Conf-900143--39

Submitted to the IEEE Nuclear Science Symposium,
January, 1990, San Francisco.

SENSOR VALIDATION IN POWER PLANTS USING ADAPTIVE BACKPROPAGATION NEURAL NETWORK

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CONF-900143--39

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SUMMARY

Signal validation and process monitoring problems in many cases require the prediction of one or more process variables in a system. The feasibility of using neural networks to characterize one variable as a function of other related variables is studied. The Backpropagation Network (BPN) is used to develop "models" of signals from both a commercial power plant and the EBR-II. Several innovations are made in the algorithm, the most significant of which is the progressive adjustment of the sigmoidal threshold function and weight updating terms, thus leading to the designation "Adaptive" Backpropagation Neural Network.

The estimation of system variables is performed traditionally using either physical models or empirical models. The prediction of system variables is important in control systems for validating instrumentation outputs and for process monitoring. The model-based prediction assumes a fixed structure for characterizing steady-state or dynamic relationship among process variables. The applications to large and complex systems require more time in order to get an accurate model. Since our goal is to relate signals in a subsystem of a plant, such a relationship can be developed by using neural network "models" which provide results faster than model-based techniques. Both steady-state and transient behavior can be incorporated into the network during training.

The use of neural networks for signal validation has several advantages. It is not necessary to define a functional form relating a set of process variables. The functional form is implicitly nonlinear. Once the network is fully trained, it has very high ability to interpolate and extrapolate the variables in real-time. The state estimation is less sensitive to measurement noise compared to model-based techniques. The BPN is capable of performing arbitrary mapping from input to output; with BPN it is possible to model a system without knowing the system specifications, black-box approach to modeling. When new information about the system becomes available, the network can be updated without relearning the entire data set. Both steady-state and transient system behavior can be predicted.

FG07-88ER12824

DISCLAIMER

One of the neural networks, called the Backpropagation Network (BPN) has been developed and implemented in a VAX station.

The most important aspect of applying neural networks is the network training. In normal use of neural network parameters that appear in the weight updating and threshold function equations are held constant during the learning period. Our studies have shown that changing these parameters during the learning phase is accelerating the convergence and improving the accuracy. Progressively adjusting the threshold shaping parameter is the most important part of accelerating the convergence and improving the accuracy. The sensitivity of the network can be adjusted by adapting the threshold shaping parameter during training. In the predictive modeling applications the target outputs are set to be within an intermediate range (0.2-0.8) of the operating interval [0-1]. In these cases progressively decreasing the threshold shaping parameter enhances convergence, and improves the prediction accuracy outside the trained domain. For the predictive modeling the value of threshold shaping parameter varied in the range (0.1-0.9). When the target outputs are in the extremities of the BPN operating range, [0-1], adaptively increasing the value of threshold shaping parameter in the range (1-4) speeds the convergence of the algorithm.

Another parameter is the weight updating coefficient. Increasing this coefficient after the initial learning period shows accelerated convergence. The third factor is the momentum term that determines the effect of previous weight changes. This term varies from 0.1 to 1.0. In our applications momentum term in most of the cases was 0.9.

The Backpropagation algorithm has been developed and applied to operational data from a PWR and the EBR-II. Networks are developed for hot leg temperature, steam generator pressure and reactor power using PWR data. Networks for reactor power and control rod position are developed using the EBR-II data. Figure 1 is a comparison of measured and predicted values of reactor power. Control rod positison, core-exit temperature and IHX secondary outlet temperature are the input signals. The standard deviation of the network global error is 0.31%. In this case number of training patterns is 100 and the number of iterations is 80. Number of hidden nodes was kept 50 in all the cases. Various improvements have been made to accelerate the training and increase the accuracy of signal prediction. Progressively adjusting the threshold shaping parameter, leading to the terminology <u>Adaptive</u> Backpropagation Neural Network, is the most significant one. The results are very encouraging, and the use of neural computing for process monitoring, pattern matching and diagnostics are being studied.

