Forecasting methodology for the Demand Management and demand response

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Load forecasting

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Introduction

Forecasting is an art and/or a science based upon which one can attempt to make a prediction on the outcome of events. It enables the forecaster to direct his/her actions in such a way to achieve the most desirable outcome. This process takes place in all walks of life and it is conducted through trial and error using our own experiences as well as the experience of others. The more significant is the desired outcome, the more critical becomes the role of forecast. Energy is undoubtedly the most important essence of our modern lives without which we cannot function in any way. Therefore careful planning for the utilisation of this key commodity deserves our utmost attention. Any illusions of: "it is our right to use the energy as we please" or "the new interventions and reforms such as the liberalisation are only for a the benefit of few fat cats who want to make more money", have long passed. Any move towards efficiency and good planning is considered now as a survival move.

One element that is vital in this endeavour is the ability to forecast and plan to achieve the optimum efficiency for the immediate, short, medium and long term provision of energy. And in order to produce a reliable forecast we need to understand the underlying effects of the elements impacting our supply and demand of energy.

The energy system of an industrial country is formidably complex and is the crucially important element of the overall fabric of the "economic-social-technical" system. The typology of the "energy systems" of different countries however, whilst their aims are the same, varies depending on the national and social structure as well as the energy regimes. Complete and interdisciplinary analysis would ideally consider all the E4 (Engineering, Economy, Environment and Energy), which are interrelated with energy at its core. However whilst the topology of a country's energy system can be carefully planned and defined by the incumbent government, various players in the system have the unenviable practical task of operating within the regime, trying to keep the balance of supply and demand within the constraints imposed by their shareholders, the regulator, the environmentalists and the consumers.

Scope Outline

This paper confines itself to providing practical answers to the challenges imposed on the energy players operating within the countries that have implemented some degree of liberalization or at least have "unbundled" their energy structure. It goes on to describe the most tried and tested mathematical modeling and forecasting techniques that are appropriate to this sector in balancing their supply and demand management, but excluding any engineering approaches that are available. We will aim to describe the approaches that are being successfully employed which combines the 'bottom-up' and the 'top-down' technologies, both micro and macro-econometric (Multidimensional Dynamic Models) which provide the starting basis of the quantitative analysis and forecasts for the immediate, short, medium and long term energy goals of each player. Although a similar approach can be implemented at the country level especially the smaller countries, and those newer arrivals into the liberalized energy community.

Setting the goals and gathering the required materials and tools needed

Obviously the goal is to achieve a good insight or forecasts for the consumption of energy of a group of consumers based upon which plans can be made for the provision and sources of supply. But what constitutes a good forecast? It is a reliable prediction of outcome based on a number of given assumptions (factors, drivers or variables). The assumptions to be used depend on the duration of forecast (or the horizon). However many or all of such assumptions (or variables) can be subject to variations or unreliability themselves. Therefore it is important to understand the underlying relationship of the variables with the demand. This leads to the conclusion that we will need to deal with a large volume of data and the ability to analyse their patterns and their relationship with the demand and with one another speedily and easily and in a form that the operator (business executive, e.g. dispatcher) can easily understand. With this introduction we can list the following materials and tool kit for our forecasting and we then decide how many of the items we can provide and at what budget:

- Data: historic data for the consumption and for any variables that we would like to use in our forecasting models such as the temperature or the portfolio size, etc.
- Data Processing: Fast & reliable data processing to store the data and to conduct various analysis
- Specialist Software: Capable & easy to use software to perform the analysis and specialist calculations
- Expertise (industry and forecasting expertise)
- Communication facility to interact with external mediums to receive and send data
- A forward plan and line of action (procedure) that will ensure

Various forecasting techniques support different forecasting needs; therefore expert advice must be available for selecting the appropriate technique(s) and provide the know-how or the teaching in order to utilize these techniques.

Author Prudence Mauthoor

Since we are expected to analyse and turnover large volume of data the need for a fast, modern and reliable data processing facility is a must. This means fast computers, data warehouse or repository and IT expertise to set up the data and support the operation.

In addition there is a need for expert software that provides the algorithms required for the forecasting. And finally the hardware and software facilities both must provide some degree of flexibility and scalability if the investment of time and money is to provide any longevity.

