Grid Reliability Enhancement by Demand Side Management on Adapting Load Forecasting

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Abstract— Raised complexity levels of conventional grids, ever increasing load demands, elevated reliability issues, limitations of conventional power generating units and quality issues associated with sustainable energy resources all highlight the need to adapt specific demand management techniques to enhance grid reliability. The stability of grids are adversely effected by varying loads, moreover the intermittent nature of the renewable resources and inability of conventional plants to deal with them make the grids even more vulnerable during peak load times. In this study we propose a tool based on Artificial Neural Network as the solution. It would forecast futuristic load enabling utilities to optimize grid performance.

Key words: Artificial Neural Network (ANN), Demand Response, Demand Side Management, Load Forecasting, Peak Load, Power Grid, Reliability, Varying Load Demand

I. INTRODUCTION

A power grid involves different power systems that together serve as the source to the grid which in turn supplies power to the customers. The performance and availability of the generated power varies from one system to another. For instance, a steam power system with fuel sources like nuclear or coal provides for the baseload which requires continuous operation with approximately constant generated power. Above this a steam powered system requires longer time for responding to the load change or varying its output. Whereas a natural gas power system responds faster to load changes.

Above these set behavioral patterns presented by power plants on the grid are the economic and environmental factors which impact the usage of these power plants to serve different loads in different patterns. For instance the conventional power systems based on fossil fuels are not encouraged anymore to cover the increase of the demand of the electrical loads. The trends have globally shifted in the favours of non-renewable power sources to cover the increased demands. But this in itself raises various other impacts worth considering like the power quality concerns and the intermittent nature of the renewable resource based power plant. Hence, a need to find ways to appropriately organise the time and output quantity of these plants.

In this paper we propose the utilization of short term load forecasting to stabilize the grid by regulating the power plants by demand management from utility side and by demand response from the customers' side [1]. This also assists to manage the irregularities associated with the non-renewable resource fuelled plants. The STLF tool mentioned in this study is based on Artificial Neural Network (ANN).

This paper first explains what is grid reliability followed by the behaviour of various power plants to help readers make a clear understanding of the need of this ANN based forecasting tool. Then the methods to counter the problems are explained under demand management to enable authors understand how forecasting is vital to the task of grid stabilization. Then the study briefly explains load forecasting, classification and artificial neural network followed by a case study which proves the utility of the proposed technique.

II. GRID RELIABILITY

Grid reliability [2] is a combination of both adequacy and security [3]; where grid adequacy is the ability of the grid to satisfy customer load demand at all times and grid security is associated with the ability to combat disturbances while continually meeting demand.

Meeting grid reliability in today's world is even a tougher task owing to the fact that grids are forced to operate at its limits because of:

- Insufficient generation
- Continually rising demands and lofty peak load data
- Aging infrastructure
- Varied power inputs inducing power quality issues especially with the renewable resources
- Large number of power transfers over longer distances increasing volatility and reducing operational margins.
- Transmission congestion due to larger installations. To list a few

A. *Behavior of Various Power Plants on Grid*

It is another important factor which suggests the use of load forecasting to optimize the performance of smart grid [4]. As evident from Figure 1. demand curve can be divided into three sections.The graph below plots the per unit load over the time axis. Where the pu load is calculated from the load data available on the website of National Regional Load Dispatch Centre [5]. The data is of Uttar Pradesh state plotted on hourly basis. Though the raw data has been treated to find average hourly load data which is then converted into per unit values which are plotted in the graph below. Details of this can be found in the case study section.

A base load which is the minimum constant load always available to be met. This load has no adverse effect on the grids.

Second is the peak load which is the highest demand over a time horizon to be met by the utilities. The most alarming fact about this category is that it is intermittent in nature with a huge magnitude. Thus, often a major factor in destabilising the smart grid and retarding its reliability.

Third category is that of the intermittent load. Though not a factor so strong to destabilize the grid it is a definite cause to disturb its efficient working.

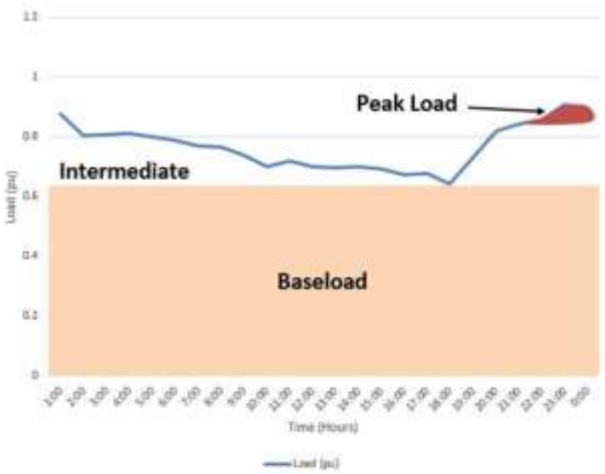

Fig. 1: Demand Curve

Following the load categories are the power plants working to supply them.