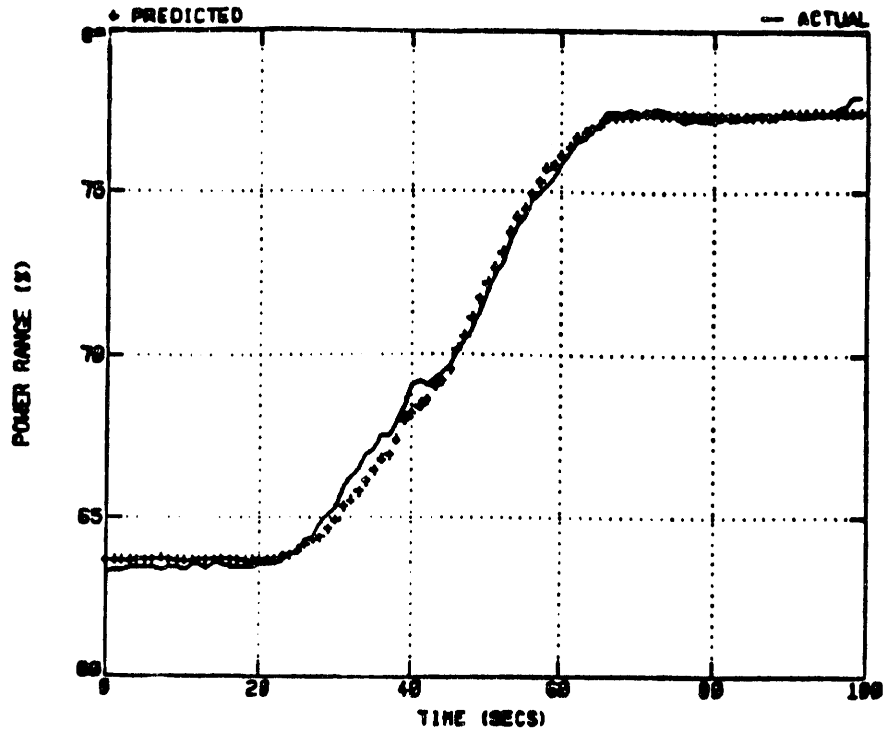

Figure 1a. Comparison of measured (-) and predicted (+) values of reactor power in the EBR-II, for the data used in network training.

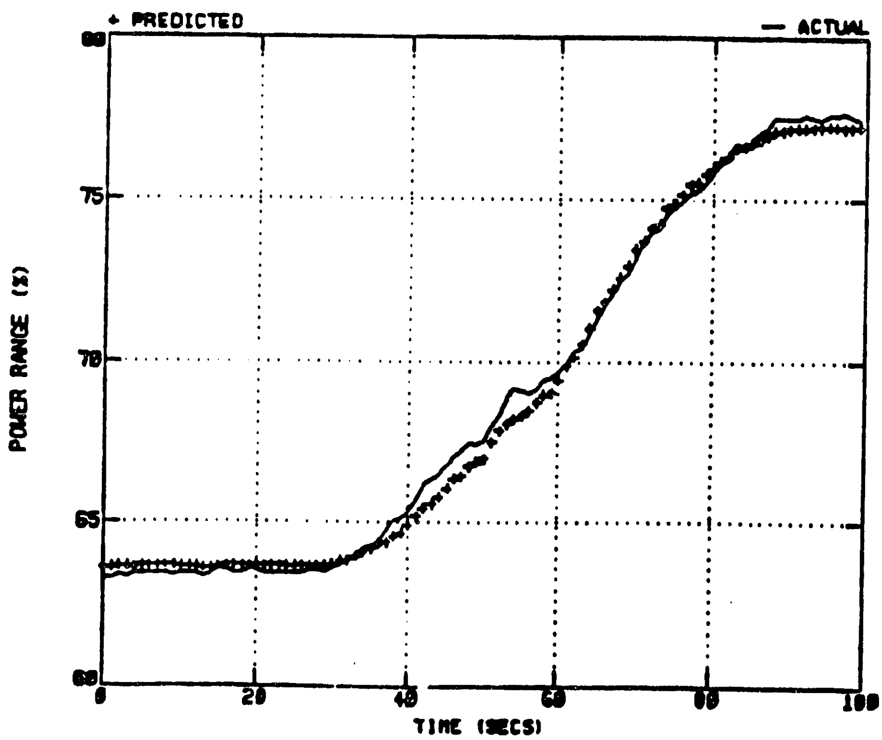

Figure 1b. Comparison of measured (-) and interpolated (+) values of reactor power in the EBR-II. The above network is used to perform the interpolation.

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