An open source tool for analyzing the impact of electricity network and retail tariffs on consumers

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***Abstract*— This paper presents an open source tool for analyzing existing and proposed electricity network and retail tariffs and particularly their impact on end users. Thousands of end-user load profiles and, where available, associated demographic information for each load profile can be used as inputs to the tool. A tariff database with associated API, that has been populated with a wide range of existing and proposed Australian tariffs, allows exploration of a wide range of possible tariff options and their implications both on cost reflectivity as well as customer bills. User defined tariffs can also be incorporated. This paper introduces some of the features of the tool as well as three case studies to illustrate how this tool can be used to better understand the potential impact of different tariffs on stakeholders including consumers of course, yet also distribution network businesses and retailers. The tool is open source and publicly available and has been developed in both Matlab and Python thereby providing flexibility for the user's preferred operating environment.**

***Index Terms*—Cost reflective tariffs, Network tariffs, Retail tariffs**

I. Introduction

Recent regulatory reform efforts in Australia's National Electricity Market (NEM) have included a number of rule changes aiming to contain electricity price rises driven by network investment by distributed network service providers (DNSPs). One focus area has been the economic inefficiencies of current network tariff arrangements, particularly for residential and small business consumers. These tariffs have generally involved a major volumetric consumption component, applied broadly across time and location, reflecting limited customer metering capabilities (e.g. simple volumetric meters) and equity considerations (requirement to apply equal tariff rates irrespective of customer location and therefore cost to supply). This type of tariff structure doesn't reflect the role of consumer contributions to network demand peaks and hence to overall DNSP expenditure [1].

As part of the regulatory reform efforts in Australia, a distribution network pricing rule change has been implemented, effective for the current regulatory period [2]. The new rule requires that network tariffs should be more 'cost reflective', motivated by the idea that efficient prices will change consumer behavior, which in turn will improve load factors, reduce network congestion and result in lower average costs for consumers. DNSPs are given discretion over the specific implementation of the rule, which provides broad pricing principles only. The rule states that network tariffs should be based on the long-run marginal costs (LRMC) of providing the service, and that the revenue to the network should reflect the efficient costs of providing the services to each consumer class. However, DNSPs are able to determine how to calculate their LRMC, and how residual costs should be collected. As DNSP tariff structures must balance efficient pricing considerations with fairness and the ability of consumers to understand and respond to the tariffs, there is considerable scope for a variety of tariff designs to emerge. In recent submissions, DNSPs have put forward a number of tariffs of varying structure and complexity [3]. It is challenging to assess how each tariff will impact on different consumer groups, and how well they can provide efficient price signals and address existing cross-subsidy issues.

A significant number of the tariff proposals now being put forward by DNSPs under the new rule might not provide appropriate price signals to consumers regarding their investment and behavior and may disadvantage some consumer groups. For instance, in the majority of proposed network tariffs, the fixed daily charge component is being increased, resulting in high unavoidable costs, particularly for low energy consuming (often vulnerable) customers. Special tariffs have also been proposed for certain classes of customers (e.g. solar PV system owners) [4], while in some areas customers are being transferred to new tariffs under opt-out arrangements, leaving them vulnerable to potentially disadvantageous new tariffs. In addition, there are concerns that the tariffs might not effectively target peak network loads (either local or region wide), and therefore may not provide an appropriate price signal of the associated network costs of consuming energy at different times and locations [1]. Poorly designed tariffs that do not appropriately align benefits and costs may lead to inefficient investment in networks and by

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consumers, and hence not be in the best interests of consumers. Specifically, they might act to reduce the consumer incentives to deploy solar PV, energy efficiency, and other load management systems that can reduce network expenditure while also delivering wider economic and environmental benefits [5].

It is possible for groups or individuals to make submissions to the Australian Energy Regulator in response to the Network Service Providers' Tariff Structure Statements and annual Pricing Proposals. The tariff design and analysis tool (TDA), presented in this paper, is developed to assist stakeholders, including consumer advocates and researchers, to investigate how different tariff structures impact on the expected bills of different types of residential and business consumers, while also estimating how well the tariffs align these customer bills with their impact on longer-term network costs.