The first category are the Base load plants which work on full capacity to supply the minimum base load at all times. They are rarely shut or partially shut during maintenance or repair. Such plants are usually based on non-renewable energy sources.

Then are the peak load supplying plants these plants work according to the need. Choice of such plants is made on the basis of time they would actually take to increase their output. Smaller the time span more preferable the power plant is to supply the peak load. They are run only for short span of times are they are not economically efficient.

Third category is of the load following power plants which are used to provide for the intermittent loads. Though peak load plants can also be put to task to supply such loads but they would not prove economic. They for fixed hours when the load is peaking and are shut down during low load hours.

B. Demand Management

Load management implies reduction of load in response to peak load conditions that cannot be dealt with. Non-emergency demand response in the range of 5% to 15% of peak load can provide substantial benefits in reducing the need for additional resources and lowering real-time prices [6]. Above this it has been estimated that if power grids were 5% more efficient, the energy savings would equate permanently eliminating the fuel and greenhouse gas emissions from 53 million cars [7].

As working with traditional grids gives no direct control to utilities to manage customer loads, they perform demand-side management, i.e., “to plan, implement and monitor activities designed to influence customer uses of electricity in ways that will produce desired changes in the utility’s load shape” [8]. Till date these techniques merely dealt with load shaping. Out of the six objectives load shifting and load shedding (peak clipping) is most popular in India.

With grids being aided with “smartness” demand management has adapted Demand response. A DR program is “a tariff or program established to motivate changes in electric use by endues customers in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability is jeopardized” [9]. Under this various techniques like time of use based electricity charges, peak time rebate and direct load control.

As is evident from the techniques implemented under demand response a primary need to implement them would be load forecasting. Only if forecasted data is available can we manipulate the load consumption at that time or imply a demand based pricing.

C. Need of Load Forecasting

It is now clear from the above section that to avoid grid un-stability and to infuse reliability we need to deal with peak intermittent loads. Load based power plant categorization clearly specifies that a variety of power plants are used to deal with the issue. In spite the quick start up these plants boast over the others, no plant can work with zero start-up time. Hence, the need to forecast load in advance which is not only essential to deal with peak load spikes but may also pose an additional advantage as it would give the utility sufficient time to imply intermittent load serving power plants instead of peak load plants as they would prove far more economical.

Demand Management is the technical response of the utilities to the problem of grid congestion or un-stability. The two subcategories have been discussed in brief above. The details mentioned again consent the need of load forecasting to implement demand response and successfully plan demand management techniques.

Not only this load forecasting is also essential to plan and operate utility companies efficiently. Accurate tracking of the peak load is a basic requirement for power systems as electricity cannot be stored efficiently in large quantities and the amount of the power which is generated at any given time must equate with the demand of consumers along withthe grid loss [10].

Load forecasting serves as the platform over which utilities base their decisions regarding the following issues:

- Stabilized and consistent load supply
- Estimation of full allocation
- Realising Operational Constraints
- Analysing equipment limitations
- Requirement to upgrade system
- Managing power resources

D. Classification of Load Forecasting

Predicting futuristic load based on historical data is simply referred to as Load Forecasting. There is no single forecasting category that can satisfy all of the requirements of a utility. Hence, utilities imply different kinds of forecasts for different purposes. With innumerable applications, it is unrealistic to define a forecasting problem for each application. We therefore, design a scientific approach to classifying the load forecasting problems. The classification not only depends upon the needs of utilities, but also on other factors like area, type of consumer etc. Based on the time horizon forecasted upon, we can classify load forecasting into the following three groups [11]:

- Short term load forecasting- time horizon ranging from one day to two weeks.
- Medium term load forecasting-two weeks to three years.

– Long term load forecasting- ranging from three years to fifty years.

As is clear from the above discussion each category has its own features and are thus, suitable for different perspectives. In novel times Short term load forecasting is the most used technique of all.

E. Short Term Load Forecasting (STLF)

Till the last century, statistical techniques, such as regression analysis and time series analysis, were applied to STLF. Then with the emergence of computers power industry went through major structural and technical change, which made accurate short term load forecasts even more critical. This was the time when Artificial Intelligence (AI) became one of the hottest terms in the scientific community, resulting in hundreds of research papers based on AI approach.

The models based on AI techniques, such as artificial neural network (ANN), fuzzy logic, and support vector machine, were black-box models that appealed to organizations which wanted to work less with on the knowledge base for forecasting. Though the classical methods such as the similar day method, and statistical techniques such as multiple linear regression were still not obsolete. They were now combined with AI techniques to produce even better results. This brought in the concept of Hybrid models which reign the industry today.

F. Artificial Neural Network Based STLF

The ANNs are being extensively used for load forecasting from the late twentieth century. ANN is a soft computing technique which does not require the forecaster to provide detailed modelling of the underlying physical system. It simply learns the patterns from historical data and constructs a mapping between the input variables and the electricity demand which is then adopted for prediction. A number of learning algorithms have been utilized for load forecasting applications, such as back propagation [12], Hopfield, Boltzmann machine, among which the most popular one is back propagation. Researchers have been also reported fairly good results with ANN models [13], though many of them were hybrid in nature.

