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MAGNET AC ANALYSIS OF A TAIWAN LIGHT SOURCE BOOSTER *

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Abstract

The Response Surface Methodology (RSM), is used to study the optimization process of magnet AC in the booster for Taiwan Light Source (TLS) in National Synchrotron Radiation Research Center (NSRRC). A study model was constructed based on the Artificial Neural Network (ANN) theory. The theoretical model and optimization procedure were both implemented to evaluate the model. The details of the study will be reported in this paper.

INTRODUCTION

This study endeavored to improve the electron beam efficiency of magnet AC in the booster for Taiwan Light Source (TLS) in National Synchrotron Radiation Research Center (NSRRC).Using the basic theory of response surface methodology (RSM). Employing the artificial neural network (ANN)-constructed experiment design software known as Computer-Aided Formula Engineering (CAFE) [3] to analyze and optimize the parameters of the electron beam efficiency, we aimed to identify the main influencing parameters and, through optimization, develop a parameter adjustment program that maximizes the efficiency of the electron beam.

RESEARCH PROCESS

Artificial Neural Network

ANNs are construction methods for nonlinear models. Among which, back-propagation networks (BPNs) are currently the most representative and commonly applied of the ANN learning models [1] [2].

Data Collection

The magnet AC has major impact on electron injection working tune and beam phase margin. The equipment that affects the electron beam efficiency of magnet AC in the booster includes. Dipole magnets AC(BDACP), Focusing quadrupole magnets AC(BFQAC), Defocusing quadrupole magnets AC(BDQAC),Focusing quadrupole magnets time delay (BSTFQ) , Defocusing quadrupole magnets time delay (BSTDQ) , Each device has a tuning knob for the magnet current and time delay settings with 5 values. These values formed the quality impact factors in this study (Fig. 1).[6] The electron beam efficiency is determined by the size of the electric current detected by current transformers （Current Transformer B10DC) Using MATLAB programming to establish the effective operating range of each quality factor, we employed a random number setting every minute to intercept different settings and response values.[4,5] In total, 789 pieces of data were obtained.

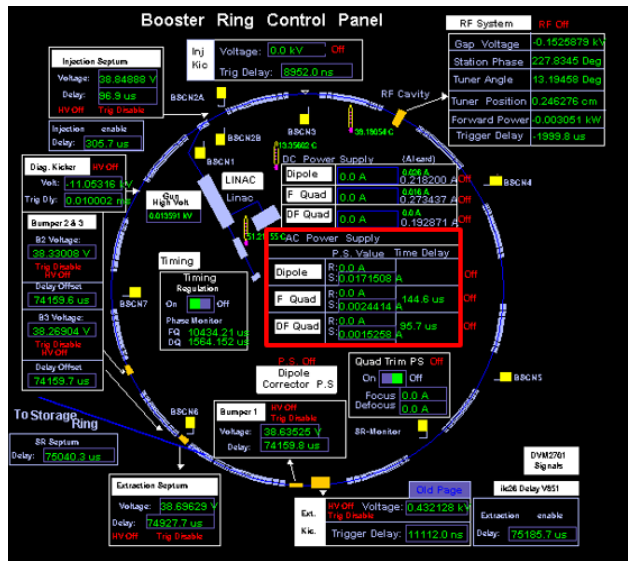

Figure 1: Booster magnet [6].

Experimental Analysis

After calculating the ANN model construction, we obtained the “cross-validation” error convergence curve, as shown in Fig. 2. The representative model construction was ideal because they appear to converge after approximately 600 computations.

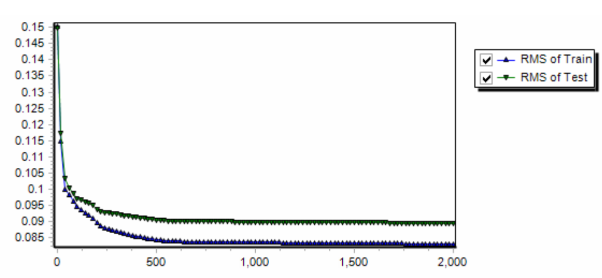

Figure 2: The “cross-validation” error convergence curve.

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The "cross validation" scatter plots for the training and test samples are shown in Figs. 3 and 4, respectively. The predictive ability of the representative model was also ideal.

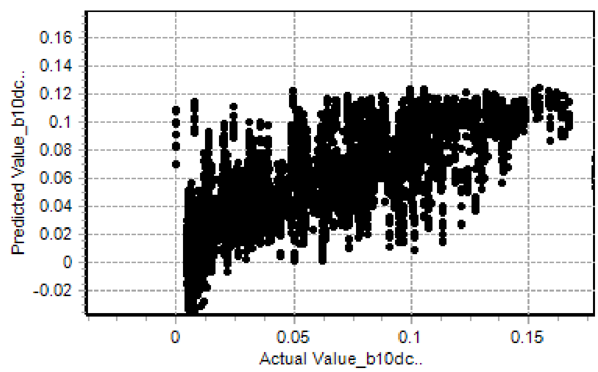

Figure 3: The "cross-validation" scatter plot of the training samples.

