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Energy Consumption and Value of Lost Load Modeling for the GCC Member State Countries

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Abstract: The current level of security of energy supply in the GCC Member States is quite satisfactory, and the network connection supports any risk faced by a GCC Member State. The Lost Load Value (VoLL) assists in assessing each GCC country, while the VoLL assessment assists in supporting energy policy decisions to prevent power outages. In addition, it helps analyze the cost benefit and find the right regulatory framework for the system in terms of reliability. This study develops the estimate of VoLL based on energy consumption and GDP. VoLL determines the lost value due to a lack of electricity. The estimated values of VoLL for the six GCC Member States are calculated. Finally, they obtained, discussed and analyzed results. VoLL can be considered one of the biggest reliability challenges when it comes to strengthening the market structure.

Keywords: VoLL, GCC, GDP, Energy Consumption.

1. INTRODUCTION

VoLL is a measure of economic value in power reliability studies [1]. In addition, the VoLL represents the costs of unused energy in the event of a power failure. It is also calculated to show consumers the amount of electricity that is not supplied. This is due to a planned or unplanned power failure. Furthermore, it is known that the interruption of the supply can possibly result from a pressure drop. The occurrence of load losses has social and financial implications for customers. Therefore, this amount of VoLL keeps customers willing to pay to avoid a power outage [1].

Slipac et al. [2] in their work they describe the LOLP calculation method and the LOLP optimization algorithm, which considers the particularities of the energy system. It also shows the difference in the processing of LOLP compared to the perceived energy system and the installed power required when applied to the calculated LOLP compared to the optimized LOLP. The study analyzed the effects of parameters on the regional electricity market, with participants from countries with different levels of development and different characteristics of energy systems. The study helps to determine the economic value of suitability, the value of the lost load must also be quantified. The term LOLP is an important security of supply criterion which depends on the VoLL. The main conclusion of the study is that the least acceptable LOLP relates to planning the expansion of electricity generation in the electricity market.

Ratha et al. [3] discussed the functioning of electrical systems in their article. Their research focuses on the paradigm that the customer must be provided with electrical systems. Their investigation showed that the chances of losing supply were high. The authors have gone through some studies that cover only a snapshot of the spectrum, where it affects the assessment. In addition, the VoLL is expressed as a function of the duration of the failure or the frequency of recurrence. The study presents an approach to using data from experimental choice studies. They authors [3] conclude that the parameters used have the possibility to use the concept of VoLL in the short term. Furthermore, the VoLL can be used for long-term planning of the reliability of the energy system.

Shivakumar et al [4], in their article studied energy supply security. In addition, the Value of Lost Load (VoLL) is calculated. For several previous studies, the cost of electricity has been calculated for several previous studies as well. The interruptions of the various member states of the European Union is studied, where the VoLL is estimated using the production function method for households in 28 European member states. Furthermore, the VoLL is used every hour in the event of a break. Finally, the results received assistance for use in the areas of European energy policy and market design.

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Castro et al. [5] focus their studies on the security of energy supply in Europe. The study shows that strengthening the market environment presents certain challenges. The VoLL is usefully evaluated to support energy decision-making. In addition, the study of decision-makers includes a cost-benefit analysis and the VoLL estimate was developed using a macroeconomic technique. The macroeconomic technique is known as the production function method which is applied for the Portuguese case and the average values of the VoLL results are 5.12 € / kWh.

Aghaei et al [6] studied a stochastic model for planning the short-term deployment of the unit with CA safety limitation. In their study, they focus on the value of loss load (VoLL). In addition, power outages from generators and transmission lines are modeled. The authors carried out the simulation after the Monte Carlo simulation with different electrical network scenarios. The calculation is based on VoLL and solve the problem which proposed by a two-step algorithm. The first step covers all components of the network, while the second step defines the stochastic part of the problem. In addition, the second scenario applies to all elements of the network and the method used is applied to the IEEE 118/300 bus test system. The purpose of the application is to assess its applicability and capacity in both scenarios.

In their theoretical analysis, Ovaere et al. [7] show that using more detailed VoLL data leads to more profitable transmission security decisions. The study applied on several countries used current VoLL data on consumers and over time. Short-term studies on the reliability of electricity grids used in different countries, such as Norway, the United Kingdom and the United States. A five-node network reduces potential operating costs by up to 43%, as demonstrated by reliability management. In addition, if some consumers stop measuring the first policy, they will collect more harmonized VoLL data. In the future, policies should improve coordination of transmission and distribution applied to smart meters and smart devices.

