Soft-Computing for Power Systems

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1. Abstract

This is a brief survey of soft-computing applications developed for power systems, using a software development environment ECANSE. The presented applications include the load forecast, neural filtering, load estimation, and monitoring of a water dam.

Keywords: soft-computing, neural networks, ECANSE®, applications for power systems

2. Introduction

Potential applications of **soft-computing** technologies for **power systems** are in the following areas: load forecasting, alarm handling, fault diagnosis, power system static and dynamic security assessment, and power system operational planning [3]. We have developed several successful **industrial applications** developed by the system ECANSE.

A brief introduction of ECANSE system is in Ch.2. A survey of the soft-computing applications for power systems is in Ch.3, and Ch.4 sketches also some other Ecanse applications. General perspectives for application of Ecanse for development of industrial applications are in conclusions.

3. Soft-Computing Tool ECANSE

A soft computing studio **ECANSE® (Environment for Computer Aided Neural Software Engineering)** [1] was used for development of the mentioned applications as a very powerful tool. ECANSE allows *flexible* and *visual programming* of complex systems combining and interconnecting the sets of defined basic modules. The modules provided by ECANSE range from data interfaces, signal generators, mathematical and statistical functions, script language, and graphical displays to new soft-computing technologies including **Neural Networks**, **Fuzzy Logic**, and **Genetic Algorithms**. Also new algorithms can be added to ECANSE and they inherit all the generic mechanisms provided by ECANSE. The flexibility of ECANSE provides an ideal framework for rapid prototyping and evolutionary system development. Owing to this high development potential, the tool is suitable for a large spectrum of application domains like *electrical engineering, finance, space engineering, environment preservation, chemical engineering, signal processing, mechanical engineering, biology, marketing, and variety of research and development* projects.

4. APPLICATIONS FOR POWER SYSTEMS

A brief description of some application projects for power systems is in this chapter. All of them are already implemented at our customers several times and running in real-life processes.

4.1. Load Forecast

A main concern in electric power distribution is to predict the future electrical load requirements for a given region so that the power generation can be planned optimally with minimum loss and cost. The load required by a region is affected by **factors** including the *general trend* (economic factors), *time dependent factors* (season, holidays), *weather*, and *special events* (strike, special television program). Load forecasting systems take into account these factors and facilitate the management of energy reserves and operation of the power generators. The accuracy of the forecast plays an important role in the operating costs of power generation plant. This predicted power system load is the quantity for planning sufficient generation, spinning reserve and standby reserve.

There are different **time horizons** to be considered in the load forecast for power systems. The time horizons rank from few minutes up to several years. The load forecast for few minutes and hours is necessary for immediate adapting of available power to customer requirements. The horizon for few days is for distribution control, fuel planning and small maintenance. The horizon for few months up to two years is for marketing, maintenance, efficiency and fuel planning, and the horizon for few years is for planning of energy production, transmission, distribution, and telecommunication development. According to these basic requirements, we have developed several *types of the load forecasts* for power systems [2]: ultra short term load forecast, short term load forecast, medium term load forecast, and long term load forecast.

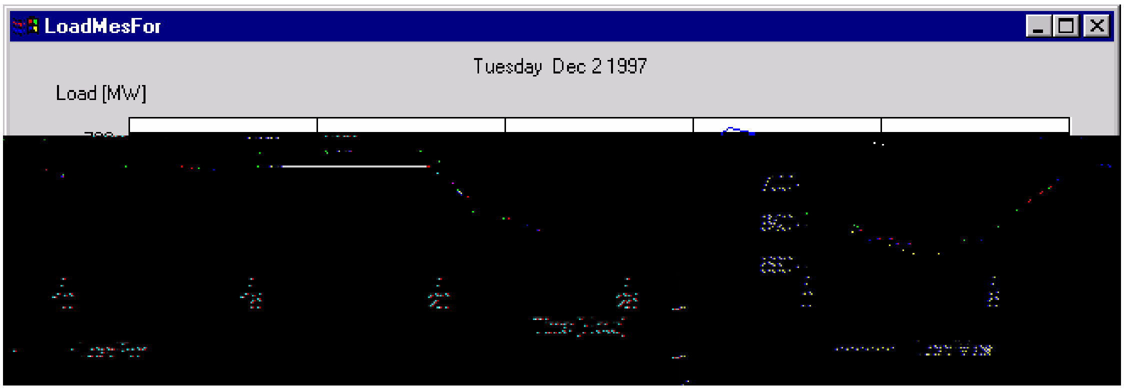


Fig.1 Result samples of STLF

USTLF – Ultra Short Term Load Forecast

USTLF has the parameterizable *time horizon* for few hours with *time step* 3 minutes. This is a very accurate forecast suitable for power control centers. The forecast is adaptable according latest development trends in power requirements.