Forecasting methodologies and supplementary techniques

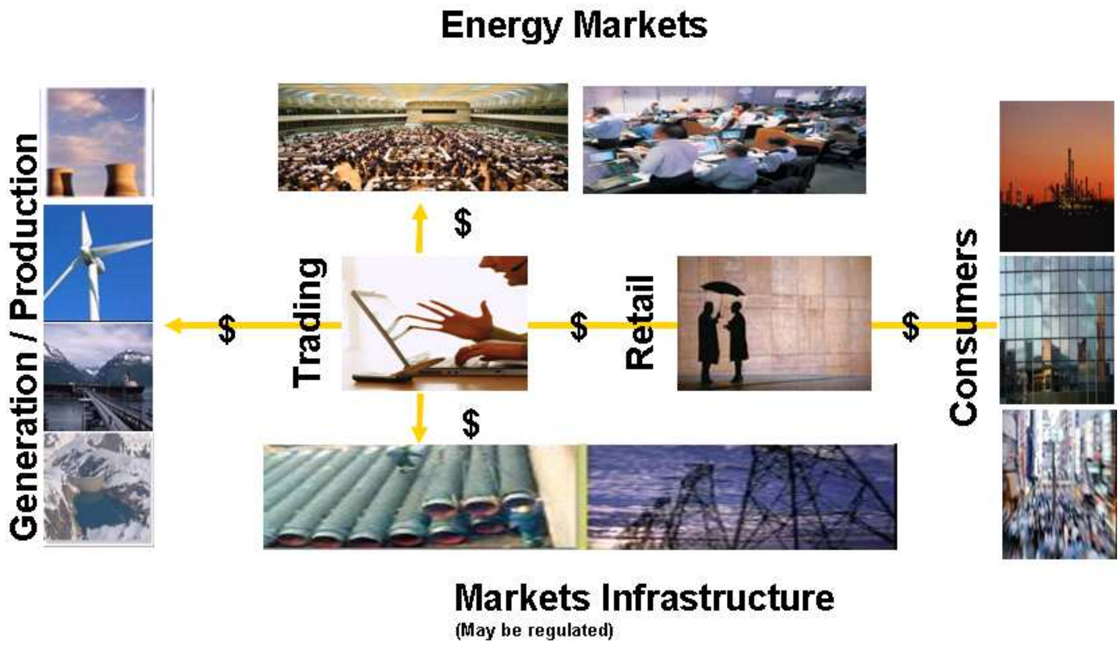
There are many forecasting techniques available each appropriate for a particular requirement. However tried and tested forecasting methods for the energy industry, especially the gas supply/demand include:

- Multivariate nonlinear and self learning techniques: Artificial Neural Networks
- multivariate linear regression,
- Exponential Smoothing (e.g. ARIMA, trend correction, etc.)
- Interpolation/extrapolation and filtering: similar day
- Impact factors that can be applied in various ways, directly or after automatic preprocessing (correlation): weather corrections
- Optimization functions continuously and automatically determining the best forecasting parameters and topology for the learning process
- Optimization functions to automatically selecting the impact factors: Combination, GRNN or Forward regression
- Segmentation techniques: rule base, statistical, self learning, customer profiles, load shapes
- Monte Carlo

A holistic forecasting approach to support the energy value chain

There is a need to take a holistic view of the forecasting needs of the business enterprise and take a connected view of the forecasting for the long, medium, short and the immediate short terms impacting the “value chain”. Energy Demand Forecasting is a permanent process that follows a fixed cycle starting with the storage, verification and management of consumption data followed by forecasts using various scenarios based on the consumption patterns examining the impact of various factors on the patterns of the demand. This result is compared with the actual consumption data to enable an imbalance analysis and the results of this analysis are in turn used as input for data management at the start of the next cycle addressing the entire value chain.

At the same time, as with any interdisciplinary representation of a complex system, there is a need for simplification in order to emphasise those aspects of the system that are being considered at any particular time, or which are important in terms of questions to which answers are being sought. In modelling the representation of the system, it is necessary for the relationships to be specified in formal terms, and for all the various variables to be measured in consistent units. This paper considers these essential elements of modelling in some detail.