Schröder et al. [8] focus their study on security of supply, which has become a major requirement for the proper functioning of modern societies. The authors in their study examine the financial consequences of a power outage. In addition, the VoLL is a monetary indicator that expresses the costs associated with a power outage. Furthermore, the authors [8] discuss various methods of calculating the VoLL in their article.

2. Case Study and Results

Worldwide, the power blackouts or interruptions of supply show the potential of severe socioeconomic disruptions and economic losses. In the present study, six models are obtained for the six GCC states countries (Bahrain, Kingdom of Saudi Arabia "KSA", Kuwait, Oman, Qatar, and United Arab Emirates "UAE") [9-11]. The models obtained based on the Gross Domestic Product (GDP) and energy consumption of the six countries under studies to calculate the VoLL for them through the years 2012 till 2019, where their equations investigated and the estimated values of the VoLL through the years 2020 till 2030 are calculated and plotted. This is preceded by modeling the energy consumptions through the years 2012 till 2019 and estimating the values of the energy consumptions through the years 2020 till 2030 (Figure 1-6). Equations (1-6) represent the energy consumption models for the six GCC states.

UAE

$$\text{Energy Consumption (Year)} = \text{d} + \frac{a-d}{1+\left[\frac{Year}{c}\right]^{b}} \quad (1)$$

where:

a=99732.1272832626

b=2385.33191381478

c=2014.39975365024

d=132702.829414616

Kingdom of Bahrain

$$\text{Energy Consumption (Year)} = \text{d} + \frac{a-d}{1+\left[\frac{Year}{c}\right]^{b}} \quad (2)$$

where:

a=-12441.6949468927

b=66.8606522532046

c=2335.64568055433

d=542806644.756129

Kingdom of Saudi Arabia

$$\text{Energy Consumption (Year)} = \text{d} + \frac{a-d}{1+\left[\frac{Year}{c}\right]^{b}} \quad (3)$$

where:

a=233840.371640116

b=507.39263039146

c=2070.51892294654

d=47224861702.6753

Oman

$$\text{Energy Consumption (Year)} = \text{d} + \frac{a-d}{\{1+[\frac{Year}{c}]^b\}^m} \quad (4)$$

where:

a=20278.8605771641

b=2910.73186491572

c=2013.16891417566

d=34885.8889958166

m=0.302612031772029

Qatar

$$\text{Energy Consumption (Year)} = \text{d} + \frac{a-d}{1+[\frac{Year}{c}]^b} \quad (5)$$

where:

a=28771.4102015815

b=1469.63673480506

c=2015.71844106409

d=47392.306141115

Kuwait

$$\text{Energy Consumption (Year)} = \text{d} + \frac{a-d}{1+[\frac{Year}{c}]^b} \quad (6)$$

where:

a=52618.7145134876

b=1529.09509341176

c=2018.5465651976

d=98383.5448717178

The VoLL values of the countries represent the loss of electricity supply to customers, where the calculation of the Value of Lost Load is assessed for the six countries. The study aims to deliver a comprehensive assessment of the countries associated with the loss of electricity supply. Figures (1-6) show the relationship of the electricity consumption (GWh) for the six GCC countries through the years 2012 till 2019 and the estimated energy consumption for the years 2020-2030 as mentioned earlier.

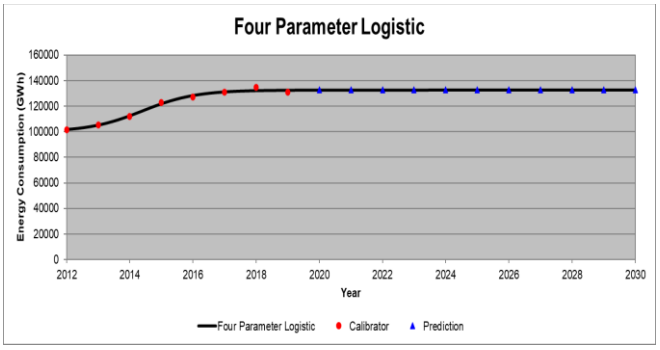

Figure 1. Energy Consumption through 2012-2019 and Estimated Values through 2020-2030 for UAE

