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ESTABLISHING THE POTENTIAL GRID BENEFITS AND DETRACTIONS OF THE DEPLOYMENT OF VEHICLE TO GRID ELECTRIC VEHICLES

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Overview

Current community concern over climate change and energy security has placed a greater emphasis on finding alternatives to consuming petroleum based products particularly for transportation. Energy production and consumption trends are being reviewed by communities requiring more cost effective and environmentally friendly technologies, particularly for transport. Some carmakers have responded by announcing production runs of plug-in hybrid (PH) and fully electric vehicles (EVs) to satisfy increasing consumer demands for greater fuel efficiency. It is currently expected that these alternative vehicles will be available for wider adoption in Australia after 2015. Several studies into the benefits and costs of the broad scale deployment of PH and EV's have showed the benefits for the shift of point source emissions from oil based fuels to electricity generation. Australia however has yet to be subject of a comprehensive analysis of the benefits, grid impacts and potential costs of the deployment and integration of PH and EV's into the future.

The focus of this paper is to describe via this work, of energy market modelling frameworks which are best suited to a diverse and very sparse electricity network which encounters different operating and policy conditions to those of North America and Europe. Prior grid based scenario analysis has been performed on a least cost unit commitment basis such as (Parks et.al. 2008). The simulation of market behaviour and the inevitable change in electricity use trends has been performed using an optimal dispatch model of the National Electricity Market (NEM) that simulates operation and dispatch of power generation assets on a half-hourly basis over the medium term. This model evaluates the dispatch of the optimal fuel type mix based on an order of merit determined by bidding behaviour of generators to recover short run and long run marginal costs (SRMC and LRMC). Marginal cost recovery for generating units is the primary driver for bidding behaviour within the NEM, while possible fuel mix changes due to increased demand during off-peak time periods will also change spot market price behaviour and emissions rates. To estimate the consumer uptake of electrified vehicles, we employ a structural model of the energy sector via the transport module of CSIRO's Energy Sector Model (ESM).

Furthermore for this study of the effects of grid integrated vehicles on the Australian electricity network, we have developed three vehicle charging scenarios. For each of these scenarios we have developed a half-hourly charging profile for a fleet of EV's and vehicle to grid capable cars. This load profile was then added to a base demand forecast via forecasts of future energy use conducted by the AEMO. After describing each of our charging scenarios we provide fleet average demand profiles and show how each scenario affects prices and available supply.

Methods

To investigate the effects that consumer uptake of PH and EV's might have on the demand for electricity on the NEM, we have used PLEXOS electricity modelling software platform, to simulates the NEM's dispatch and bidding behaviour on a half hourly basis over a ten year time frame. PLEXOS is a commercially available optimization theory based electricity market simulation platform which was developed by Energy Exemplar. At its core is the implementation of rigorous operation algorithms and tools such as Linear Programming (LP) and Mixed Integer Programming (MIP). PLEXOS takes advantage of these tools in combination with an extensive input database of regional demand forecasts, inter-regional transmission constraints and generating plant technical data to produce price, generator and demand forecasts by applying the SPD (scheduling, pricing and dispatch) engine used by the AEMO to operate the NEM.

This model will optimally dispatch generating units based on marginal cost recovery and availability at half hour intervals by using forecasts of system loads. The Short Run Marginal Costs (SRMC) and Long Run Marginal Costs (LRMC) for each generating unit is calculated by using data on fuel costs, O&M, startup costs and weighted average costs of capital (WACC) from AEMO's (AEMO 2011). The database that we have used also includes transmission, inter-connector flow, emissions and fuel availability constraints. Furthermore, we are also able to examine marginal loss factors, planned and unplanned outages and unit performance. Network system load profiles for each region were used to estimate individual demand behaviour. We then applied alternative charging scenarios to gauge the effects on network demand. To estimate the customer uptake of electrified vehicles, we employ a structural model of the transport sector via the transport module of CSIRO's Energy Sector Model (ESM).

Initially we run a base case scenario to establish load forecasts and capacity factors which we shape to historical data obtained from AEMO's data server. We then use our model to establish a benchmark for greenhouse gas (GHG) emissions which provides an emissions profile for the NEM. Having established a base case we move on to establishing a variety of new demand scenarios based on customer uptake of PH's and EV's in the Australian NEM.

The development of our study begins with a forecast of network and market behaviour for our 10 year time frame to establish a base case scenario which we will then compare our results. Forecasts of demand within the NEM were obtained via data available from AEMO, allowing us to develop a 50% Probability of Exceedance (POE) scenario. Network system load profiles for all regions of NEM were also used to produce a forecast of regional demand. Furthermore, generating plant behaviour was obtained from (ACIL Tasman, 2009) and AEMO's data server to produce a forecast for available supply across the NEM, with particular attention to new plant development. While forecasted customer growth in the NEM has been identified by AEMO as a network planning issue, the broad scale deployment of PH's and EV's have yet to be seriously considered by the market operator.

Results

The uptake of these vehicles, while slow in the early stages due to their initial high capital costs, will enable Australia to reduce its overall GHG emissions. The results of our simulations indicate that wholesale prices during the off-peak period will increase slowly over time. This increase in spot prices will require further review by policy makers of regulated retail electricity tariffs. We also discuss the implementation of possible changes to the retail tariff structure to accommodate the charging of these vehicles. Furthermore, the broad deployment of battery storage across the grid will help to abate previous concerns of high a volatile prices due to uncontrolled charging of vehicles.

Conclusions

The results of our simulations indicate that wholesale prices during the off-peak period will increase slowly over time with controlled charging. While uncontrolled charging increases the incidence of extreme price events and a considerable number of hours with unserved energy within the network. This increase in spot prices will require further review by policy makers of regulated retail electricity tariffs. We expect the transfer of greenhouse gas emissions from petrol fueled personal transportation to electricity generation will assist Australia in achieving emissions reductions from the transport sector. Our results also indicate a variety of demand scenarios which will impact on spot prices throughout the NEM. Increases to spot price exposure for electricity retail firms could signal possible tariff price restructuring for retail consumers. However, vehicle to grid options may have extensive benefits for dealing with spot price spikes during peak load periods to reduce volatility an improve power quality.

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