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Electric Load Forecasting Using Genetic Algorithm – A Review

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Abstract: *Many real-world problems from operations research and management science are very complex in nature and quite hard to solve by conventional optimization techniques. So, intelligent solutions based on genetic algorithm (GA), to solve these complicated practical problems in various sectors are becoming more and more widespread nowadays. GAs are being developed and deployed worldwide in myriad applications, mainly because of their symbolic reasoning, flexibility and explanation capabilities.*

This paper provides an overview of GAs, as well as their current use in the field of electric load forecasting. The types of GA are outlined, leading to a discussion of the various types and parameters of load forecasting. The paper concludes by sharing thoughts and estimations on GA for load forecasting for future prospects in this area. This review reveals that although still regarded as a novel methodology, GA technologies are shown to have matured to the point of offering real practical benefits in many of their applications.

Keywords: *Load Forecasting, GA, Types of Load Forecasting.*

I. INTRODUCTION

Load forecasting plays an important role in power system planning, operation and control. Forecasting is the study to estimate active loads ahead of actual load occurrence. Planning and operational applications of load forecasting requires a certain 'lead time' also called forecasting intervals. Accurate models for electric power load forecasting are essential to the operation and planning of a utility company. Load forecasting helps an electric utility to make important decisions including decisions on purchasing and generating electric power, load switching, and infrastructure development [1]. Load forecasts are extremely important for energy suppliers, and other participants in electric energy generation, transmission, distribution, and markets. The forecasts for different time horizons are important for different operations within a utility company.

The standard back propagation training-based rules can be used to solve a variety of load forecasting problems. However, as problem complexity increases, their performance falls rapidly. Other drawbacks include issues like: long training period, single point search, scaling, initial parameters dependence etc. However, genetic algorithm (GA) is regarded as an alternative approach. This technique was initially discovered in the mid-1970s at University of Michigan by John Holland. The main idea was to design artificial systems retaining the robustness and adoption properties of natural systems[2]. Since the inception, these methodologies were then further improved by other researchers and are now widely used in various fields (business, science, engineering etc) to solve a variety of optimization problems that lie outside the scope of the standard optimization toolbox.

GA mimics the biological processes to perform a random search in a defined N-dimensional possible set of solutions. For an optimization problem, one needs to search and find the best solution in a given search space. The idea behind the GA's principle is inspired by Darwin's theory of evolution (survival of the fittest).

II. CONVENTIONAL OPTIMIZATION VERSUS GA

GA differs considerably from conventional search and optimization techniques. The most notable and important differences are (Goldberg, 1989 and Maifeld et al., 1994):

1. GAs do not require derivative information or other auxiliary knowledge but use an objective function instead.
2. GAs implement a parallel search in a population, not single point [3]
3. GA use probabilistic transition rules, not deterministic ones.

4. Except in real-value representations, GAs work on encoding of the parameter set rather than parameters themselves.

III. FACTORS AFFECTING LOAD FORECASTING

Generally, the load of an electric utility is composed of very different consumption units. A large part of the electricity is consumed by industrial activities and another part is used by private people in forms of heating, lighting, cooking, laundry, etc. Also many services offered by society demand electricity, for example street lighting, railway traffic etc.

Factors affecting the load depend on the particular consumption unit[4]. The industrial load is usually mostly determined by the level of the production. The load is often quite steady, and it is possible to estimate its dependency on different production levels. However, from the point of view of the utility selling electricity, the industrial units usually add uncertainty in the forecasts. The problem is the possibility of unexpected events, like machine breakdowns or strikes, which can cause large unpredictable disturbances in the load level.

In the case of private people, the factors determining the load are much more difficult to define. Each person behaves in his own individual way, and human psychology is involved in each consumption decision. Many social and behavioral factors can be found. For example, big events, holidays, even TV-programs, affect the load. The weather is the most important individual factor, the reason largely being the electric heating of houses, which becomes more intensive as the temperature drops.