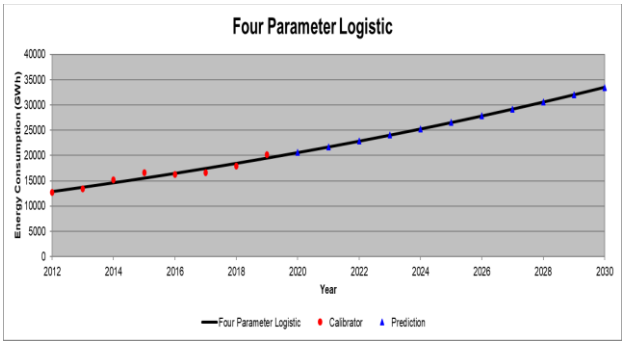

Figure 2. Energy Consumption through 2012-2019 and Estimated Values through 2020-2030 for Bahrain

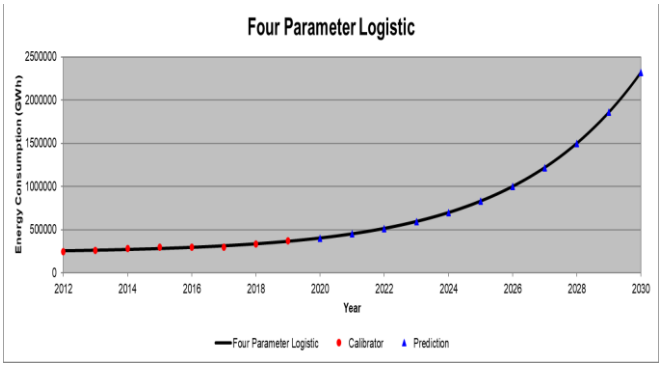

Figure 3. Energy Consumption through 2012-2019 and Estimated Values through 2020-2030 for KSA

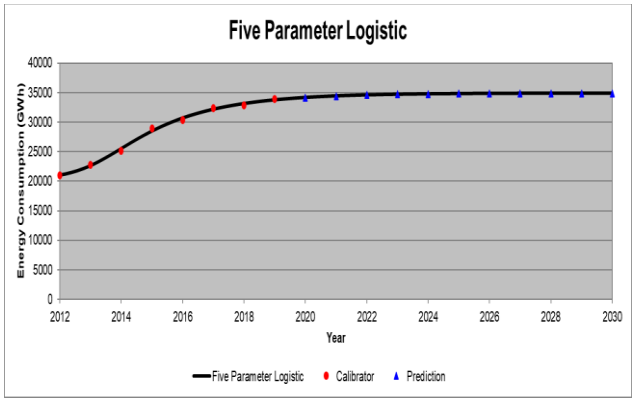

Figure 4. Energy Consumption through 2012-2019 and Estimated Values through 2020-2030 for Oman

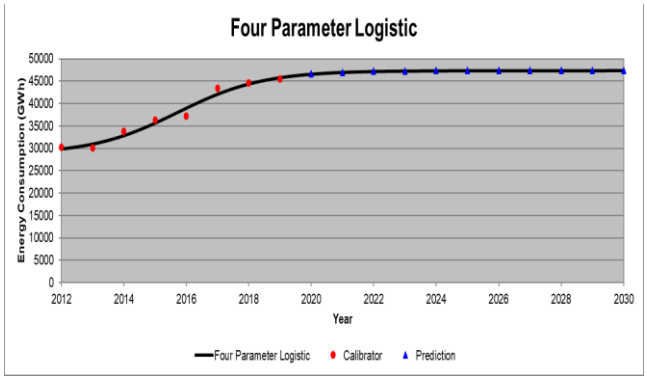

Figure 5. Energy Consumption through 2012-2019 and Estimated Values through 2020-2030 for Qatar

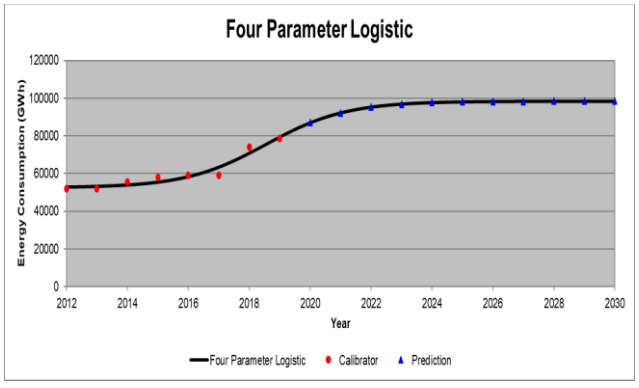

Figure 6. Energy Consumption through 2012-2019 and Estimated Values through 2020-2030 for Kuwait

Figure (7) represents the GDP for the same countries as recorded through the years 2012 till 2019.

