependent on electricity and do not have direct interaction with customers. Consequently, the net SPC can be estimated at 50% of the total operation cost.

The second group comprises firms which provide services directly to customers. A characteristic of such service firms is the inability to reschedule or delay provision of services. Hence, an outage will cause total loss of revenue making the net SPC of equal 100% of expected revenue.

Therefore, for the commercial sector the average SPC component can be estimated at 75% of the total production cost =

$$\frac{.050}{.03} \times .75 = \text{JD } 1.25 \text{ /Kwh}$$

As for the other two cost components; IFC and OPC it can be concluded that the first is negligible while the other was included in the calculation of net effect of the spoiled production cost as indicated above.

In summary, the weighted average outage cost, considering the above outage costs of the domestic industrial and commercial sectors and their respective electricity consumption percentages, is calculated as follows:

sector	outage cost JD/Kwh	electricity consumption %
Domestic	0.31	30
Industrial	0.30	40
Commercial	1.25	20

Note : 10% of the electricity consumption is accounted for other sectors which are not included in the survey.

The weighted average outage cost

$$= \frac{0.31 \times 0.3 + 0.3 \times 0.4 + 1.25 \times 0.2}{0.9}$$

$$= \text{JD } 0.51/\text{Kwh}$$

4.3 Summary of Findings From the Survey

As a result of the analysis of the responses to the survey the following conclusions are reached:

a) The high response to the questionnaire from the domestic sector leads to substantial findings; On the other hand, the response from the industrial and commercial sectors was not adequate, as experienced by other researchers previously[19].

b) The lack of some information in some of the interviewed firms were apparent and worrisome.

c) The results of this empirical study are indicative and can be used in economic feasibility studies. Furthermore, the methodology used in this research can be readily applied in other countries leading to more substantial results than other methods.

d) The survey produced important results other than those related to the cost of outage. (e.g. average monthly electricity bill, preferred time of outage, and usage of autogeneration).

5. CONCLUSIONS

Two theoretical approaches and one empirical approach are used to estimate the cost of electricity outage. The first approach is based on the relationship between the GDP and electricity consumption. The result of outage cost using this approach is JD 0.75 /Kwh for total electricity consumption and JD 1.17 /Kwh for the consumption of economic sectors only.

The second approach is based on disagregating the analysis to the three main consuming sectors; namely, domestic, industrial and commercial. The result of outage cost using this approach is JD 0.24 /Kwh for domestic consumers, JD 1.53 /Kwh for commercial consumers and JD 0.33 /Kwh for industrial consumers. The weighted average cost of outage comes to about JD 0.7 /Kwh.

The third approach is based on a field survey whereby the questionnaires and the interviews concentrated on facts that could give result to the willingness to pay of domestic consumers and direct and indirect outage costs for industrial and commercial consumers. The outage costs estimated using this methodology are : JD 0.31 /Kwh, JD 0.30 /Kwh and JD 1.25 /Kwh for domestic, industrial and commercial consumers respectively. The weighted average outage cost is about JD 0.50 /Kwh using this empirical approach.

Combining the results of all three approaches one gets a range for the outage cost between JD 0.50 /Kwh and JD 0.75 /Kwh. Even though, these two numbers were calculated using two different methodologies, however, if one desires to obtain a single indicative value an overall average cost of outage figure of about JD 0.63 /Kwh can be safely recommended (roughly 1 U.S.$ /Kwh). This single estimate can be used as a proxy for outage cost in planning studies.

However, if specific consumer category outage costs are required then JD 0.28 /Kwh for domestic, JD 0.32 /Kwh for industrial and about JD 1.4 /Kwh for commercial consumers are recommended.

REFERENCES

[1] Munasinghe, M., "The Economics of Power System Reliability and Planning", World Bank/John Hopkins University Press, 1979.

[2] Billinton, R, Oteng-Adjei, J, Chajar, R, "Comparison of Two Alternate Methods to Establish an interrupted Energy Assessment Rate", IEEE Transactions on Power Systems, PWRS-2, 751-757, 1987.

[3] Shipley, R.B., Patton, A.D., Denison J.S., "Power Reliability Cost Vs. Worth". IEEE-PES Winter Meeting, New York, February 1972.

[4] Munasinghe, M., Gellerson, M., "Economic Criteria For Optimizing Power System Reliability Levels", The Bell Journal, Spring 1979.

[5] "Generation Expansion Study up to 2000" Draft Final Report by Electricité De France (EDF) submitted to JEA in August 1989.

[6] "Load Research and Management Study of the Electrical Power Sub-Sector", Final Report submitted to the Ministry of Energy & Mineral Resources and Jordan Electricity Authority (JEA), Gilbert Commonwealth Inc., U.S.A., Oct. 1986.

[7] Subramaniam. R.K., Billinton, R., Wacker, G., "Factors Affecting the Development of Industrial Customer Damage Function.", IEEE Transactions on Power Apparatus and Systems 1985; PAS - 104, 3209-3215.

[8] Wacker, G, Wojezynski, E, Billinton, R, "Interruption Cost Methodology and Results - A Canadian Residential Survey", IEEE Winter Power Meeting, 1983.

[9] Kharabsha, A.A., Malkawi, A.K., "Productivity in Industrial Corporations Employing 20 Workers and More" DIRASAT, 15, 98-121, 1988.