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The Forecast of Value of Lost Load in Slovenia

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Abstract

In modern society, we are increasingly dependent on electricity, which makes interruptions in supply affect us even more and also causes both direct and indirect costs. Various indexes are available to evaluate the costs associated with interruptions in supply. Recently, the Value of Lost Load (*VOLL*) has been the most commonly used index to evaluate costs. Moreover, a determination of this index is mandatory in the EU and ENTSO-E countries, as a measure of the Reliability Standard.

Since the determination of the *VOLL* based on surveys is time-consuming and estimates based on macroeconomic indicators do not provide realistic values, a regression method with the gross domestic product (*GDP*) as the impact factor is used to forecast the value of the *VOLL* for Slovenia until the year 2030. The estimated value of the *VOLL* for Slovenia in 2022 is 10.0€/kWh, which is in line with the value of 10.6€/kWh used to measure the Reliability Standard in Slovenian electric power system.

Furthermore, the obtained results are compared with the results for Italy, which has carried out a survey-based analysis in 2021 and has a *GDP* in 2021 slightly higher than projected for Slovenia in 2030. Based on the regression method, the value of the *VOLL* for Slovenia for 2030 is estimated at 26.0€/kWh, while the value of the *VOLL* for Italy in 2021 based on survey is 28.4€/kWh.

The results show that the application of the regression method to predict the value of the *VOLL* using the *GDP* as impact parameter is reasonable and appropriate.

Key words

Gross domestic product (GDP), Regression, Reliability Standard, Slovenian power system, Value of lost load (VOLL)

1. INTRODUCTION

In modern society, we are increasingly dependent on the use of electricity, so the continuity of power supply is essential for the functioning of the society. However, in certain, albeit very rare cases, the power supply is interrupted.

Each interruption of the power supply can incur costs for the customer. Their size is affected by the different nature and diversity of the consequences of power supply interruption. For household customers, costs can be reflected in the form of:

- lost income,

- deterioration of living quality,
- costs due to repair and wear of appliances,
- replacement of unsupplied electricity, and
- in the case of prolonged outages, also as food destruction.

However, in the industry sector the costs of unsupplied electricity are incurred due to:

- additional material consumption,
- repair of fixed assets,
- restart the process,
- replacement of unsupplied electricity,
- costs due to delays, and
- loss of sales.

A special group of costs is the costs of civil disobedience and looting during prolonged downtime and failures of safety devices in industrial plants, which can lead to mandatory evacuation from all facilities in the area [1].

The literature [2] describes several methods for calculating the value of unsupplied electricity, which is defined as the monetary value of costs, normalized to unsupplied electricity. Methods can generally be divided into three groups:

- **Survey of customers** is the most common method for evaluating cost because of unsupplied electricity. Based on the questionnaire, the respondent assesses the damage or monetary loss suffered in case of interruption of the power supply. The disadvantage of the method is that the customer either overestimates or underestimates the costs associated with interruption of the power supply. In addition to the damage survey, a survey, in which respondents are asked about the willingness to pay so that they will not suffer a supply interruption, or to evaluate the compensation in the case of a supply interruption, can also be used.
- **Specific outage studies** are most commonly used when actual power outages occur. This method gives the best estimate of the damage, but is not useful in cases where there has been no power failure in the past.
- **Indirect analytical assessments** define the value of unsupplied electricity on the basis of various macroeconomic indicators. The advantage of this method is that the estimates are easy to calculate. However, its disadvantage is that they are based on limited and sometimes unrealistic assumptions.

In addition to various methods, various indicators are also used to evaluate the value of unsupplied electricity [3], which are:

- Cost of Energy Not Supplied – *CENS*,
- Value of Lost Load – *VOLL*, and
- Interrupted Energy Assessment Rate – *IEAR*.

Although various indicators have been developed to evaluate undelivered electricity, the *VOLL* indicator is the most commonly used. The main reason for this is also Regulation (EU) 2019/943 of the European Parliament and of the Council of the European Union on the internal market for electricity [4]. The regulation determines that European Union (EU) countries must develop reliability standards based on the methodology Methodology for calculating the value of lost load, the cost of new entry and the reliability standard [5]. The methodology defines the procedure for calculating the *VOLL* indicator, which is based on the survey method. The methodology also requires that the *VOLL* indicator based on survey method must be calculated every 5 years.

However, as the values of the *VOLL* indicator changes over the years, the forecast of the *VOLL* indicator until the year 2030 using regression depending on gross domestic product (*GDP*) has been used in this paper to speed up the process of determining the *VOLL* indicator.