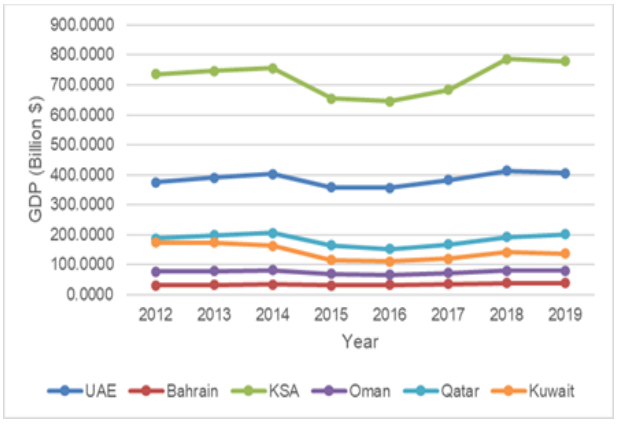

Figure 7. GDP through 2012-2019 for the GCC Countries

The estimate values of VoLL for the six GCC states countries are calculated using the following equation:

$$VoLL = \frac{GDP}{Total\ Consumed\ Energy} \quad (7)$$

The models of VoLL for the six GCC states are obtained and represented by the six equations (8-13).

UAE

$$VoLL\ (Year) = \frac{V_{max} \cdot Year}{K_m + Year} \quad (8)$$

where:

$V_{max} = 41.8767904872447$

$K_m = -1989.14324482724$

Kingdom of Bahrain

$$VoLL\ (Year) = \frac{V_{max} \cdot Year}{K_m + Year} \quad (9)$$

where:

$V_{max} = 32.0203295760419$

$K_m = -1985.06064469754$

Kingdom of Saudi Arabia

$$VoLL\ (Year) = \frac{V_{max} \cdot Year}{K_m + Year} \quad (10)$$

where:

$V_{max} = 23.666731071366$

$K_m = -1995.8064689405$

Oman

$$\text{VoLL (Year)} = \text{d} + \frac{a-d}{1+[\frac{Year}{c}]^b} \quad (11)$$

where:

a=3572.85013529289

b=6996.75246779478

c=2014.26688662672

d=2299.0783423603

Qatar

$$\text{VoLL (Year)} = \text{d} + \frac{a-d}{1+[\frac{Year}{c}]^b} \qquad (12)$$

where:

a=6395.30985655352

b=7404.98911758186

c=2014.53347214465

d=4173.89193928185

Kuwait

$$\text{VoLL (Year)} = \text{d} + \frac{a-d}{1+[\frac{Year}{c}]^b} \qquad (13)$$

where:

a=6395.30985655352

b=7404.98911758186

c=2014.53347214465

d=4173.89193928185

Figures (8-13) illustrate the VoLL for the six countries through the years 2012 till 2019 and their estimated values for the years 2020 till 2030.

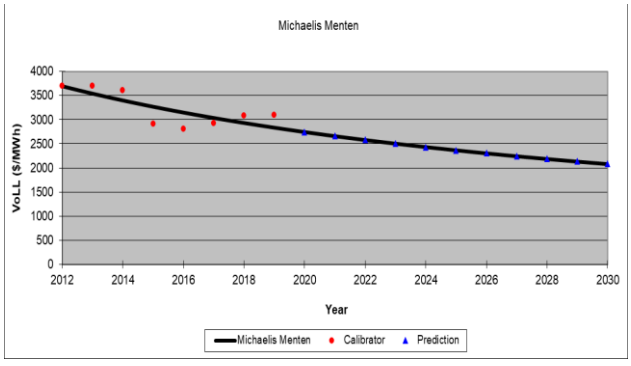

Figure 8. VoLL through 2012-2019 and Estimated Values through 2020-2030 for UAE

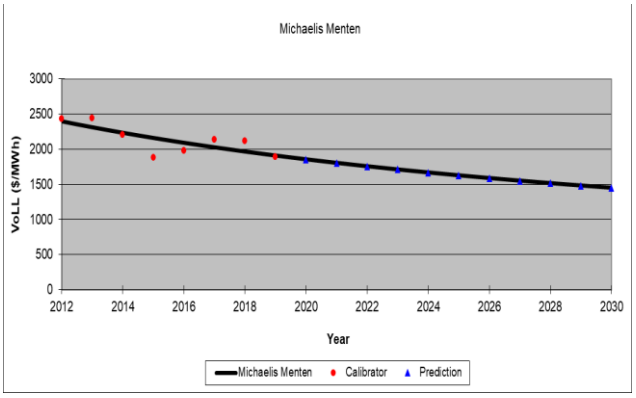

Figure 9. VoLL through 2012-2019 and Estimated Values through 2020-2030 for Bahrain