II. Tariff Design and Analysis Tool

The TDA has been developed in both Matlab and Python programming languages and is open source and publicly available for researchers, consumer advocates, regulators, and other electricity tariff stakeholders. The tools are available at https://github.com/UNSW-CEEM/TDA_Matlab and https://github.com/UNSW-CEEM/TDA_Python for Matlab and Python versions respectively. A standalone executable version of the tool is also available for both versions making it easy to run the tool without having to install Matlab or Python. The TDA tool can be used to apply existing, proposed, or user-defined network or retail tariffs to a set of customers' load profiles to evaluate the impact of different tariffs on consumers' electricity bills. Aspect of users' load profiles or bill components, and the distribution of these variables across a set of users can be studied in the tool, allowing for detailed analysis of the impact of different tariff designs. The variables include annual kWh, average peak demand, average demand at the time of network peaks (coincident demand), and individual bill components. Fig. 1 shows the graphical user interface of the Matlab version.

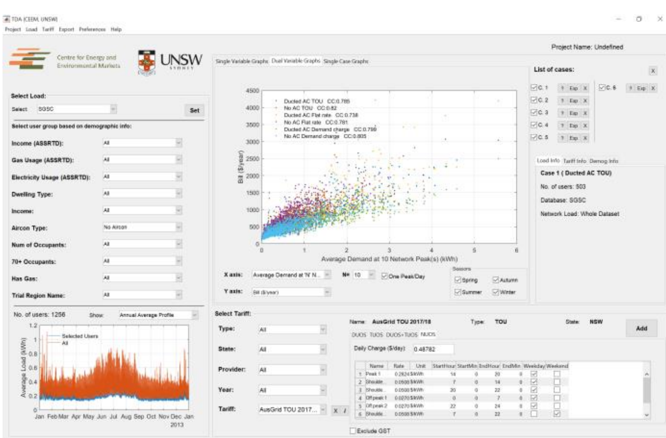

Fig. 1 Screenshot of TDA user interface (Matlab version)

The TDA user interface has three main parts: (i) for selecting loads and demographics, (ii) for selecting tariffs, (iii) for visualising the results. In addition to those packaged with the software, a new set of load profiles or network load profile can be imported and used for analysis. Existing tariffs in the database can be adjusted or new tariffs created in the tool.

During the process of designing or evaluating network and retail tariffs, interested stakeholders can use the TDA tool to perform evidence-based analysis, including study of the following aspects of tariff design:

- Impact of different tariff types on customers' bills
- Effect of tariff parameter variations on the customers' bills, or sensitivity analysis
- Comparison of the impact of proposed tariffs on different customer groups (e.g. based on demographic information)
- The correlation of customers bills with their contribution to network peak demand

Three visualisation types are available in the tool to allow the user to present the results in a variety of different ways. Single variable graphs can be used to show results such as Average annual kWh, Histogram of kWh, Monthly average kWh, Seasonal daily pattern, Monthly peak time, Load duration curve and Bill distribution. Dual variable charts are available for plotting different results against each other such as Annual kWh, Average demand at network and users' peaks, Daily kWh, and Annual bill. And finally, a single case chart type can be used for plotting the results for single scenario such as bill components and interquartile ranges for load profiles. Complete instructions on how to access and run the tool can be found in the wiki page of the github repositories listed above. The Python version extends the functionality of the Matlab version by including firstly wholesale electricity price data, which can be used to compare wholesale electricity costs to retail and network bill components; and secondly the ability to assign end-user technologies such as rooftop PV, battery, and demand response to the load profiles.

III. Database

The TDA is packaged with load and survey data from over 4,000 homes, collected under the Smart Grid Smart City [6] trial program, as well as load data from 300 homes in the Ausgrid network area (with and without solar contribution) [7]. The user also can add their own load profiles for analysis. Around 60 different distribution network and retail tariffs from throughout Australia have also been integrated into the tool. An Application Programming Interface (API) includes updated tariffs which allows the tool to update with the latest tariffs. The API can be accessed via http://api.ceem.org.au/electricity-tariffs/network for network tariffs and http://api.ceem.org.au/electricity-tariffs/retail for retail tariffs.