III. CASE STUDY

In this section we shall presenta case study which would confirm the utility of load forecasting as a technique in maintaining grid stability and enhancing grid reliability. Let us begin with the data utilized shown in figure 2.

As we have already discussed that load forecasting is the predicting of futuristic load. To facilitate this past load data is studied to:

– Analyse the trend and implement as in case of similar day approach of STLF
– Study the load with reference to the factors which effect it enabling the formulation of functions implemented for STLF, as is the case with regression techniques.
– Or simply feed in the data as an input to the network upon which it trains

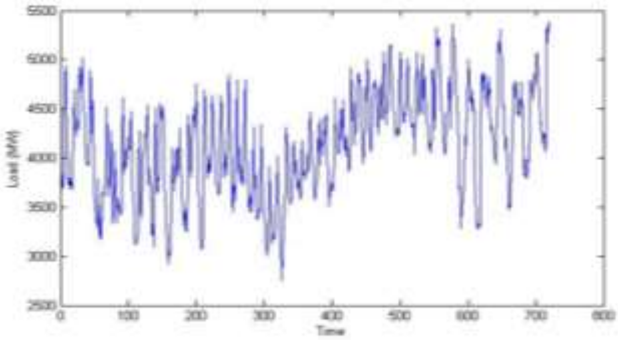

Fig. 2: Load Time Series

In this model where we utilize ANN, data is utilized by the network for training without any specific prior knowledge of the data. The raw data has been taken from the website of NRLDC where it has been mentioned in slots of fifteen. The data has been processed to obtain average hourly load data which has been used in this modelling.This has been simply used by the model to train itself. The training algorithm utilised in the model is Back Propagation. After the model has been trained with the monthly data of the month of April i.e. from 1st april to 30th april, the trained network is used to predict the data of 1st May. This data has then been compared with the actual load of 1st may and error has been found.

IV. RESULTS

Figure 3. shown below presents the load forecast compared with the actual data of 1st May. Green line graph plots the actual data whereas blue colored data represents the load which has been forecasted by the ANN based STLF model used by us. Figure 4. shows the load predicted along with the forecasted on in per unit values.

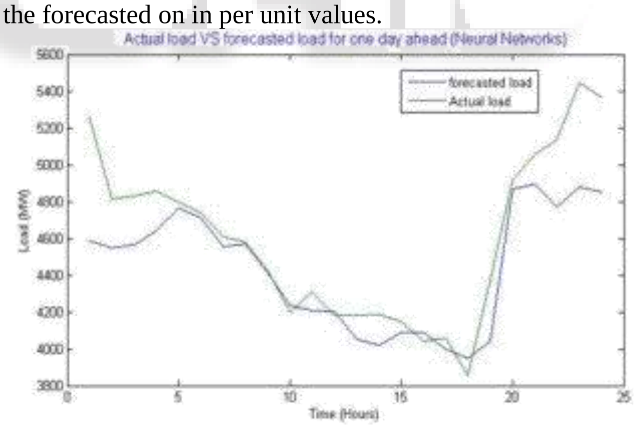

Fig. 3: Actual Vs Forecasted load (MW)

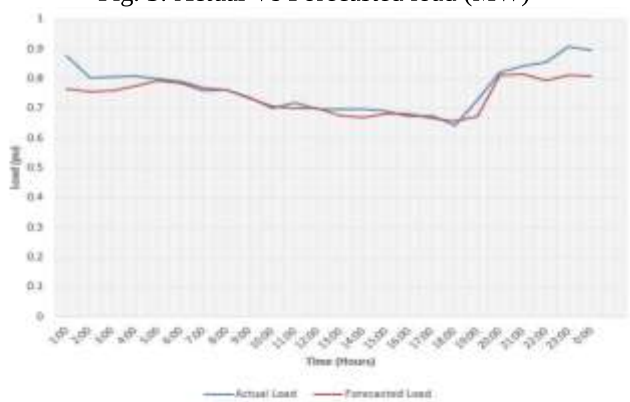

Fig. 4: Actual vs. Forecasted load (per unit values)

V. CONCLUSION

In this paper, load forecasting is adapted in the power system to enhance its reliability. The case study implemented is that of Uttar Pradesh state for the month of May and April. While training is done with the 30 day data of the April month, forecasting done is of the 1st May which is then compared with the actual data available of the sameday. The load distribution and re-distribution between different power systems holds chances of optimization of the generated power. Thus, the influence f forecasting on load management can be understood. The simulation results compare the forecasted data with the actual one. The achievement of optimization has been successful since the MAPE found is 5.748%, which signifies that the off base load periods could be detected to reasonable limits with the help of the forecasting tool, as is also evident from the simulation graph and the graph for per unit load. This shall give sufficient time and resources to the utilities to implement various load management techniques guarding the stability of the grid.

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