**1 Introduction**

**1.1 System Operator Challenges**

The core goal of managing electrical supply load is that power generated should be equal to the load demanded. It is expensive and inefficient to store large amounts of electricity; it should be generated as it is demanded. System operators require electricity load forecasting to predict what the load will be in the future to determine a balance between customer demand and generated supply. If the predicted load is greater than the actual load (over-forecasting), the operator will buy more electricity than they need and consequently increase their operating costs with ordered generation units’ output exceeding the required generation to match demand.

System operators ensure they deliver a safe and stable feed of electricity by maintaining their grid frequency within an acceptable range using high inertia power generation sources, for example fossil or nuclear fuels [1]. If the forecast is lower than the actual load (under-forecasting), the operator will have to buy considerably more expensive (peaking power) electricity as redundancy to eliminate the power deficit. This makes control of the grid frequency more difficult for the operator and decreases their power generation efficiency by increasing operational costs.

There is an environmental incentive for system operators to predict next day load accurately by optimizing load predictions to accommodate the presence of non-dispatchable renewable energy sources that cause a negative load effect. This can reduce CO2 emissions and reliance on fossil fuels by reducing dispatchable power generation [2]. The efficient use of electricity is a major talking point regarding the environmental impact and reducing availability of non-renewable sources [3], and therefore it is important operators reduce waste electricity generation.

**1.2 Northern Ireland Context**

The dataset used in analysis and development of the solution is from SONI (System Operator for Northern Ireland). SONI operate the electricity transmission system in Northern Ireland, one of the four countries in the United Kingdom. Electricity in Northern Ireland is generated by three main power stations which are use coal and gas. SONI use short term next day forecasts of 48 half hourly values early in the afternoon of the preceding day to bid for electricity in I-SEM (Integrated Single Electricity Market). I-SEM is a wholesale market for the whole of the island of Ireland. SONI buy the bulk of their electricity for the following day from the day-ahead I-SEM market which consists of one auction with a deadline of 11:00 GMT [7]. SONI’s aim when bidding is to buy the least expensive electricity to match forecasted system demand. Hence, they require accurate forecasts to buy electricity a day ahead without having to resort to bidding for more expensive on demand electricity in intraday markets if they under forecasted the system demand load. Error maximization in short-term load forecasting can result in a substantial growth in SONI’s operating expenses. [5]. Furthermore, over forecasting the system demand would increase their operating costs by bidding for electricity generation that exceeds system demand.

A growing challenge for SONI in creating accurate load forecasts for Northern Ireland is the growth in small-scale renewable energy sources funded through government incentives. Small-scale renewable energy sources offsets home owner’s electricity bill by using it in preference to grid power, hence reducing the system demand. Installed small scale generation is now approaching a considerable 20% of NI’s average demand [2]. The main two renewable sources are photovoltaic and wind energy with both contributing over 100MW of electricity to the grid. SONI cannot accurately measure the influence of renewable energy generation with different weather conditions as they do not possess the data to pinpoint the exact locations, orientation and the amount of electricity generation. Additionally, in Northern Ireland there is an increasing use of low carbon technologies that increase system demand, e.g. electrical vehicles. Hence, SONI require forecast models that takes account of impact of embedded unmetered renewable generation and growth in low carbon technologies.

**1.3 Approaches to Short-Term Load Forecasting**

A short-term load forecasting approach is using a displacement model. A displacement model uses an historical system demand value that is displaced from the system demand date as the load forecast. The displacement value is a unit of time, which when an typical unit (e.g day, week, month, year), take advantage of the standard daily cyclic pattern of load for forecasting each system demand time interval. These models have been found to perform well when they use a previous occurrence of the same week day as the load forecast. A limitation of using displacement model’s prediction as the load forecast are not considering load deviations caused by weather-related and/or social factors.

Another approach is using a linear regression model. A linear regression model can provide accurate forecasts when included explanatory variables have a strong linear relationship (correlation) with load. Therefore, variable selection for a linear regression model is an important step in building a model that can predict accurate load forecasts. Variables are typically chosen through prior heuristic knowledge and understanding of variables that deviate load. A linear regression model can consider load deviations caused by weather-related and/or social factors by including weather and date-time explanatory variables that strongly correlate with system demand load in their construction. More advanced linear regression models include a strong performing displacement prediction and correct it with deviations in explanatory variables between the day to be predicted and the day used for the prediction. The challenge is choosing a load forecasting model for a specific day that performs optimally while managing its complexity i.e. number of explanatory variables included.

**1.4 Weather-Related Factors**

There are weather-related factors that influence the pattern of electricity load demand. The power output of renewable energy is dependent on the sun and wind. For measuring the influence renewable energy has on system demand load there is not typically a one single base variable, rather a combination of variables. For example, an approach to calculating the power generation output from photovoltaics is by using the product of potential solar irradiance and sun duration. There is a notable delay in time before people react to changes in the weather. Hence, using weather-related temperature variables instead of base temperature variables in models can account for this delay and produce more accurate load forecasts.

Northern Ireland has specific trends in weather pattern unique to its location. Weather conditions as an influencer to system demand load have been most influential in the summer than any other season [6]. Additionally, there are rare freak weather conditions such as storms and sudden drops in temperature that have not been forecast. This increases the error of short-term day ahead load forecasts as next day forecasts using inaccurate weather forecasts cannot consider their impact on system demand load.

**1.5 Social Factors**

There are social factors that influence load with people using more heating and lighting in the winter months than the summer months that increases electricity demand. People’s activities throughout the day effect the load pattern with night time, when most people are sleeping having a less variable load pattern than the period in which people wake up and participate in their daily activities. Unexpected changes in the daily load pattern not considered in the short-term day ahead forecasting model can increase the error of the load forecast. Intraday forecasts are a topic of research not considered in this dissertation which can react to unexpected changes in the daily load pattern.

The pattern for electricity demand becomes more complex when considering public holidays, which do not conform to normal day load patterns. Days have been observed to be affected by their recency to public holiday days with people taking extended leave, especially in the Christmas period in Northern Ireland. Further increasing the complexity of abnormal day’s load pattern, there are one-time events e.g sports games or local events that have an influence on Load. Therefore, load forecasting models should include the numerous unique characteristics of a day as parameters to predict an accurate load forecast.

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