2. METHODOLOGY FOR FORECASTING THE VOLL INDICATOR

Generally, forecasting is the process of making predictions based on past and present data, where different qualitative and quantitative methods can be used. Qualitative forecasting techniques are subjective, based on the opinion and judgment of consumers and experts and are appropriate when past data are not available. On the other hand, quantitative forecasting techniques are used to forecast future data as a function of past data. They are appropriate to use when past numerical data is available and when it is reasonable to assume that some of the patterns in the data are expected to continue into the future. Quantitative forecasting techniques comprise different methods as time series methods, artificial intelligence methods, extrapolation and relational methods [6].

In this paper, one of the relation methods has been used. More specifically, the regression analysis has been used to predict the value of the *VOLL* indicator. Regression analysis is a statistical method used in finance, investing, and other disciplines that attempts to determine the strength and character of the relationship between one dependent variable and a series of other impact variables. Mathematical form of connection can be linear, power, exponential, reciprocal, logarithmic, root … In practice, a linear connection (1) is most often used, also that a nonlinear regression relationship is attempted to be transformed into a linear relationship by transforming variables [7].

$$Y = \beta_1 \cdot X + \beta_2 \tag{1}$$

In the next step, theoretical assumptions about the dependence between variables are made to make a regression analysis. As statistically significant, the Cambridge Economic Policy Associates [8] study showed a trend that EU countries with a higher standard of living also have higher values of *VOLL* indicator. As one of the macroeconomic parameters, describing the standard is also *GDP*, it has been used as impact parameter for forecasting the *VOLL* indicator by regression analysis.

The next step is to calculate or estimate the parameters of the regression model, where the parameters of the model are determined by the method of least squares. The least squares method is the standard approach for determining the dependence function of an oversized system, by minimizing the sum of the squares of the deviations.

The last step is the calculation or forecast the value of the *VOLL* indicator based on the regression function determined in the previous steps.

3. THE FORECAST OF VOLL INDICATOR

To forecast the value of the *VOLL* indicator by the regression method, at first the influencing factor has been selected. As it is mentioned in the literature [8] that there is a statistical connection between the standard of living and *VOLL* indicator, we chose the macroeconomic indicator of *GDP* per capita as an influential factor. *VOLL* indicator, obtained on the basis of the survey method, was determined in years 1995, 2006 and 2016. For these years, the *VOLL* indicator as a function of *GDP* is drawn in the Figure 1.

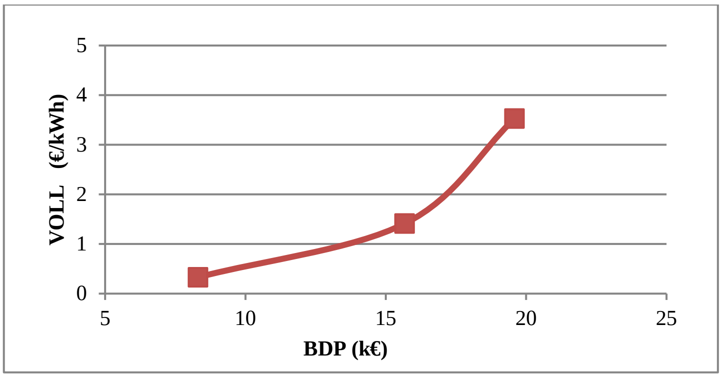

Figure 1. GDP per capita - dependent VOLL indicator

The next step in the forecast using the regression method is the selection of the regression model. Since Figure 1 shows that the most commonly used linear relationship is not the best possible relationship for this case, the transformation of the *VOLL* variable was performed. For that reason the transformation (logarithmization) of the *VOLL* indicator was performed and the result was a linear relationship between the *GDP* per capita and *VOLL* indicator (Figure 2).

The next step was determination of regression (linear) function parameters using the least squares method. The linear function that connects the *GDP* per capita and the *VOLL* indicator is given by the equation (2).

$$ln(VOLL) = 0.2085 \cdot GDP - 2.8627 \quad (2)$$

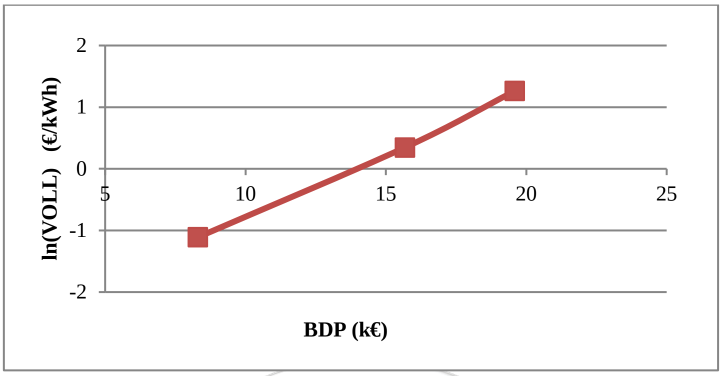

Figure 2. GDP per capita - dependent logarithmize VOLL indicator

Based on the *GDP* forecast until 2030 [9], the *VOLL* indicator for all subsequent years has been calculated and are presented in Table 1 and on Figure 3. As it can be seen from Table 1, *GDP* per capita is increasing over the coming years. Due to the linear dependence, this trend is also followed by the value of the *VOLL* indicator.