As a large part of the consumption is due to private people and other small electricity customers, the usual approach in load forecasting is to concentrate on the aggregate load of the whole utility. This reduces the number of factors that can be taken into account, the most important being:

- In the short run, the meteorological conditions cause large variation in this aggregated load. In addition to the temperature, also wind speed, cloud cover, and humidity have an influence [5].
- In the long run, the economic and demographic factors play the most important role in determining the evolution of the electricity demand.
- From the point of view of forecasting, the time factors are essential. By these, various seasonal effects and cyclical behaviors (daily and weekly rhythms) as well as occurrences of legal and religious holidays are meant.

The other factors causing disturbances can be classified as random factors. These are usually small in the case of individual consumers, although large social events and popular TV-programs add uncertainty in the forecasts. Industrial units, on the other hand, can cause relatively large disturbances.

IV. CLASSIFICATION OF LOAD FORECASTING METHODS

In terms of lead time, load forecasting methods are divided into four main categories as listed below:

4.1 Very short-term load forecasting (VSTLF)

It is used for lead time from few seconds to few minutes. In VSTLF instead of modeling relationships between load, time, weather conditions and other load affecting factors we have to focus on extrapolating the recently observed load pattern to the nearest future. Methods for very short-term load forecasting are not so numerous. Some reported techniques include first or second order polynomial extrapolation, autoregressive and autoregressive moving average models, and artificial neural networks. VSTLF is used in prediction of generation, distribution schedules, contingency analysis for system security etc.

4.2 Short-term load forecasting (STLF)

It is used for lead time from few minutes to few hours. For short-term load forecasting several factors should be considered, such as time factors, weather data, and possible customers' classes. Short-term load forecasting plays a vital role in system operations and is the main source of information for all daily and weekly operations concerning generation commitment and scheduling. STLF is also important for the economic and reliable operation of the power system. In order to achieve high forecasting accuracy and speed, it is required to know the factors that affect the load. Some of these factors are: the type and time of day, the weather conditions of the forecasting area, the season, etc. Since most days have different load profiles, it is necessary to have a day type. Time of the day is an important factor in short term load forecasting. It is required to know the forecasting time of the day because the level of demand at any time of the day is different. Therefore, the relationships between these factors and the load demand need to be determined so that the forecasts may be as accurate as possible. STLF is generally used for allocation of spinning reserve, operational planning and unit commitment, maintenance scheduling [6].

4.3 Mid-term load forecasting (MTLF)

It is used for lead time from a few days to a few weeks. MTLF is used for prediction load in for seasonal changes such as peak-summer, winter.

4.4 Long-term load forecasting (LTLF)

It is used for lead time from a few months to few years. The medium and long-term forecasts take into account the historical load and weather data, the number of customers in different categories, the appliances in the area and their characteristics including age, the economic and demographic data and their forecasts, the appliance sales data, and other factors. LTLF is used for planning generation growth.

Table 1.Different Types of Load Forecasting

Sr. No.	Type of Forecast	Lead Time	Application
1.	Very Short Term	Few Minutes	Generation, distribution schedules, contingency analysis for system security
2.	Short Term	Few Hours	Allocation of spinning reserve, operational planning and unit commitment, maintenance scheduling
3.	Mid Term	Few Days	Planning for seasonal peak-summer, Winter
4.	Long Term	Few Months	Planning generation growth

V. How Does GA Works?

The algorithm is commenced with a search space containing set of solutions (or chromosomes) called population. Like its counterpart in nature, Chromosomes from one population are chosen based on fitness and then combined to form new generation. The best fit individuals are more likely to be selected and subsequently reproduce in the next generation. This approach is encouraged by a hope that the new population will be better than the old one. These procedures are carried out repeatedly until some pre-determined stopping conditions (such as generation, time limits) are met. Like its counterpart in biology, this process requires some genetic operators such recombination, crossover, and mutation [7]. To implement a genetic based search, one needs to define the objective function to be optimized. Strictly speaking, the objective function can be viewed as the input to the algorithm. This function is primarily intended to provide a measure of how individuals have performed in the problem domain. Depending on the optimization goal, most fit elements in case of a maximization problem would ideally have the largest numerical values. The process of a GA is shown by following flowchart:

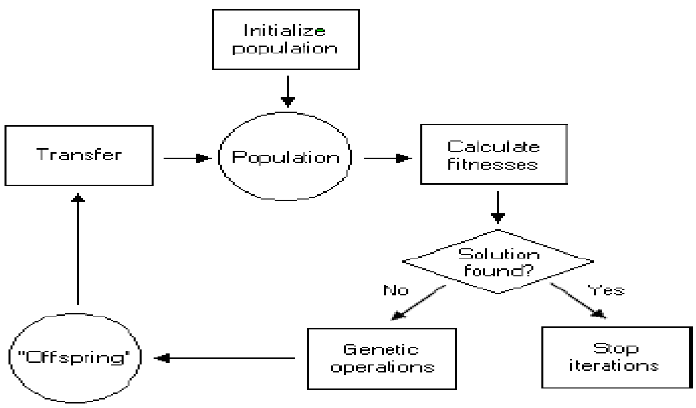


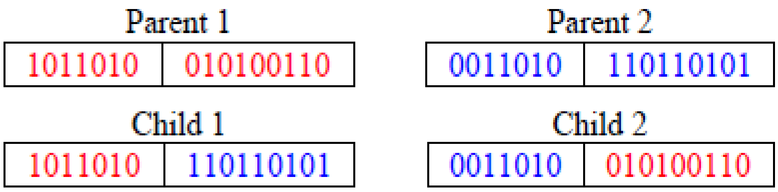
Fig. 1 Flow Chart of GA Process

5.1 Selection:

There are many different types of selection, this paper covers the most common type - roulette wheel selection. In roulette wheel selection, individuals are given a probability of being selected that is directly proportionate to their fitness. Two individuals are then chosen randomly based on these probabilities and produce offspring.

5.2 Crossover:

After selecting individuals, how these individuals produce offspring with them? The most common solution is something called crossover, and while there are many different kinds of crossover, the most common type is single point crossover. In single point crossover, choose a locus at which you swap the remaining alleles from on parent to the other. This is complex and is best understood visually.



As the figure shows, the children take one section of the chromosome from each parent. The point at which the chromosome is broken depends on the randomly selected crossover point. This particular method is called single point crossover because only one crossover point exists. Sometimes only child 1 or child 2 is created, but oftentimes both offspring are created and put into the new population. Crossover does not always occur, however. Sometimes, based on a set probability, no crossover occurs and the parents are copied directly to the new population. The probability of crossover occurring is usually 60% to 70% [8].

5.3 Mutation:

After selection and crossover, we have a new population full of individuals. Some are directly copied, and others are produced by crossover. In order to ensure that the individuals are not all exactly the same, system allow for a small chance of mutation. The system loop through all the alleles of all the individuals, and if that allele is selected for mutation, system can either change it by a small amount or replace it with a new value. The probability of mutation is usually between 1 and 2 tenths of a percent. A view of mutation is shown below.

Before: 1101101001101110

After: 1101100001101110

As we see that, mutation is fairly simple. It just changes the selected alleles based on what you feel is necessary and move on. Mutation is, however, vital to ensuring genetic diversity within the population [9].

VI. DIFFERENT ALGORITHMS OF GA

6.1 Greedy Strategy Algorithm:

The greedy algorithm, always takes the best immediate, or local, solution while finding an answer. Greedy algorithms find the overall, or globally, optimal solution for some optimization problems, but may find less-than-optimal solutions for some instances of other problems. In general, we use greedy algorithms for optimization problems [10].

Optimization problems, by their very nature, always require an overall solution that is globally optimal. The best solution is necessary. Imagine the following decision tree scenario: Greedy walks through the following tree, beginning from the root node, and at each node looks around and picks the local optimum. As you can see in figure below, there are always two routes to take; it picks the one that currently looks best.