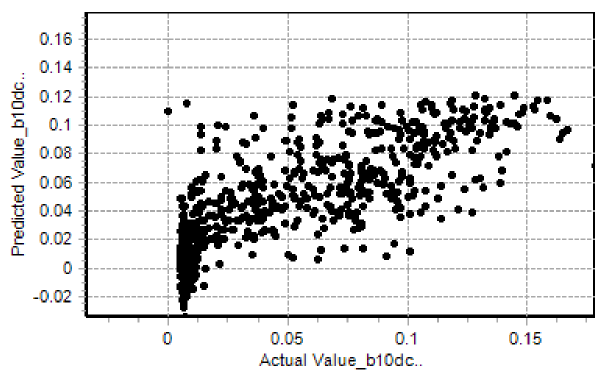

Figure 4: The "cross-validation" scatter plot of the test samples.

Analysis of the experimental results included sensitivity analysis and influence line analysis. Sensitivity analysis was conducted using weight value analysis graphs, and influence line analysis was conducted using a main effect diagram with status. The sensitivity analysis results revealed the significance of quality factors, as shown in Figs. 5 and 6. We found that all quality factors had the highest significance.

- The weight of the dipole magnets AC(BDACP) current setting was 0.226.
- The weight of the focusing quadrupole magnets AC(BFQAC) current setting was 0.258
- The weight of the defocusing quadrupole magnets AC(BDQAC) current setting was 0.207
- The weight of the focusing quadrupole magnets time delay (BSTFQ) setting was 0.232
- The weight of the Defocusing quadrupole magnets time delay (BSTDQ) setting was 0.215

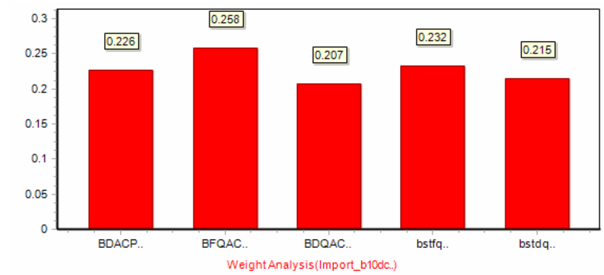

Figure 5: A bar graph of Y significance.

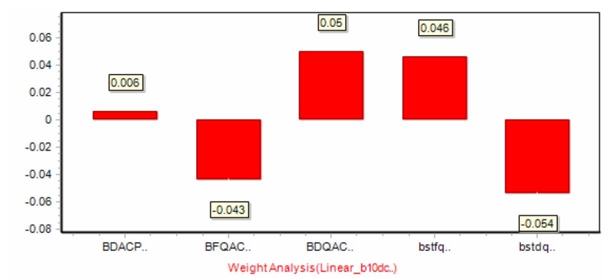

Figure 6: A bar graph of Y linear sensitivity.

Analysis of the results clearly showed the curved figure and significance of the quality factors (Fig. 7).

- Dipole magnets AC(BDACP) current setting
- Focusing quadrupole magnets AC(BFQAC) current setting
- Defocusing quadrupole magnets AC(BDQAC) current setting
- Focusing quadrupole magnets time delay (BSTFQ) setting
- Defocusing quadrupole magnets time delay (BSTDQ) setting

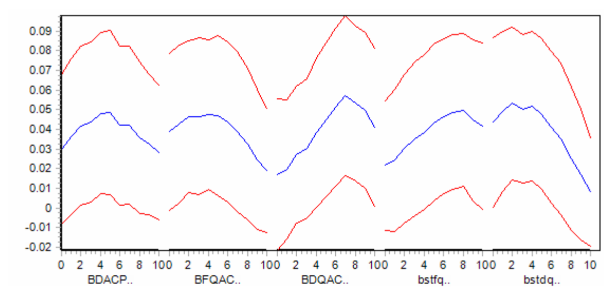

Figure 7: Status effect diagram.

After programming the quality factors for optimization, the ANN-optimized parameter solution was found. The ANN-optimized parameter solution is shown in Fig. 8. The electron beam efficiency was estimated as 0.1793(B10DC).

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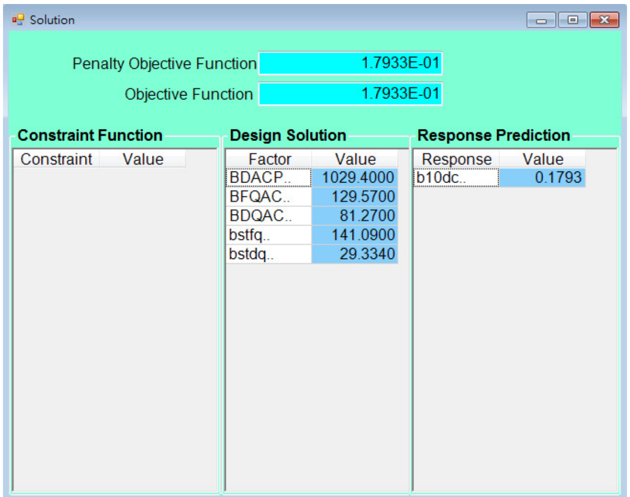

Figure 8: Optimal solution settings for ANN-optimized quality factors.

CONCLUSION

This study endeavoured to improve the electron beam efficiency of magnet AC in the booster for Taiwan Light Source (TLS) in National Synchrotron Radiation Research Center (NSRRC). Using BPN for analysis and the cross-validation experiment method to effectively estimate the generalization error, we developed an electron beam efficiency estimation method using beam tuning knobs of magnet AC as the variables. The expected efficiency performance of electron beam (B10DC) is 0.1793 through analysis. The current operating parameter average setting is approximate 0.1695. Only 1% improvement can be achieved excluding the prediction error. Current operating parameters had been set nearby to the optimum value.

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