A GUN TO LINAC OPERATION ANALYSIS OF THE TAIWAN LIGHT SOURCE INJECTOR

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Abstract

A response surface methodology (RSM) was used to study the gun to linac optimization process of the Taiwan Light Source (TLS) injector at the National Synchrotron Radiation Research Center (NSRRC). A study model, based on artificial neural network (ANN) theory, which uses electron beam tuning knobs as variables, was constructed. An optimization procedure was developed by designating electron beam efficiency as the objective function and the selected beam tuning knobs as the variables. The theoretical model and optimization procedure were both implemented to evaluate the model. By properly applying the constructed optimization procedure, the beam efficiency was improved. This report outlines the details of the gun to linac optimization process experiment.

INTRODUCTION

Using the basic theory of response surface methodology (RSM), this study aimed to improve the gun to linac electron beam efficiency of the National Synchrotron Radiation Research Center (NSRRC) injector. Artificial neural network (ANN) design software, known as computer-aided formula engineering (CAFE) [1], was used to analyze and optimize the parameters of the electron beam efficiency. We aimed to identify the main influential parameters and, through optimization, develop a parameter adjustment program that maximizes the efficiency of the electron beam.

RESEARCH PROCESS

Artificial Neural Network

ANN is a construction method intended for nonlinear models. Currently, back-propagation networks (BPNs) are the most well-known and commonly applied of the ANN learning models [2] [3].

Data Collection

The equipment that affects gun to linac electron beam efficiency at the injector includes Quadrupole Lens 1, Quadrupole Lens 2, Quadrupole Lens 3, Corrector GTLHC1, Corrector GTLVC1, and a chopper. Each device has a tuning knob for the magnet current settings with 6 values, which formed the quality impact factors in this study (Fig. 1) [4]. Electron beam efficiency is determined according to the size of the electric currents detected by current transformers (CTs) (Fig. 2). 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 [5]. In total, 287 pieces of data were obtained.

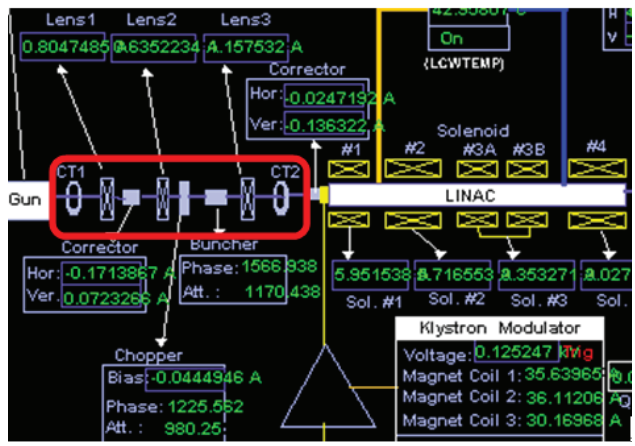

Figure 1: The quality impact factors [4].

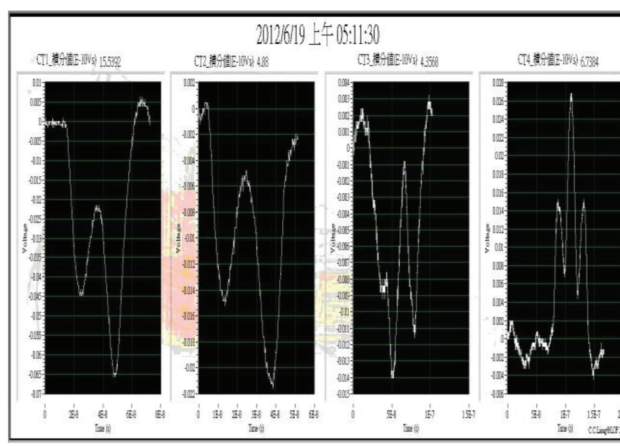

Figure 2: Current transformers.

Experimental analysis

After calculating the ANN model construction, we obtained the “cross-validation” error convergence curve, as shown in Fig. 3. The representative model construction

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was ideal because they converged after approximately 15 000 computations.

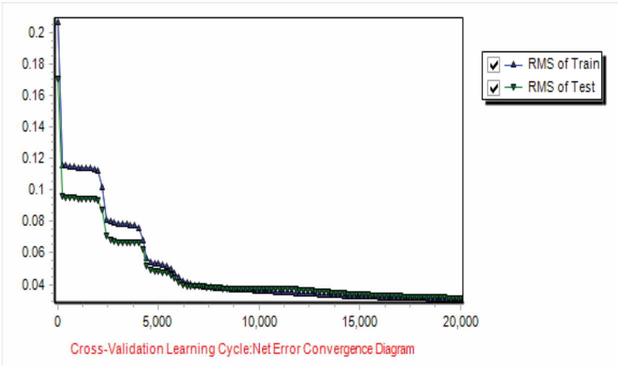

Figure 3: The "cross-validation" error convergence curve.