IV. Sample Case Studies

To demonstrate some of the tool's features, three case studies are presented below. Three different tariffs have been used in the analyses, namely flat rate, time of use (TOU), and demand charge tariffs for Ausgrid and Citipower, two major

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DNSPs in New South Wales and Victoria, Australia. The parameters of the tariffs are presented in table 1.

Table 1. Tariff parameters used in the case studies

Ausgrid flat rate tariff	Rate ($)
Daily Charge	0.39311 $/day
kWh charge	0.113 $/kWh
Ausgrid TOU tariff	
Daily Charge	0.48782 $/day
Peak charge (2pm to 8pm weekday)	0.2824 $/kWh
Off peak (10pm to 7am)	0.0508 $/kWh
Shoulder (rest of times)	0.027 $/kWh
CitiPower Demand Charge	
Daily	0.25616 $/day
Peak 1 (Dec to March, 3pm to 9pm)	9.427 $/kW/month
Peak 2 (April to Nov, 3pm to 9pm)	3.223 $/kW/month

A. *Impact of solar customers on network revenue*

In this case study the impact of solar PV uptake by customers was evaluated by applying two different network tariffs (flat rate and TOU) to the customers' load (a) with net-metered PV (referred to as 'Net' in Fig. 2 and 3) and (b) without PV (referred to as 'Gross'). The 300 solar home database was used for this analysis.

The analysis shows that when customers add PV, the average annual network component of their bill decreases from $697.10 to $571.10 (under the TOU tariff) and from $775.50 to $647.50 (under the flat tariff). This corresponds to 18% and 16.5% bill reductions respectively, which is a corresponding revenue reduction for the network. Since the focus of this case study is on the network impacts the feed-in tariff is not considered, as it is passed through by the retailer independently of the network business. Fig. 3 shows the correlation of the customer's annual bills to their contribution to the network's highest ten demand peaks for the year. This feature in the TDA tool allows users to examine the contribution of customers to network peaks, and therefore how well different tariffs reflect customer contributions to network marginal capital costs. The analysis shows that under a flat tariff, the contribution of solar customers to the network peak events has a similar correlation with their bill to that of the non-solar customers. For customers both with and without solar, the TOU tariff appears to show a higher correlation between customer bills and their contribution to the network peak, indicating that the tariff is more cost-reflective since those customers that use more electricity during network peak events, which are the main driver of network costs, are paying more.

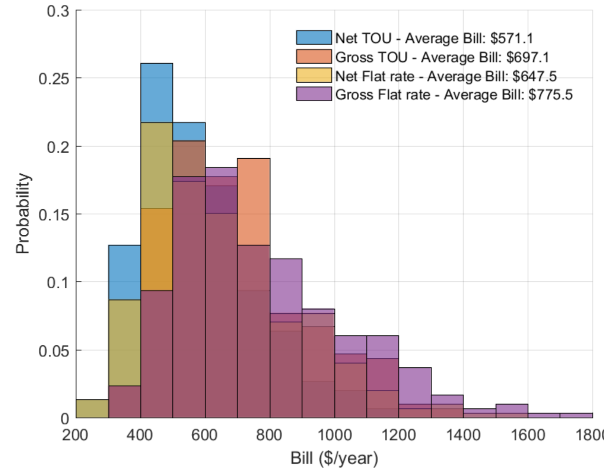

Fig. 2 Tariff impact analysis for case study 1: distribution of bills

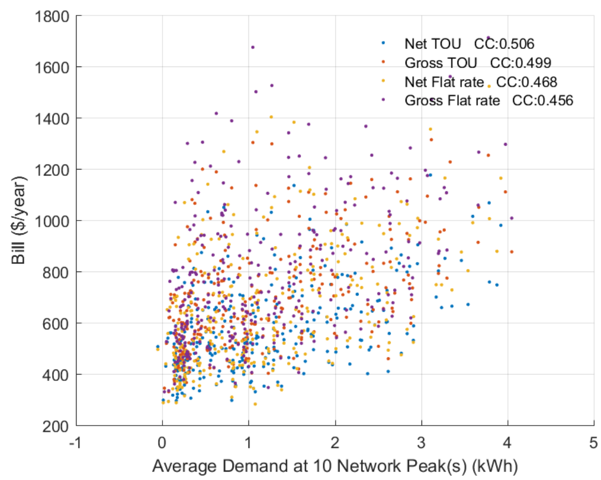

Fig. 3 Tariff impact analysis for case study 1: scatter plot of bill versus demand of customers in top 10 network peaks

