An economic model for the cost of electricity service interruption in South Africa

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Abstract

Cost of unserved energy provides an economic measure of the cost of electricity interruptions to electricity customers. These values inform investment and refurbishment decisions related to the power system, with the aim of optimizing network reliability. This paper reports on the development of an economic model to estimate the value of electricity reliability in South Africa by Eskom to meet regulatory requirements. The model allows for the scalability of COUE from national level to more detailed resolutions. The impact is that decisions for power system investment can be made to meet the needs of planning and regulatory applications.

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1. Introduction

In South Africa, the Cost of Unserved Energy (COUE) is used to provide an economic measure of the cost of electricity interruptions to electricity customers and the economy as a whole. These values are used to inform a number of investment and refurbishment decisions related to the electrical power system, with the aim of optimising network reliability. The economic cost of electricity service interruptions has been of considerable interest due to load-shedding in South Africa in the period 2008 to 2015.

The benefit of reducing the frequency and duration of electricity interruptions is quantified in economic terms for planning and regulatory purposes so that the business case for network investment and refurbishment can be defined and optimal levels of reliability can be engineered for the needs of the South African economy.

COUE is defined as the value (in South African Rands per kWh) placed on a unit of electricity not supplied due to an unplanned interruption of a short duration. These unplanned, short-duration outage events are expected in a well-planned system with an adequate reserve margin as a result of random failures of equipment. Typically, a power system planner would balance the total COUE against the cost to supply the energy not served in order to make optimal planning decisions. It is assumed that businesses and households experience these outages infrequently, irregularly, and of short duration; and therefore little or no mitigation measures are implemented by customers. However, over the long-term, the economic impact to customers of regular short-duration interruptions or the quantifiable “nuisance value” to customers should be factored into planning and investment decision-making to optimize systems and improve reliability.

The contributions of this paper include the development of a model for COUE for the residential sector and the economy at large, focusing on South Africa. The methodology takes into account both the direct and consequential indirect economic effects of electricity interruptions. We develop a macro-economic approach that utilises publicly available data and enables repeatable, transparently calculated numerical values to represent the COUE.

2. Where and how is COUE used?

Electricity interruption cost studies have been conducted in numerous jurisdictions worldwide. Billinton (2001) and more recently Electricity Reliability Council of Texas (ERCOT, 2013) reviewed studies from different regions worldwide. ERCOT concluded, however, that the findings across regions are limited by lack of comparability.

Nooij et al. (2007) identified two decision-making applications for interruption-cost values: first, to make socially optimal investment decisions, and second, to decide which customers should be cut off in times of electricity supply shortages.

COUE values have been applied in transmission planning and investment in Australia (Hicklin, 2010), Canada (Bhavaraju, 2004)
3. Methods to estimate the value of service interruptions

International researchers have developed several approaches to determining the cost of interrupted electrical power service. Primary amongst these are the production-function and customer surveys (Nooij et al., 2007).

3.1. The production-function method

The production-function method uses official, published macro-economic data, such as gross domestic product (GDP) and gross value added (GVA), and household expenditure measures. This method estimates the impact of electricity interruptions due to lost production for businesses or lost utility for households.

According to Billinton (2001), the production method has several advantages: it is feasible and simple to implement as a result of data availability; it uses official, publicly available data, and is thus, transparent, verifiable and repeatable; it is consistent with the System of National Accounting (SNA) methodology of the United Nations (UN, 1993); it enables and supports macro-economic modelling, and it allows for scalability of COUE measures from a national level to a more detailed resolution (e.g., the municipal level).

The key disadvantage of the production approach is that it assumes that macro-economic indicators are a reasonable proxy for costs of unserved energy. This is because the approach is based on macro-economic estimations and no data are collected directly from customers, and it is insensitive to variations in costs associated with time-of-day, day-of-week, and time-of-year in which interruption occurs (Billinton, 2001). The impact of time dependency on interruption costs is well documented (ERCOT, 2013) and methods to account for this effect include using weighting factors (Billinton and Wangdee, 2005) as well as associating interruptions with time-of-day and seasonal intervals (Herman and Gaunt, 2010). These methods are used in conjunction with customer surveys to account for the impact of the time dependence of interruptions and its potential relevance to planning and investment decisions.

While the relevance of interruption timing is relevant, the time-consuming nature and high cost of surveys to collect relevant data are also considered when assessing interruption costs. As a result, the production approach is often used because it does not account for time dependence. Interruption impact studies using the production function method have been conducted in the Netherlands (Nooij et al., 2007), Ireland (Leahy and Tol, 2010), Germany (Praktiknjo et al., 2011), and Spain (Linares and Rey, 2013).

3.2. Proxy indicator methods

It is possible to estimate COUE from proxy indicators using data collected from business. These indicators relate to purchases of backup generation and other relevant measures. The key assumption is that customers would invest in backup generation to avoid interruptions at the point at which the value of generation equals the cost of unreliability. Disadvantages associated with this method include high data collection costs and the inability to disaggregate the data to a more detailed spatial resolution.

3.3. Blackout case studies

Past blackout events can be used to estimate the cost of electricity interruptions by conducting after-the-fact case studies (Billinton, 2001). The advantage of this method is that estimations are based on real events and not hypothetical situations. However, these findings are limited to the characteristic of the events studied, and these experiences can usually not be generalised to other events (Targosz and Manson, 2007).

3.4. Customer surveys

This method uses survey questionnaires to collect data from customers on the impact of unserved energy. It is based on the
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