Customer Segmentation

The customer portfolio is rarely homogenous and Energy Demand forecasting is a balance between the two extremes from:

- a single forecast of the combined energy consumption of all customers (the top down approach) to
- the individual forecasts for every customer (the bottom up approach) , which are then combined to produce an end result

In reality normally a middle course is adopted: bottom up for very large C&I customers and intelligent data grouping and Customer Profiling (aggregation by clustering the customer portfolio in segments):

- By customer or contract type, geographic region or even individual consumer

Standard approach at most energy companies is splitting customers into clusters and producing a number of virtual load curves or virtual meters; with many consumer data series in each segment. Forecasts are produced for each of these virtual meters or segments and aggregated. Process for individual forecasts and aggregated cluster forecasts can be applied concurrently, thus making it possible to obtain an optimal demand forecast.

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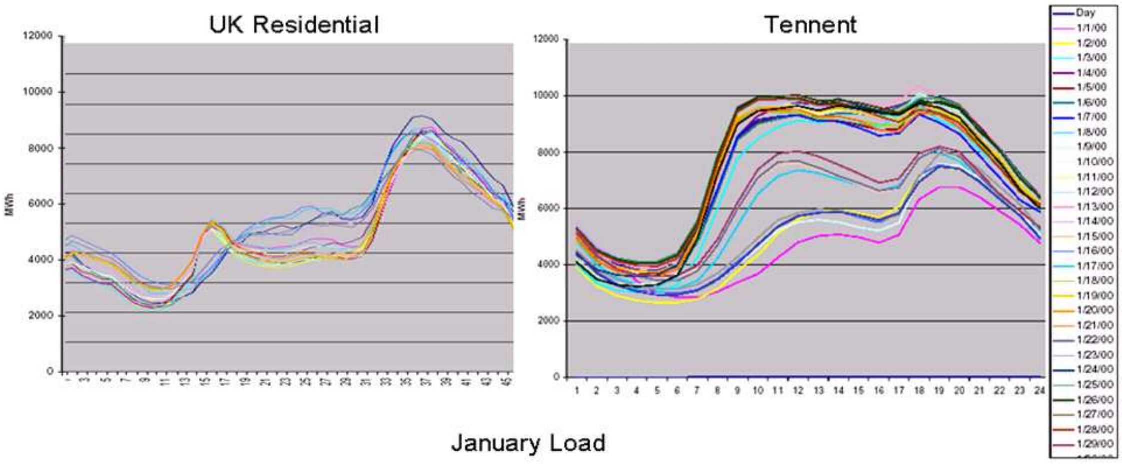
Gas Users

Source Shell2007

Frame 2

Variability in Demand



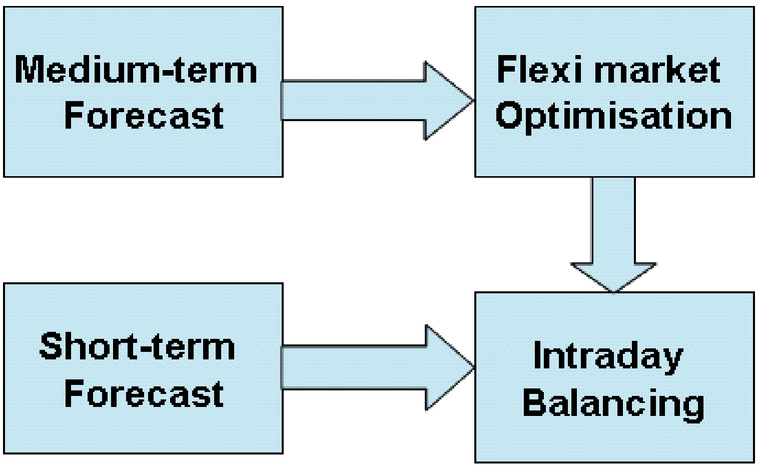
Above are demand profiles of 2 regions with similar economies, weather and culture. Yet their consumption pattern is very different. Profiling permits viewing these differences and can have significant impact on production and distribution decisions.