B. *Impact of tariffs on different user groups: high income and low income customers*

This case study presents a feature of the tool that allows the user to select a subset of load profiles for the analysis, and hence evaluate the impact of tariffs on particular user types. This case study presents the impact of three different tariffs (flat rate, TOU, and demand charge) on customers with low income and high income using demographic information linked to the load profiles in the SGSC program database, which is packaged with the TDA. Users can easily import other demographic or meta-data corresponding to load profiles being analyzed using the tool, As described in the project's github wiki.

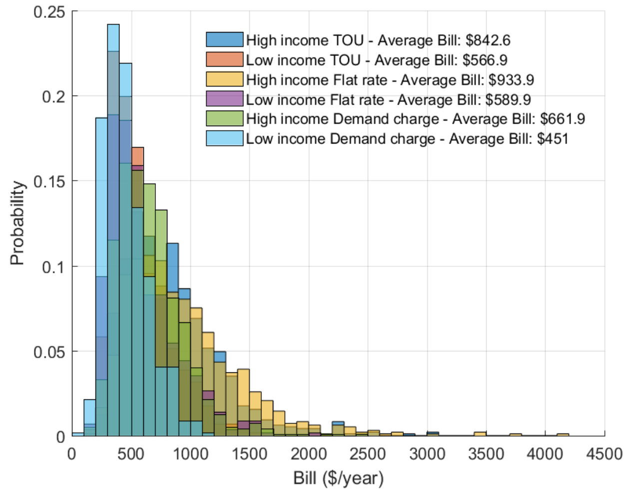

Fig. 4. Tariff impact analysis for case study 2: distribution of bills

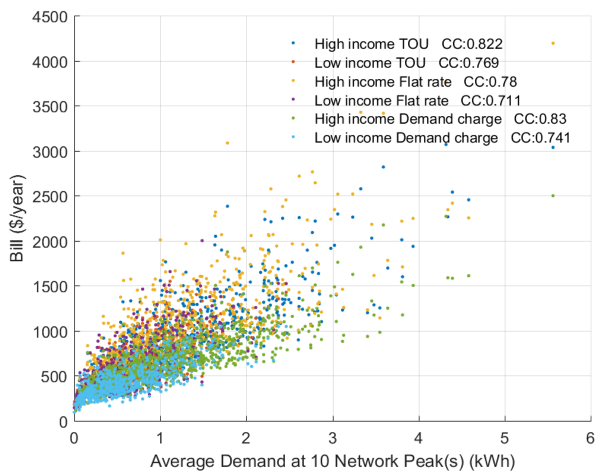

Fig. 5 Tariff impact analysis for case study 2

Comparison of the annual bills of high income and low income households under the different tariffs shows that high income users have 58%, 48% and 46% higher bills compared to low income users for flat rate, TOU and demand charge tariffs respectively. This highlights the fact that customer groups with different demographics experience different impacts when moving between different tariffs. In this case it is typically more profitable for the high income households to move to TOU or demand charge from flat rate than it is for low income households. Fig. 5 also shows a generally lower correlation coefficient between bills and network impact for low income customers, which may indicate a systematic issue in the design of those tariffs for this group, at least in terms of their cost reflectivity.

C. Impact of Air conditioner ownership on customer's bill and load profile

This case study presents a comparison of customers with different types of air conditioner (AC) and without AC. Fig. 6 shows a box plot of annual bills for customers with ducted AC and users without AC, under different tariffs.