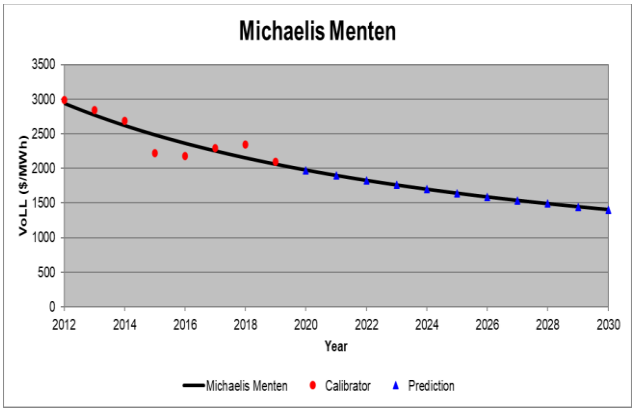

Figure 10. VoLL through 2012-2019 and Estimated Values through 2020-2030 for KSA

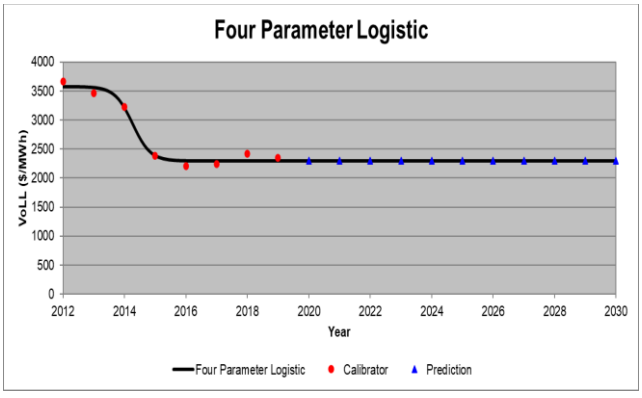

Figure 11. VoLL through 2012-2019 and Estimated Values through 2020-2030 for Oman

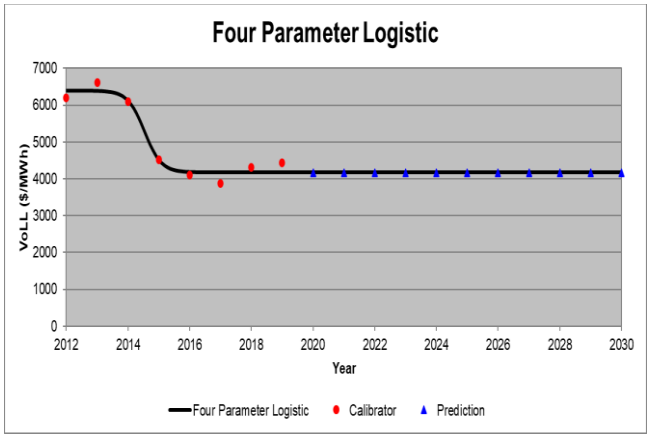

Figure 12. VoLL through 2012-2019 and Estimated Values through 2020-2030 for Qatar

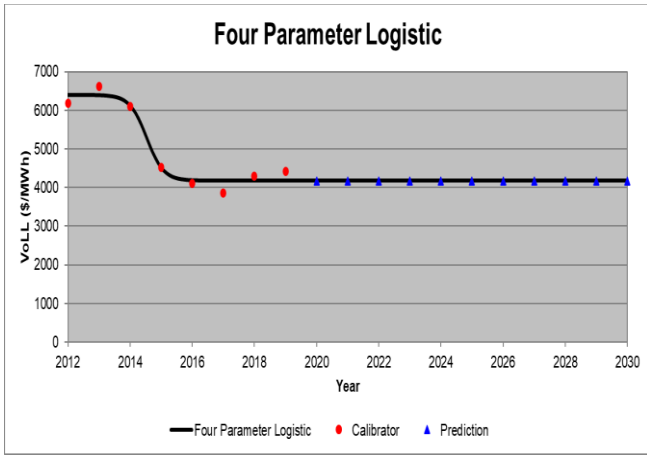

Figure 13. VoLL through 2012-2019 and Estimated Values through 2020-2030 for Kuwait

Out of the obtained equations (8-13), the VoLL can be estimated with reference to the year as illustrated and plotted in figures (8-13).