Frame 3

Forecasting for gas dispatching and portfolio management

A good starting point for balancing provides the best chances of minimizing flexibility costs, optimizing the use of flexibility in a gas portfolio is also discussed. Minimizing imbalance costs within an entry-exit model by optimizing flexibility and imbalance costs for gas dispatching:

- A 'state of the art' forecasting tool/mechanisms to apply the intraday corrections to re-nominate supply at the latest permitted time
- Rolling reliable forecasts a few days ahead (mid term) to make sure that facilities (contingencies) are in place for the intraday balancing. Intraday readjustment schematics to re-nominate:



Frame 4
Flow of Forecasting to Balancing Optimisation

Day Ahead Forecasting

Given the need for accurate balancing in any regime, both the day ahead and intraday forecasting are the very important steps in reducing penalties. For the day ahead forecasts we require quantitative techniques which need:

- A solid history of consumption data for the individual exit points that form the portfolio to create a model that explains the underlying patterns and forms the basis for future forecasts
- Good knowledge of the behavioral patterns of different consumer groups which is needed to create appropriate customer segments and decide on the appropriate forecasting approaches/methods for different segments of the portfolio, obtaining massive imbalance reductions
- An understanding of the drivers influencing the demand variations, e.g. weather.
- History of the data for the relevant influencing drivers

Author Prudence Mauthoor

- Using frequent measurement of data where possible, especially for large volume C&I customers
- Using customer nominations/forecasts directly (depending on the contract terms), or as a factors to create better forecasts thus improving the overall forecast results

Variable Selection

As to what variables should be employed to construct mathematical models of demand, unfortunately there is no single rule available. It is based on a process of trial and error using the local industry/utility knowledge. And since all end users do not have the same characteristics, consumption data for each customer segment should be analysed for correlations with various known drivers to assess the forecasting ability of the algorithms/models. Seasonal and periodic patterns should be taken into account while determining a correct learning data set for forecasting. For the intraday forecasting the latest measurements should be used as soon as available. An advanced forecasting environment should be able to process this automatically and readjust its forecast for the coming hours by applying a correction for imbalance in previous hours. Therefore the forecasting environment should be able to respond very quickly to sudden changes in energy demand (e.g. an industrial site's unplanned stoppage).

Variables for the Bottom up, Top-down or Profile demand models are typically:

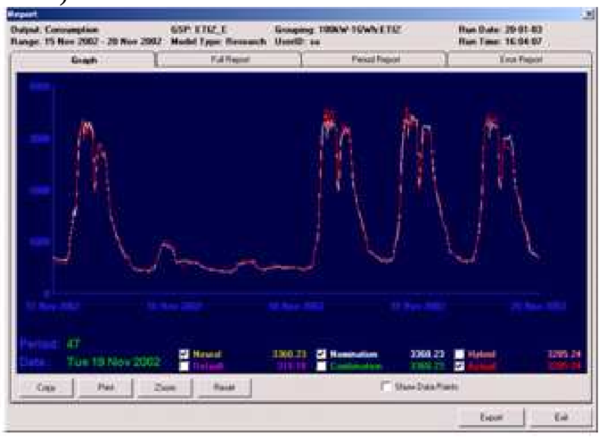
- Number of customers in the group (aggregate models)
- Weather elements, temperature, wind, radiation, humidity, pressure, etc.
- Seasons, months, week days, hours, sub-hours
- Holidays, special days, regional factors, work patterns and practices, school holidays, academic start/end
- Electricity demand (affecting gas demand for power production): TV Programs, Football, election, new year, etc.
- Long/short days
- Gas-day Issues
- Price tariff & Marketing (demand response issues)
- Economic & Socio-economic factors, etc. (for long term)
- Technological, political, environmental, social, regulatory changes and trend (for long term models)

Carefully constructed models with appropriate variables can display the underlying patterns and produce very good results as it is depicted in the following graphs (Frames 5, 6 & 7), whether it is for individual large C&I consumer or a domestic group or a regional top-down approach.