STLF - Short Term Load Forecast

STLF has the *time horizon* for one or several days up to two weeks. The *time step* of the forecast is one hour, 30 or 15 minutes. This type of the forecast takes into account several influence factors like time factors (seasonal trending, daytype, legal and religious holidays), weather effects (temperature, light intensity, humidity, wind), and special events (shutdown of facilities, TV programs).

The automatic neural network based method in ECANSE, with a modular system architecture, has very high prediction accuracy. Using this method, the mean absolute error of the forecast is between 1 and 2 % (including special days such as public holidays). This type of the forecast generates a typical daily load diagram for control centers.

The daily load diagram is introduced in Fig.1 as a result sample of STLF by testing processing of real data. The testing processing in this context means that it is not the result of the finished project and therefore the accuracy might be still higher. Despite of that, it is possible to see a very small difference between the measured and forecast load for 24 hours.

MTLF - Medium Term Load Forecast

MTLF has a parameterizable *time horizon* from few weeks up to two years with the *time step* one week. The forecast provides the predicted data for the maximum and minimum load, and total energy demand for every week. This type of the forecast is suitable for planning energy exchange contracts, revision periods of power stations and substations, and for planning the application of hydroelectric power stations with reservoir.

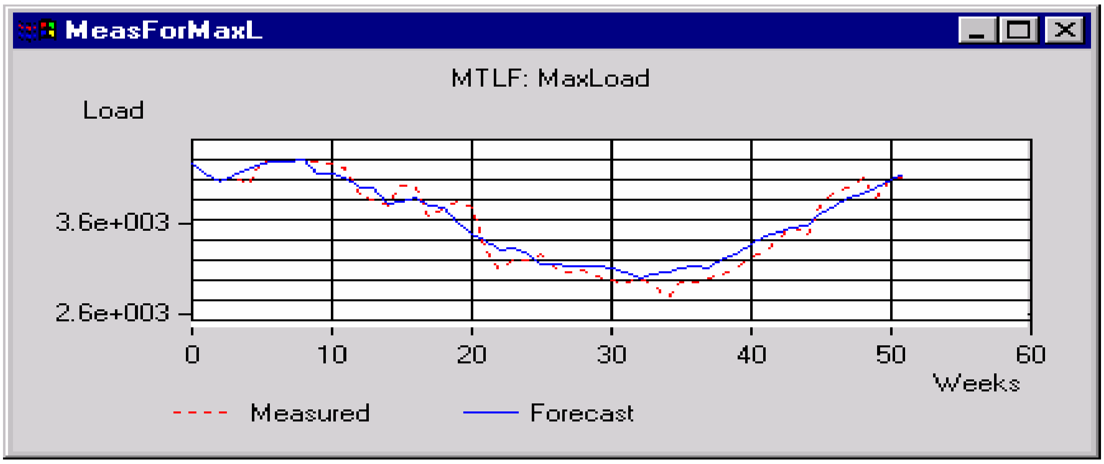
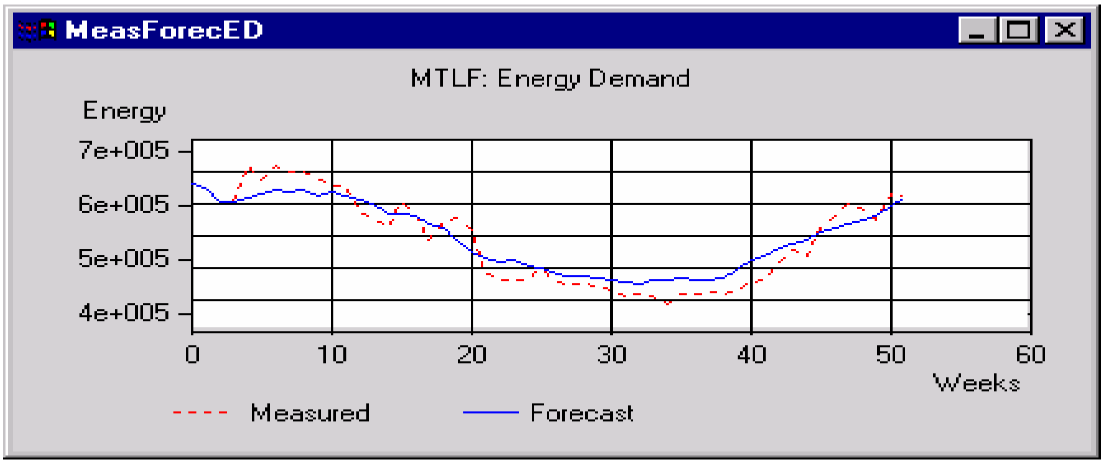


Fig.2 Result samples of MTLF

Result samples of MTLF by testing processing of real data are in Fig.2. The testing processing, again in this context means, that the accuracy of the finished project might be still higher. The measured and forecast values of weekly energy demand [MWh] for one year are in lower part of the figure. In the upper part, there are measured and forecast values of the week maximum load [MW] for the time horizon one year.