The "cross validation" scatter plots for the respective training and test samples are shown in Figs. 4 and 5. In addition, the predictive ability of the representative model was ideal.

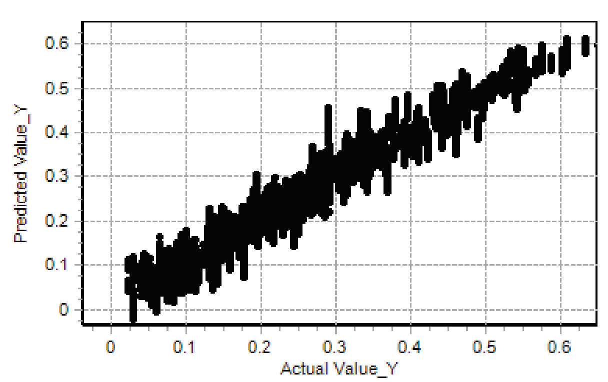

Figure 4: The "cross-validation" scatter plot of the training samples

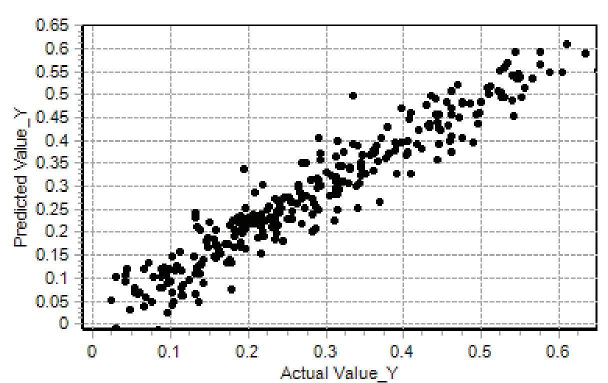

Figure 5: The "cross-validation" scatter plot of the test samples.

A sensitivity analysis and an influence line analysis were conducted when reviewing the results of the experiment. The sensitivity analysis was conducted using weight value analysis graphs, and the influence line analysis was conducted using a main effect diagram with status. The sensitivity analysis results revealed the significance of the quality factors, as shown in Figs. 6 and 7. We found that four quality factors had the highest significance, of which, the corrector (GTLVC1) current setting (C), and lens (Lens2) current setting (D) were the most significant.

- The weight of the corrector (GTLVC1) current setting (C) was 0.288.
- The weight of the lens (Lens2) current setting (D) was 0.269
- The weight of the corrector (GTLHC1) current setting (B) was 0.196
- The weight of the lens (Lens1) current setting (A) was 0.173

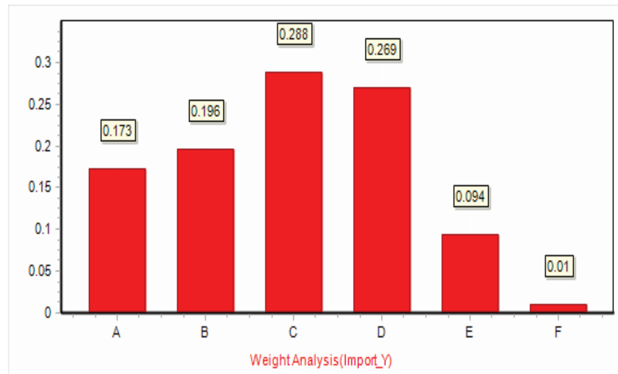

Figure 6: A bar graph of Y significance.

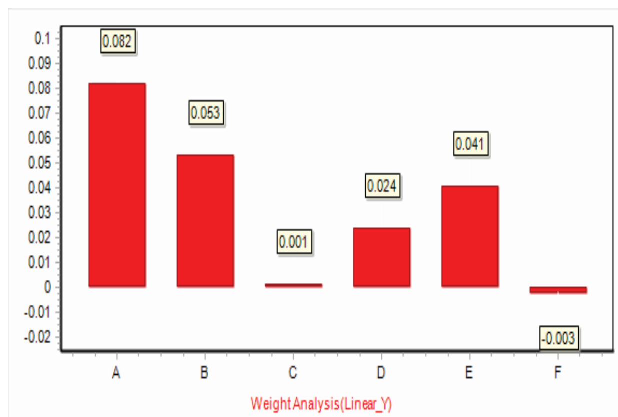

Figure 7: A bar graph of Y linear sensitivity

The results show the curved figure and significance of the quality factors (Fig. 8).

