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Forecasting Hydroelectric Dam Energy Production Using a Hybrid Ann-Arima Model

FORECASTING HYDROELECTRIC DAM ENERGY PRODUCTION USING A HYBRID ANN-ARIMA MODEL

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In the last several years, particularly during the summer, electric energy and water demands problems have increased in Greece. The massive use of highly consumptive electrical devices (e.g. air conditioners) has led to a substantial increase in energy demand. In addition, the decrease in precipitation due to climate change along with major changes in agricultural practices has increased water demand. These problems impact negatively the economy of Greece because it needs to import electricity from neighboring countries to cover its needs, and because agricultural production is decreased. Innovative use of the existing hydroelectric dams can remedy these problems by increasing energy production and improving water supply efficiency for the various uses.

The purpose of this study is to use new technologies to accurately forecast electric energy production from the hydroelectric dam of Thisavros. This dam is the first from a set of three hydroelectric dams on Nestos River (Thisavros-Platanovrisi-Temenous), in Northern Greece. It belongs to the Public Power Corporation (PPC), has a height of 175 m and produces 426 GWh.

To forecast the hydroelectric energy produced by the dam, a hybrid model was used that combined an Auto-Regressive Integrated Moving Average model (ARIMA) with an Artificial Neural Network (ANN). The combination of the two produces more reliable and accurate results compared to each methodology separately. The datasets used were two time-series; the monthly rainfall in the study area and the mean monthly lake water level of the dam from July 1997 until December 2011. Each time-series had 176 observations.

The ANN was trained by using the monthly rainfall time-series as the input data and the lake water level as the output data. At the end of the training, the ANN was further tested by an independent validation. Next, the ANN was supplied with the expected rainfall values calculated by the ARIMA for the period 2012-2015. Afterwards, the expected lake water level was forecasted.

ARIMA models are constructed as linear functions of past values of the series and/or previous random shocks (or errors). Forecasts are generated under the assumption that the past history can be translated into predictions for the future. The simple non-seasonal ARIMA model has a general form of (p, d, q) where p is the order of the non-seasonal autoregressive term (AR), q is the order of the non-seasonal moving average term (MA) and d is the order of the non-

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seasonal differencing. In this study, the SPSS Statistics v.19 was used to create a (1, 1, 2) model. This model was selected among others because it produced the best correlation coefficient (R^2), minimum Mean Absolute Percentage Errors (MAPE) and Root Mean Square Errors (RMSE).

The ANN used was a Nonlinear Autoregressive with External Input (NARX model). This model relates the current value of a time-series to current and past values of the driving (exogenous) series. The driving series in our case is the monthly rainfall while the current values that are related to the driving series are the mean monthly lake water level of the dam. The model also contains an error term which relates to the fact that knowledge of the other terms will not enable the exact prediction of the current value of the time-series. The ANN used in this research was created using the nntool of MATLAB 2011 and consisted of 20 hidden neurons, two number of delays and used the sigmoid function as the transfer function. The input data were divided randomly for: network training (70% of the data), network validation (15% of the data) and network testing (15% of the data). This division is crucial because the network must generalize into various inputs. Additionally to produce better results the input parameters where normalized into values [0, 1]. The results produced by the ANN where very good with an R^2=0.8164 for the training, R^2=0.6392 for the validation and R^2=0.7012 for the testing, when all results are combined.

The predictions of the lake water level by the hybrid ANN-ARIMA model for the years 2012-2015 are presented in Figure 1. The results clearly indicate that lake water levels will be below average for the next 4 years. This will have serious implications since the energy produced by the plant will decrease and the water available for agriculture will also be substantially less. The current management plans will need to be modified based on the below average water level conditions. Overall, this ANN-ARIMA hybrid model will provide the appropriate authorities a new tool to improve the efficiency in the management of the hydroelectric dams in Greece.

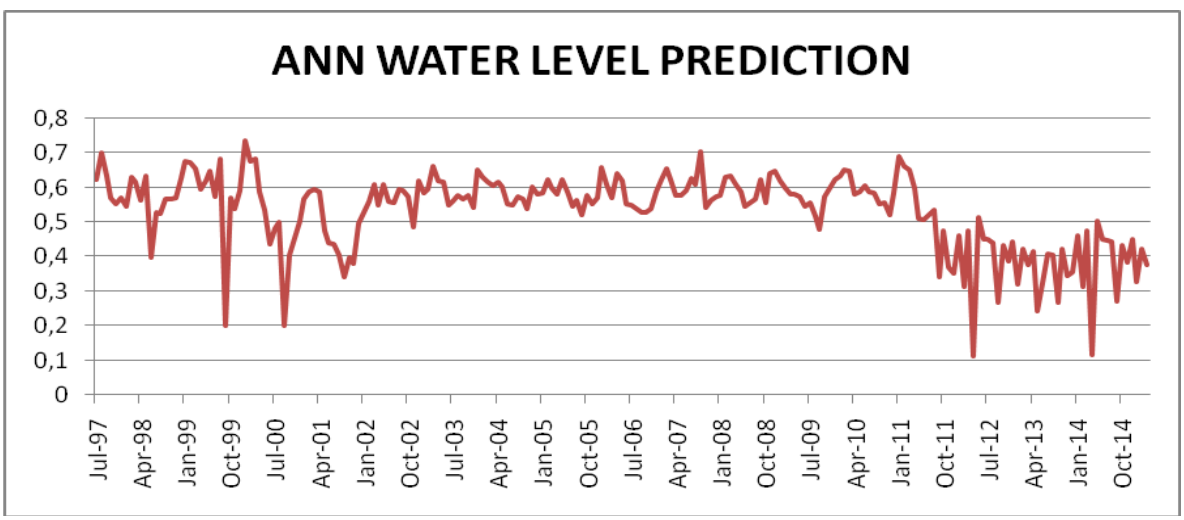

Figure 1 Prediction of the water level produced by the ANN for the years 2012-2015. The water level (x axis) output of the model was normalized in the [0, 1] range in order to produce better results.