LTLF - Long Term Load Forecast

LTLF has a parameterizable *time horizon* from one year up to ten years with the *time step* one year. The forecast provides predicted data for the peak load, and total energy demand for every year. Additional input parameters, which determine the future



development of the predicted ones, are some econometric and demographic variables. This type of the forecast is suitable for the extension planning of the power system and for long term primary energy purchasing.

Finally, we can summarize the basic characteristics of the different types of the load forecast available to our customers. The *forecast time horizon* ranks from two hours up to ten years by the *time step* of the forecast from three minutes up to one year. This is really a broad spectrum of load forecast varieties covering demanding requirements of the electric power systems.

4.2. Neural Filtering in Automatic Generation Control

An electric load varies frequently in area power systems and the power generation has to be adapted continuously to this changing load. This is a task of **Automatic Generation Control** (AGC). The principle objective of AGC is to adapt the power output of defined generators within a prescribed area in response to changes in system *frequency* and/or tieline *loadings* as well as their reference values. This is necessary to be possible to meet the area's obligation to contribute to the system regulation and/or power interchange agreements with other/neighbor utility areas.

The deviations from the area's obligations are defined as the *Area Control Error* (ACE). This signal is introduced to a controller and distributed to generators participating in AGC. The regulation action impacts the economy of energy production. For this reason, unnecessary control movements should be avoided and a quick response of the control is necessary, in a case of disturbances in the system. Usually low-pass filters are used for this purpose to smooth the ACE signal.

An ANN (Artificial Neural Network) model, used as a neural filter, which adapts to different situations by automatic learning [2] can replace a classical low-pass filter. This neural approach reduces the filter performance up to 50% compared to a conventional low-pass filter without any influence on the area's contribution to system regulation and/or interchange agreements.

4.3. Load Estimation

Power utilities are interested in the **instantaneous total load** on the power system. A **precise estimate** of instantaneous load is important for the economical and effective planning of operations as well as load following. These problems are much more topical for power utilities with distributed energy sources and working in the free energy market environment.

In real life, the instantaneous total load is not known and the total can only be determined with a delay of several hours or days. The only available or economically feasible information is the instantaneous load measurements from specific points in the network. However, the deduction of total load from these measurements is not an easy task since the relationship is not known.

This unknown relationship can be "learned" using the historical data by a neural network model providing a precise real-time estimate from the instantaneous load measurements. The real application performs with a mean estimate error of about 1%.

4.4. Monitoring of Water Dam

A **concrete wall of the water dam** is a subject to **deformation** due to various influences. The most important factors are the height of the water level and the temperature. A large dam may be deformed up to several centimeters within a year. In order to assess the security of the dam, it is important to model the *elastic and reversible displacement* of the dam. Comparing measured data to this model can do **monitoring**. In addition, irreversible deformations such as shrinkage and cringing of concrete as well as deformations of the underlying boulder have to be considered in the model during the first years.

Modeling of the dam displacement is developed using an ANN model [2] that is well suited in treating non-linear problems. A Multi Layered Perceptron with error back-propagation learning is applied to model the dam displacement. The neural network based method in ECANSE offers a significant improvement in modeling. Depending on the modeling period, the mean absolute error for the ECANSE based model lies between 0.1% and 1.0%. The quality of the neural monitor has been verified in cooperation with a customer.

5. OTHER APPLICATIONS

Because ECANSE is a universal and powerful development system, there are also several other application projects mentioned briefly in the following.

Nondestructive diagnostics is very important for **machinery, oil-pipelines, gas-pipelines, aviation, nuclear power engineering**, etc. Owing to a huge amount of data to be processed and a continuous scale of values, the diagnostics made even by an expert might be very difficult and error prone. A neural network model developed by ECANSE provides a high accurate solution, high speed of detection process, high reliability, and simple adaptation for new types of error characteristics.

Neural network methods are applied also in **telecommunication** for diagnostics of telecommunication networks and devices, for risk management like fraud detection by telephone cards, and load forecast for telecommunication networks. Interesting results have already been achieved by ECANSE in all these areas.

One of the main concerns in **pollution monitoring** is a prediction of the ground-level ozone concentration for the next 24 hours, for a given region. The forecast results enable to warn people whether the National Ambient Air Quality Standard is exceeded. In comparison to conventional methods, the prediction by ECANSE using neural networks is typically twice more accurate and adaptable on-line.

Very new application of the system ECANSE is **financial forecasting software** called FinCast. This software helps to determine in what direction the financial market will move. It forecasts the direction of a set of share indices and a set of exchange rates using neural networks. FinCast works with Reuters data from Reuters terminals.

6. CONCLUSIONS

We have presented a brief survey of **applications** of soft computing technologies **for power systems**. All these applications have been developed by the **soft-computing studio ECANSE**. Both, the Ecanse system and applications are under an intensive development for their improvement and extension, to be possible to cover a large area of requirements of customers from power systems area and also from different industrial branches.

7. REFERENCES

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