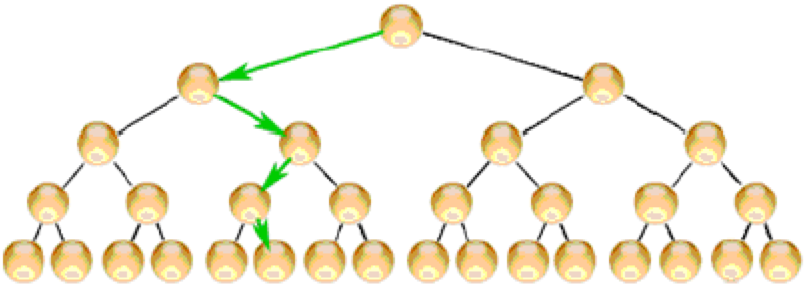


Fig. 2. Greedy Decision Based on Local Optimum Algorithm

However, walking through the tree using the aforementioned mentality does not guarantee that you end up with a globally optimal solution despite the fact that you have always picked the "local best" route on each level. You cannot be absolutely sure that this leads to the overall best solution. This is why greedy often gives the optimal solution, but not always.

6.2 Dynamic Programming:

By its very nature, is the most appropriate algorithm for those problems that have the aforementioned complex structure. As we know that, the greedy algorithm wouldn't suffice because its approach works only until the second type of tree comes in. But this combination is the specialty of dynamic programming. The dynamic programming technique can be approached in two distinctive ways: top-down and bottom-up. The former is an advanced recursion combined with memorization, since it means breaking the problem into all of its sub-problems, solved them, and storing the solutions, assuming we're going to re-use them. The latter predicts the sub-problems that might be required and solves them in advance; this is the way it tries to build the final solution from the sub-problems' solutions. This approach requires more resources (stack space).

All in all, the dynamic programming technique is based on the optimality principle. It starts from the trivial but optimal solutions of the sub-problems; moving further, it builds the final solution. However, it's really important that the algorithm stores the solution of each sub-problem; we use an array for this purpose. The array can be multi-dimensional depending on how many parameters describe the solution(s).

Branch and Bound: It is an algorithm technique that is often implemented for finding the optimal solutions in case of optimization problems; it is mainly used for combinatorial and discrete global optimizations of problems. In a nutshell, we opt for this technique when the domain of possible candidates is way too large and all of the other algorithms fail. This technique is based on the en masse elimination of the candidates [11].

Greedy and Dynamic Programming are methods for solving optimization problems. Greedy algorithms are usually more efficient than Dynamic Programming solutions. However, often you need to use dynamic programming since the optimal solution cannot be guaranteed by a greedy algorithm. Dynamic Programming provides efficient solutions for some problems for which a brute force approach would be very slow. To use Dynamic Programming we need only show that the principle of optimality applies to the problem.

VII. Conclusion

Load forecasting plays a dominant part in the economic optimization and secure operation of electric power systems. Load forecasting represents the future generation, transmission and distribution facilities. Any substantial deviation in the forecast will result in either overbuilding of supply facilities, or curtailment of customer demand. The confidence levels associated with classical forecasting techniques, when applied to forecasting problem in mature and stable utilities are likely to be similar to those of dynamic and fast growing utilities. Different methods of load forecasting are defined in this paper. All of these methods can forecast the load of the power system, but the amount of previous data and such variable which they need to forecast, make them different in accuracy from area to area. Finally, for load forecasting, we should know the power system in details, and after that we can select the best method for the specified power system.

Traditional methods, such as time series, regression models etc. are used in most of the countries, because of their reliable result.

Neural networks can solve nonlinear problems, and because of nonlinear behavior of load, so they can be useful for load forecasting.

Genetic algorithm can forecast the load, when we have a lot amount of different variables and we want to find the best solution to follow the future load. In this paper different techniques of genetic algorithm are defined and we can use these techniques depending on the variable and efficiency of the technique.

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