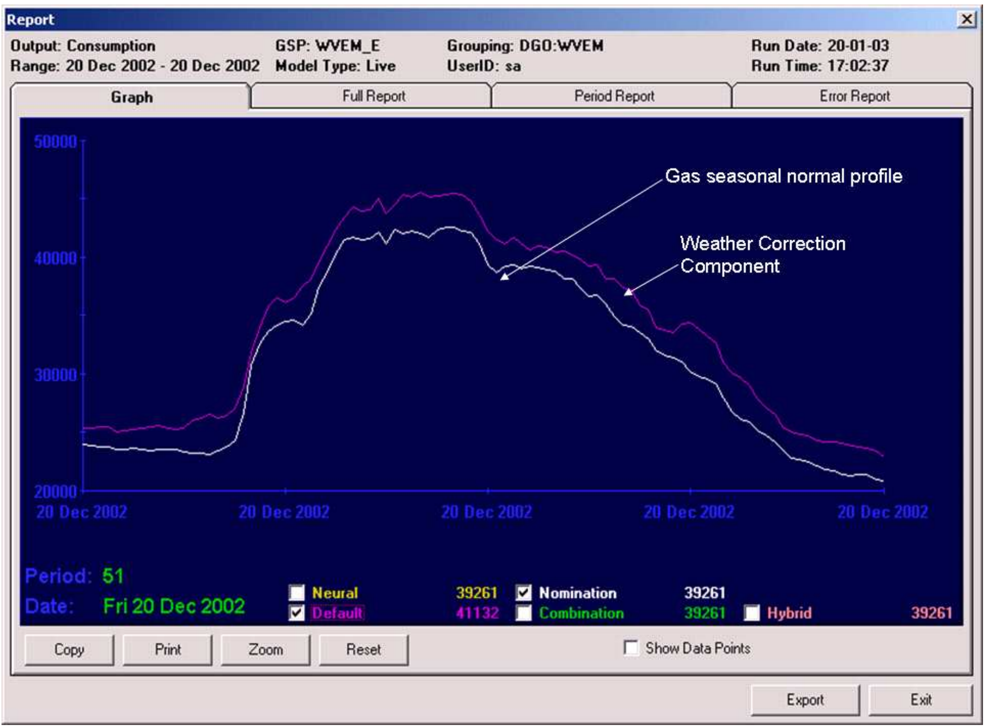
Author Prudence Mauthoor

Depicting the forecast produced by mathematical Short Term forecasts for the residential (Frame 5) and C&I (Frame 6)

Frame 5



Frame 6



Frame 7

Above is the graph of the winter demand in the UK with weather correction component

Intraday Balancing

Assuming a correct forecasting environment has been put in place, the challenge to properly use the forecast results to minimize the imbalance costs is still considerable. The imbalance volume has 2 components:

- Error of Supply (supply nomination - supply realization) and
- Error of Demand (demand forecast - demand realization). Even with a perfect demand forecast, imbalance may still occur.

Cumulative imbalances in some markets dictate a need for a mechanism with which the dispatcher can counter steer the earlier imbalances, i.e. intentionally generate an hourly imbalance if this helps to avoid a penalty for highest hourly or daily cumulative imbalances. This may result in the transportation nominations to deviate from (intra-company) forecasts. While it is advisable to have a dispatcher decide *where* to (re)nominate supply, relieving the dispatcher from the calculation of *how much* to (re)nominate buys the dispatcher time to investigate more alternatives before he makes a decision. This allows the dispatcher to choose the least expensive option.

Making use of flexibility in gas supply and demand

A sound starting point for intraday balancing is prepared before a day starts. Mid-term portfolio management should anticipate on changes in demand as predicted in a midterm forecast and provide a tool to show the sequence of flex tools to be used for balancing purposes. Flexibility options are traditionally the relatively expensive purchase contracts, therefore it is worthwhile to check value and cost of all sources of flexibility options in supply and demand.

End-users' demand can only marginally be influenced, except with some large energy intensive industries with interruption option contracts. Flexible power production units, that sell part of the production to a power exchange, are often used for correcting imbalances intraday, but opportunity costs may be underestimated. Industry is often balanced by a reduction of (gas for) power production, whereas other flex sources may be financially more attractive during the spark spread.

A tool that can produce good rolling forecasts for the next few days makes it possible to correct gas and power positions several days ahead in time to limit intraday risks and opportunity costs considerably.

Flexibility on the supply side can also be utilized in hub trading, storage and special flex contracts. Gas Entry-Exit Systems require the balance between the gas injected at entry points and gas withdrawals at exit points often with a virtual trading point for shippers to sell their oversupply or buy gas to meet unexpected high demand by their customers.