- Lens (Lens1) current setting (A)
- Corrector (GTLHC1) current setting (B)
- Corrector (GTLVC1) current setting (C)
- Lens (Lens2) current setting (D)

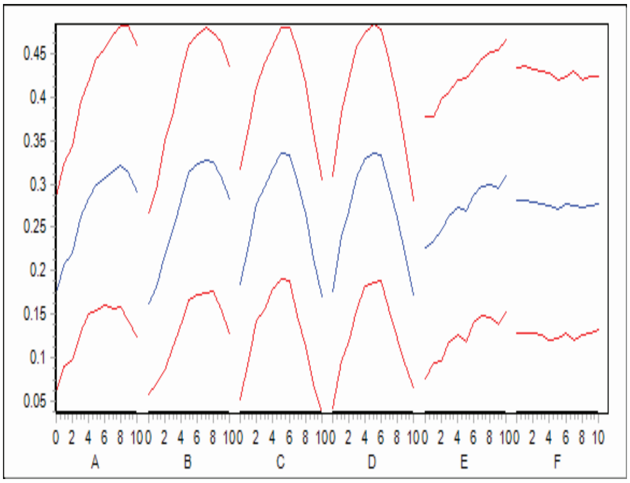

Figure 8: Status effect diagram

After programming the quality factors for optimization, the ANN-optimized parameter solution was found. The ANN-optimized parameter solution is shown in Fig. 9. The estimated electron beam efficiency was 0.6505(E-10Vs)

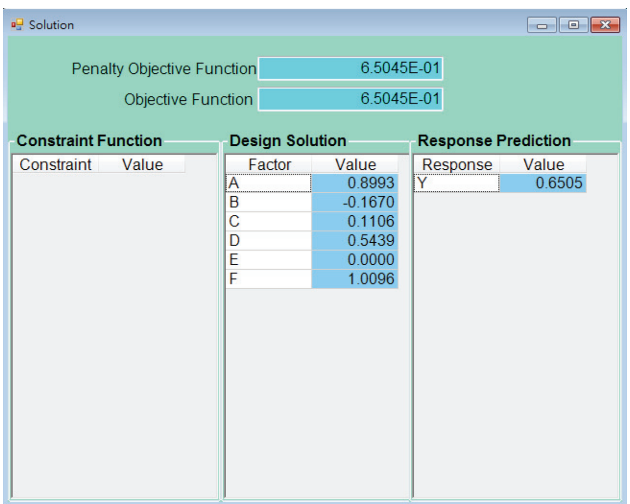

Figure 9: Optimal solution settings for ANN-optimized quality factors.

Result Verification

Using the ANN-optimized quality factor setting combination, actual machine tests showed that the electron beam efficiency could be increased from an average of approximately 0.45 (E-10Vs) to approximately 0.63 (E-10Vs), as shown in Fig. 10.

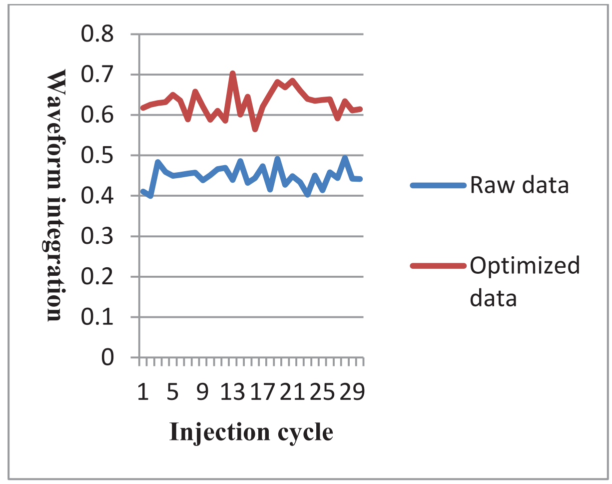

Figure 10: Electron beam efficiency.

CONCLUSION

This study aimed to improve the Taiwan Light Source (TLS) gun to linac electron beam efficiency for the NSRRC injector. Using BPN for analysis and the cross-validation experiment method to effectively estimate the generalization error, we developed an electron beam efficiency estimation method that involves using gun to linac beam tuning knobs as the variables. The verified results of the experiment revealed that the electron beam efficiency increased to an average of 0.63(E-10Vs). These results demonstrate the significant benefits of using ANN parameter optimization theory to enhance accelerator operation quality.

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