VoLL is used to measure the marginal benefits of improving the level of security of electricity supply. The VoLL helps in the wholesale market design of the countries and to improve the level of supply's security. The index VoLL is becoming an important concept in the GCC countries and it will increase the electricity markets.

The analysis yields VoLL estimates for the GCC countries, which plotted the VoLL variation for both years 2019 and 2030 as shown in Fig. (14 a, b). In the year 2019, the VoLL values are plotted for the six countries and estimated for the year 2030. It is estimated that VoLL will decrease by the year 2030. The reduction of the VoLL for the GCC countries by comparing both years 2019 and 2030 concludes that VoLL helps in reducing the loss cost, which is an advantage of the GCC's interconnection to serve each other.

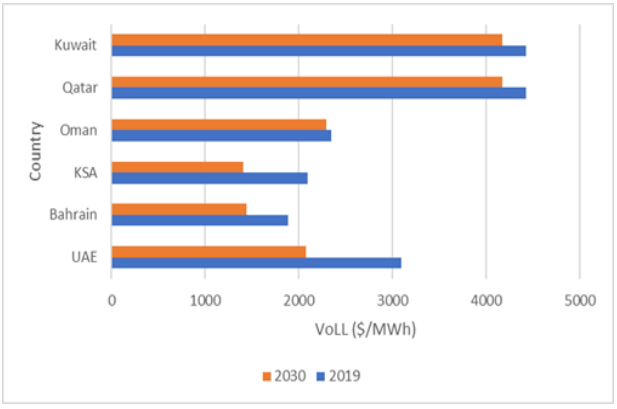

Figure 14a. VoLL Histogram for both years 2019 & 2030 of the GCC

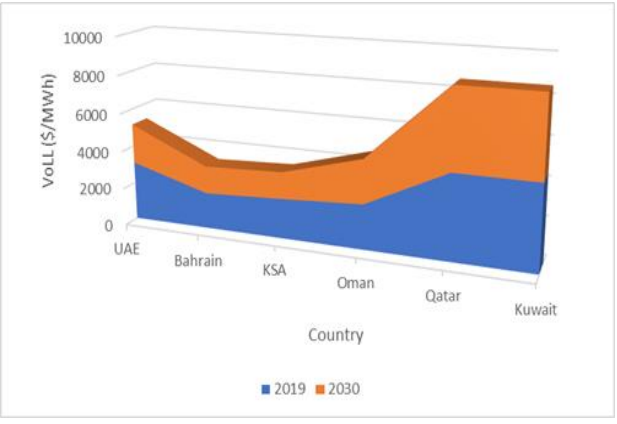

Figure 14b. VoLL Variation for both years 2019 & 2030 of the GCC

The liberalization of electricity markets across the GCC allows for more efficient flow of electricity based on the electricity prices within each respective market. It also improves the efficiency of electricity markets and presents a reliability standard. The VoLL in terms of evaluation of supply security, the electricity market liberalization allows for more socially optimal outcomes.

3. CONCLUSION

Both models, the energy consumptions and VoLL for the six GCC states are derived. At the same time, the VoLL examined to manage electricity outages. At present study for the GCC-countries, a single VoLL is adopted to evaluate the country payment that would be willing to avoid a supply interruption. Through the previous illustrated and identified research it has been introduced that VoLL varies significantly among the customers. The value may vary within each member states of the GCC-countries. The existing VoLL calculated in the present study helping to avoid the blackout and load shedding as well. This study investigates if a single uniform VoLL applied it will help to remain appropriate moves a

USD/MWh which vary according to how electricity intensive the industrial process is. The calculated VoLL for the six GCC-Countries were plotted in the previous section. These values helping the power engineers with the obtained models for the countries to estimate the future values that avoid the electricity interruption. The outage-specific calculation of VoLL helps the possible application in the operation planning of power systems. In the other words, the power plant maintenance outages might be schedule. In addition, the forced load shedding response in a manner to reduce the net economic costs on account of loss of supply. Furthermore, the model can help the method of long-term reliability investment decisions.

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