Medium & Long Term Forecasting and Scenarios

Medium term models have in principal the same structure as the short term models and are usually based on multivariate techniques in order to provide the elasticity for the scenario analysis and calculations of the confidence intervals. However the complete process of medium term forecasting includes scenario forecasts in order to examine stress points in the models and extreme conditions for the purposes of risk management and contingency planning. Results of the medium term forecasts and use of the flexibility options are used to plan for the day ahead and intraday balancing process.

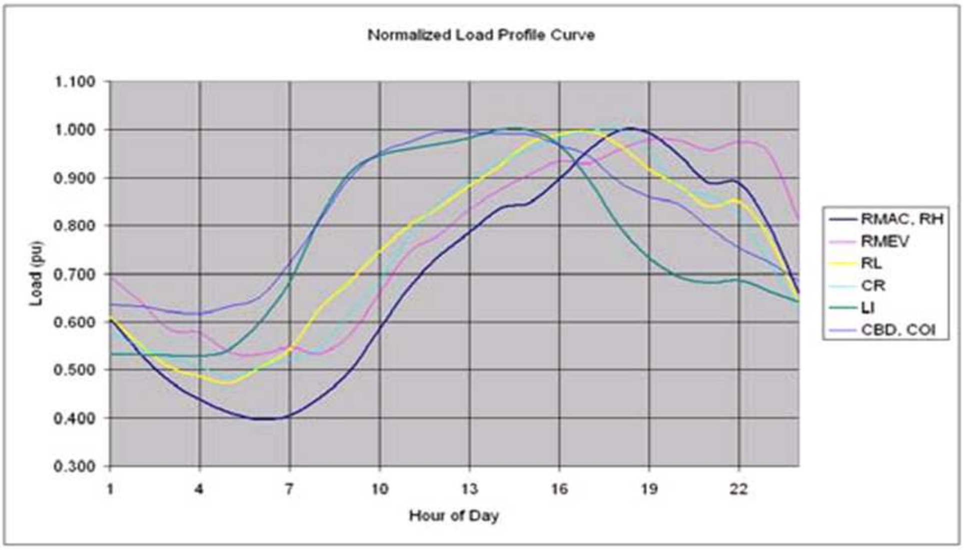
Long term models are based on a combination of mathematical models for underlying and/or changing patterns coupled with a set of rule-based assumptions to incorporate planned commitments: e.g. housing developments, license for new hospitals, factories, power plants, etc.

In long term forecasting sometimes is preferable to use load profiles (or load shapes) for simplicity. However it is important that the load profiles themselves are modelled using a multivariate technique such as regression in order to provide some degree of elasticity for examining different scenarios.

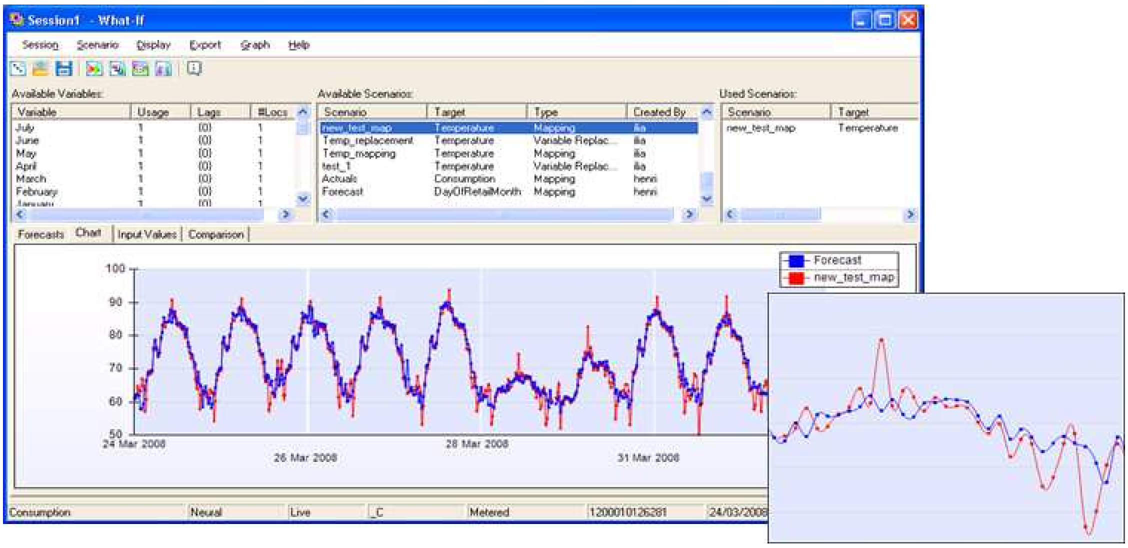
Forecasting Scenarios can be created through the:

- Confidence Limits, Optimal Exit point volumes, Interconnector usage volumes, National Aggregate Demand (U.K, Spain, etc)
- What-if Scenarios and Monte Carlo simulations should be used for the analysis and assessment of risks.