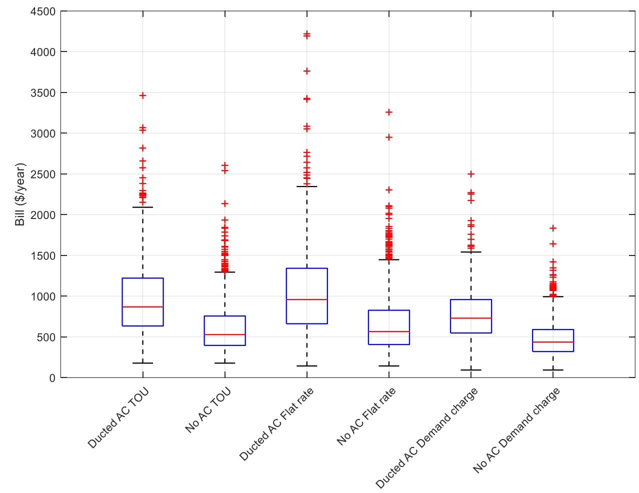

Fig. 6. Comparison of tariff impacts on different AC for different tariffs

Fig. 7 shows the average seasonal load profile for users with ducted AC, no AC and split AC. This feature of the tool is useful for investigating load profiles and for analyzing their impact under different tariffs.

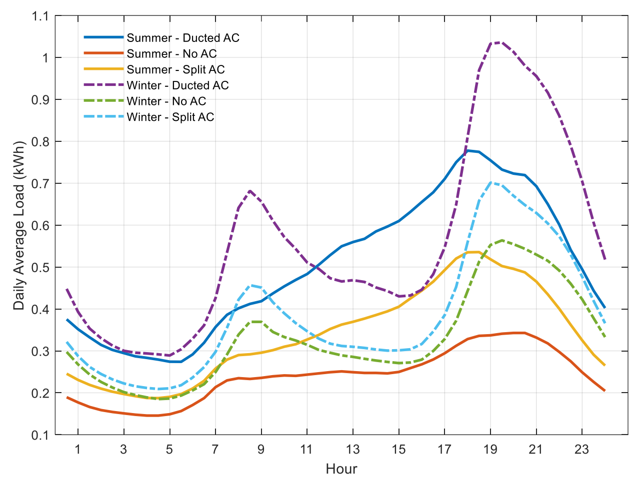

Fig. 7. Seasonal load pattern in case study 3

Fig. 8 shows the average load profiles on the annual network peak day (18th Jan 2013) and two days prior to the peak. The contribution to the network peak is significanly different for the Ducted AC customers, Split systems customers, and customers with no AC. The boxplot of different tariffs for different customer groups in Fig. 6 is useful to understand the impact of tariffs on customers and, combined with the analysis of load profiles seasonally in Fig. 7 and on peak days in Fig. 8 provides insight into customer impact on network costs and how cost-reflective the customers bills are across different customer groups.

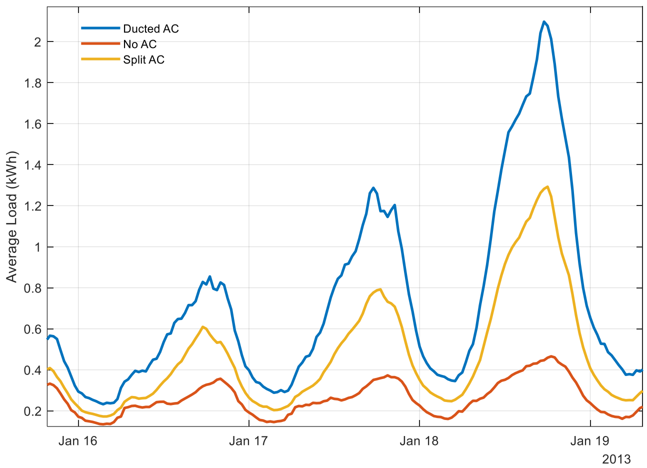

Fig. 8. Load profile on peak day and two days prior

V. CONCLUSIONS AND REMARKS

This paper has presented some of the features of the Tariff Design and Analysis (TDA) tool, designed for analysis of the impact of different tariffs on customers. The tool is open source and publicly available for download and can be used to derive insights from large sets of customer load profiles, and subsets of these customers according to demographic, appliance ownership or uptake of end-user technologies such as rooftop PV, battery, and demand response. It is envisaged that the tool will be of interest to many stakeholders impacted by electricity tariff design, including electricity networks, retailers, customers and their advocates.

Three case studies have been introduced to highlight some of the features of the tool including distribution of bills, correlation of bills with other parameters such as contribution of customers demand to the network peak and insights from load patterns, across different customer groups.

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