Table 1. Forecast of VOLL indicator

Year	*GDP* per capita (k€)	ln(*VOLL*) (€/kWh)	*VOLL* (€/kWh)
2022	24,772	2.3	10.0
2023	25,293	2.4	11.1
2024	25,827	2.5	12.4
2025	26,377	2.6	13.9
2026	26,942	2.8	15.7
2027	27,522	2.9	17.7
2028	28,119	3.0	20.0
2029	28,732	3.1	22.8
2030	29,362	3.3	26.0

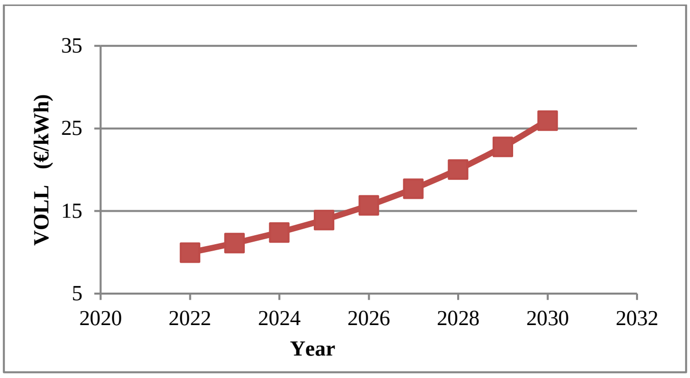

Figure 3. Forecast of VOLL indicator

At this point, the question is whether the forecast is realistic or not. The estimated value of the *VOLL* indicator for Slovenia in 2022 is 10.0 €/kWh, which is in line with the value of 10.6 €/kWh used by Slovenian transmission system operator [1].

Furthermore, the obtained results are compared with the results for Italy, which has carried out a survey-based analysis in 2021 and has a *GDP* per capita in 2021 slightly higher than projected for Slovenia in 2030. Based on the regression method, the value of the *VOLL* indicator for Slovenia for 2030 is estimated at 26.0 €/kWh, while the value of the *VOLL* indicator for Italy in 2021 based on survey is 28.4 €/kWh [10]. The results are in range of ± 10 % of estimation error, which we considered as good estimations, as not much data was available to calculate or estimate the parameters of the regression model.

4. CONCLUSIONS

In this paper, we predicted the value of the *VOLL* indicator using regression analysis. With regression analysis, we first developed a regression model, based on which we predicted the value of *VOLL* indicator for years from 2022 to 2030, where *GDP* per capita is used as an impact factor to forecast the value of the *VOLL* indicator.

The estimated value of the *VOLL* indicator for Slovenia in 2022 is 10.0 €/kWh, which is in line with the value of 10.6 €/kWh used by Slovenian transmission system operator. The estimated value of the *VOLL* indicator for Slovenia in 2030 has been also evaluated and the error is in range of ± 10 %.

The field of forecasting is a very sensitive topic, especially when there is not much data available. Also in our case, not much data was available, which made it impossible to perform a more detailed analysis and comparison of the final results.

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CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest.

REFERENCES

[1]. F. Hočevar, J. Bogovič, K. Dragaš, and M. Pantoš, "*Vrednotenje nedobavljene električne energije*," in *Referati in predstavitve 14. konference slovenskih elektroenergetikov CIGRE-CIRED*, 2019, pp. 1–6.

[2]. A. Shivakumar et al., "*Valuing blackouts and lost leisure: Estimating electricity interruption costs for households across the European Union*," *Energy Res. Soc. Sci.*, vol. 34, no. Supplement C, pp. 39–48, Dec. 2017.

[3]. Z. Bozic, "*Customer interruption cost calculation for reliability economics: practical considerations*," in *2000 International Conference on Power System Technology Proceedings*, 2000, pp. 1095-1100.

[4]. *Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (Text with EEA relevance.),* vol. 158, 2019.

[5]. *Methodology for calculating the value of lost load, the cost of new entry and the reliability standard,* ACER, 2020.

[6]. *Forecasting*, Wikipedia, 2022.

[7]. J. Bogovič, "*Vrednost nedobavljene električne energije v Sloveniji*," *Elektrotehniški vestnik*, vol. 88, no. 5, pp. 236–240, 2021.

[8]. *Study on the value of lost load of electricity supply in Europe - ACER*, Cambridge Economic Policy Associates, 2018.

[9]. B. Tavčar, I. Zakotnik, I. Strmšnik, and T. Kraigher, *Scenariji gospodarskega razvoja Slovenije do leta 2030*, Urad RS za makroekonomske analize in razvoj, Ljubljana, 2007.

[10]. *Proposta in merito allo standard di adeguatezza del sistema elettrico Italiano*, Terna, 2020.