Frame 8



- Load profiles or shapes represent the average daily patterns of energy usage for a particular load class. This is used to build a load model from the represented land use
- Planners need to know how loads behave during the system peak
- Hourly data should be taken from the SCADA at the distribution-level feeder to develop the final load curves



Frame 9

Scenario Analysis for mid term risk and long term forecasts

With scenario forecasts;

- Assess the probability of forecasts diverging from the normal patterns
- Assess the Risk, Stress test and for the Planning purposes
- Scenario analyse based on: (i) different weather conditions or (ii) calendar variables (iii) any other variables in the model: Business growth; Hot/Mild winter; High cost of Oil/Gas; Global warming
- Generate Scenario Forecasts
- Run Monte Carlo simulations on scenarios for risk assessments

Defining the Growth or Shrinkage rates in long term models

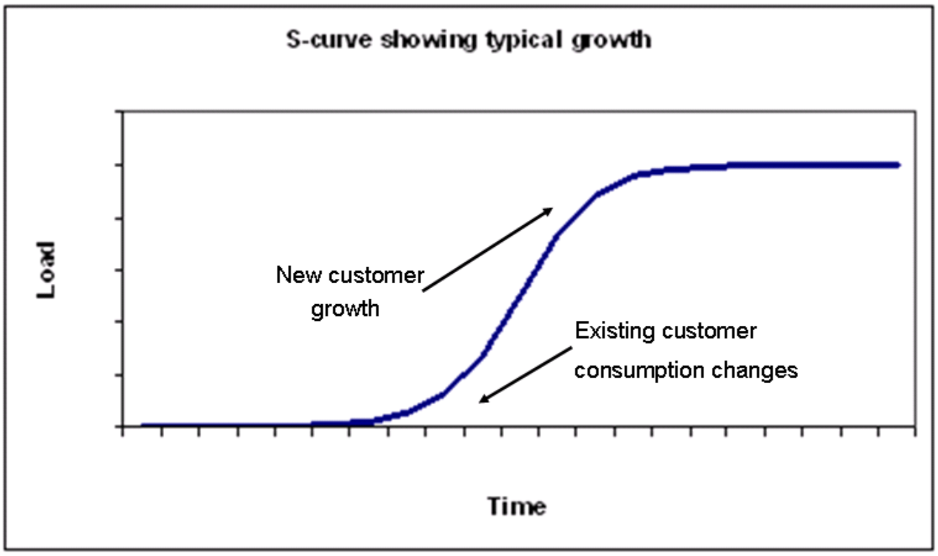
Growth rate in a demand model can stem from two different sources; from the affect of new customers and/or from the changes in the consumption pattern of the existing users, e.g. installation of central heating systems in the domestic sector.

The demand growth related to New customers creates for the steep step increase (the 'S' shape area of the curve of Frame 10 below). However the consumption change related to the changes in the pattern of usage of the existing customers is represented by a slow trend (the flatter sections of the 'S' curve). For representing these changes into the long term demand models the following approach can be used:

- The number of new contracts should be forecasted then converted into growth rates using counts of existing customers by class
- The growth rates are adjusted to produce an overall % electrical load growth from the base year to the first forecasted year
- The consumption growth rate for existing customers should be identified as a trend and examined for saturation drivers then applied to the long term model

Author Prudence Mauthoor

Frame 10



Long Term Planning: Spatial Load Forecasting

Spatial forecasting is the marriage of GIS with the models of load profiles and the planned commitments for distribution system and other development plans such as transportation infrastructure, current land use & forecast of urban centers, location and the timeline of community development, etc.

Spatial load forecasting can be used to predict the extent and the timeline of community's developments identify where infrastructure investments should be directed to. It can help to explore the impacts of new initiatives or localized development events, to demonstrate the effects of changes in fully developed areas, e.g. Conversion to central air conditioning and conversion from winter to summer peaks, community redevelopment. It can anticipate the location of future demand in a relative timeline, assisting capital investment planning, acquisitions, permitting lead times. It allows a more productive interaction with the community being served with the energy planners and engineers to predict large load additions to the system years in advance of their current methods. It helps to determine where new infrastructure should be added. It helps the authorities to plan property for requisite permits, etc.
Forecast results are used to predict future load centers, set priorities on projects, and obtain budgeting approval while minimizing risk.

The first step is to determine the load classes to be represented according to current land use; representing the regional load defined by its consumer load class. A load class (profile class) is based on a typical load behavior, usage, and patterns that lead to a typical daily load curve. It is critical to model both the known and the anticipated development in a region for both supply and demand. However it must be kept in mind that land will generally develop to its highest financial potential and often developers have the money and influence to alter development plans. Therefore any model must be flexible enough to be regularly revised and updated.

The model should construct:

- Long term scenarios based on the changes in the current load patterns
- Developments whilst taking into the account the practical constraints due to the resources, timescales or social constraints, e.g.
- Locating regions of employment or commercial activity as a factor in the model that encourage residential and commercial growth in locations

Demand Response

Demand response is a form of demand management under the direct control of the consumer rather than being operated and controlled by the energy provider or utility. Demand response differs in a number of ways from the DSM (demand side management) including: active load control, time-of-use metering, and passive energy efficiency programs. This approach is currently applicable to power utility, except for the large C&I customers in gas. However it has an impact on the gas demand and therefore its trends should be considered in gas demand models.

Demand response implies that large customers are financially motivated to actively control their demand and scale back levels of their loads, or shed them on short notice, and/or shift their loads from on-peak to off-peak times. Therefore the dispatcher must either rely on the customer forecasts and/or price curves and the spot markets behavior.

For the C&I customers and aggregated loads (e.g. energy cooperatives), demand response programs can work very much like the interruptible and curtailable rate programs that have been available for sometimes. However, whereas curtailment and interrupt tariffs offer low average prices as incentives, Demand Response programs tend to offer reasonable prices plus actual payments made to customers when they make a demand shift or cut back

Role of Data in Forecasting

Forecasting is a process of learning from the past (*constructing models*) and applying what has been learnt to predict the future (*generating forecasts*). Quantitative modelling techniques need *historic data* to learn the underlying patterns and relationship with the relevant explanatory factors (or drivers). And for the purposes of prediction (forecasting) the need the forecasts of the explanatory drivers as *on-going data.*
Availability of sufficient and good quality data is of paramount importance in any modelling technique or otherwise we will have the case of "*Rubbish in Rubbish out"*

Definition Good Quality Data is:

- Representative data pertaining to the problem and the solution
- Complete set of date with no missing value or gaps
- Data must be in the correct periodicity (granularity) for the forecasting, e.g. half hourly forecasting models require half hourly historic and on-going data

- All explanatory drivers should be presented to the models in periodicity that is compatible with the forecasting model, i.e. all data elements must have matching periodicity and time scale
- Data measurements must be sufficient, consistent (i.e. in the same unit) and reliable through strict validation process which is based on a well tested automated process to reduce risks associated with human error.

Conclusion

Since heydays of demand-side management (DSM) mid-1980s to early 1990s, advances in technology/communications, internet, manufacturing process, etc. has had an impact the electricity marketplace and resulted in a need to provide a new and improved generation of demand management tools and services.

The shift in emphasis from residential load management to commercial and industrial (cm) demand management has also increased the effectiveness of many DSM initiatives Resulted in the need to use demand response initiatives, DSM, and active load control systems to meet demand/ supply imbalances and maintain a reliable and stable electric delivery system.

There is the economic imperative of implementing demand response and load controls when spot prices exceed a certain set point and market pricing is volatile in an ongoing basis. The deregulated energy business itself can implement demand management programs as a strategic measure, part of an enterprisewide operating strategy, for the benefit of both energy supplier and user. Finally, another important incentive for the players is the opportunity to sell reserves created by effective demand management programs, including demand response initiatives.