

Research on Early Warning of Power Grid Construction Safety Based on PSO-SVM Model

Yuwei Sun*, Jianbao Zhu, Xinchun Yu, Chao Ye, Guoxiang Fan

Nantong Power Supply Branch of State Grid Jiangsu Electric Power Co., Ltd.,
Nantong, Jiangsu, 226006, China

*Corresponding author's e-mail: yuxinchunntpower@163.com

Abstract. Electric power system is an important symbol of China's economic development, and electric power construction is an important way of electric power system. However, the potential safety hazards and safety accidents generated during its development have a great impact on economic and social development. In order to reduce the occurrence rate of such accidents, this paper proposes a power grid construction safety early warning model based on PSO-SVM. The quantitative model adopted by the traditional SVM safety early warning method has limitations in parameter optimization. The particle swarm optimization (PSO) algorithm is superior to the traditional method in parameter optimization because it cannot obtain better early warning effect. It uses the information sharing between the whole group and the mutual cooperation between individuals to search, thus searching for better parameter combination and achieving better early warning effect. Finally, the traditional SVM model test for power grid construction is compared, further proving the improvement of the model after improvement.

1. Introduction

With the rapid development of China's domestic economy, electric power construction projects are expanding correspondingly. In the process of electric power development, power grid construction is an essential element. Due to the environment, management difficulty and personnel quality of power grid construction, the safety management of power grid construction has become a challenging task, which also makes the safety early warning in safety management the core content. How to better ensure the safety of power grid construction and reduce the accident rate is the focus that we need to pay attention to and the problem that needs to be solved urgently [1].

Early warning was first applied in the military field. Due to the later development, it gradually involves various fields [2]. In the 1970s, Japan applied early warning to environmental pollution. In the 1980s, the United States extended early warning to enterprise management [3]; Since the 1990s, early warning in most countries has been further developed. Our country has applied [4][5][6][7] in coal mine safety early warning, financial risk early warning, industrial investment early warning, construction safety early warning, technology early warning, aviation industry early warning, unemployment risk early warning, etc.

Vapnik extended the statistical learning theory in 1995 and proposed a new classification prediction method, Support Vector Machine (SVM). The traditional machine learning method mainly adopts the principle of empirical risk minimization, while SVM mainly uses the principle of structural risk minimization. This method has unique advantages in solving nonlinear, small sample and high dimensional pattern recognition problems [8]. Compared with the artificial neural network method, the



statistical learning theory proposed to solve the small sample problem has more advantages. Therefore, statistical learning is a better choice to solve the problems of regression and classification of small samples [9].

In 1997, Eberhart R.C and Kennedy proposed a new artificial intelligence algorithm, particle swarm optimization. The improvement research of particle swarm optimization algorithm in recent years mainly includes the following aspects: First, introducing advanced mechanism improvement algorithm into PSO; Second, PSO is combined with other intelligent optimization algorithms to achieve complementary advantages in algorithm performance [10].

Security early warning of power grid construction projects usually uses fuzzy comprehensive analysis, dynamic analytic hierarchy process and fault tree analysis, etc. Because these methods have inherent limitations, including strong subjective factors and poor generalization ability, they cannot meet the current security early warning requirements. Support Vector Machine (SVM) can approximate the superiority of nonlinear function with any precision.

Based on the existing safety early warning model and combined with more advanced particle swarm optimization algorithm, the power grid construction project in this paper improves the accuracy and stability of regression prediction of the model, enhances the early warning capability of the safety early warning model, and improves the safety management level of power grid construction. The structure of this paper is as follows: The second part discusses the construction of safety evaluation system for power grid construction; In the third part, a power grid construction safety early warning model based on PSO-SVM is established. The fourth part of the simulation verifies the accuracy and superiority of the theory.

2. Construction of Safety Evaluation System for Power Grid Construction

2.1. Construction Principles of Safety Evaluation System for Power Grid Construction Projects

Scientific and reasonable formulation of evaluation index system is directly related to the quality level of safety evaluation. Due to the complexity of the construction of safety evaluation index, it is necessary to make judgment and analysis according to relevant principles in order to establish a suitable safety evaluation system and obtain better evaluation results. The principles of safety evaluation system for power grid construction projects are as follows:

- Hierarchy and systematicness. The index system for safety evaluation of construction projects involves many levels. The internal relations among these levels combine to form the whole system. The upper and lower levels of the index system shall conform to the hierarchical structure [11].

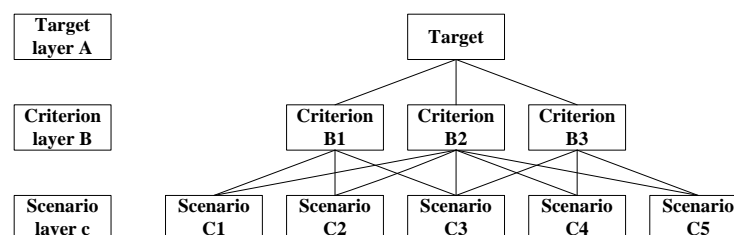


Figure 1. hierarchical structure

- Scientific nature. The setting of indicators is neither repeated nor omitted.
- pertinence. The index system should adapt to the characteristics of the power grid.
- Good operability and easy realization.
- advancement. The latest theoretical research is applied to the actual power system to improve the safety analysis of the power grid.

2.2. Selection of Safety Evaluation Indicators for Power Grid Construction Projects

On the basis of the existing power grid safety evaluation system, some indexes are re-screened, the management factors and human factors are collectively referred to as human factors, and then the

physical factors are further divided into more detailed ones. New technical factors are introduced to make the structure of the evaluation layer more reasonable. For the detailed evaluation indexes included in each evaluation layer, some highly relevant indexes are re-eliminated, thus making the coverage more detailed and comprehensive. The whole safety evaluation index is re-divided into 5 criteria, 3 levels and 26 evaluation indexes [12].

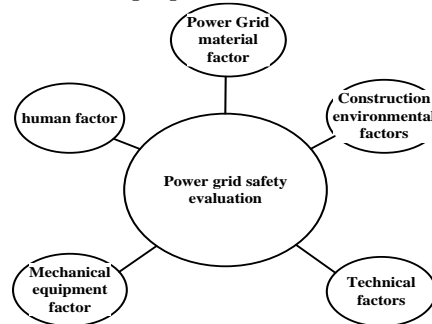


Figure 2. improvement of power grid construction safety evaluation system

- Human factors U1: average educational level (U11), safety inspection (U12), average age and length of service (U13), safety education and training (U14), professional quality of employees (U15), management organization and staffing (U16).
- Factors U2 of mechanical equipment: construction facilities (U21), construction electricity (U22), equipment maintenance (U23), ease of operation (U24), construction equipment and vehicles (U25).
- Factors U3 of construction materials: power grid materials (U31), construction quality (U32), protective equipment testing (U33) and safety protective equipment input (U34).
- Technical factors U4: safety inspection (U41), emergency measures (U42), on-site hazard sources (U43), various acceptance forms (U44), and project complexity (U45).
- Environmental factors U5: working space (U51), lighting intensity (U52), construction site layout (U53), noise and dust pollution (U54), safety signals and labels (U55), seasons and weather conditions (U56).

2.3. Construction of Safety Evaluation System for Power Grid Construction Projects

The safety evaluation system for power grid construction projects established in this paper has been analyzed and studied from two aspects: hierarchical structure of the system and quantification of safety indexes [13].

The factors for safety evaluation in the safety evaluation system of power grid construction projects are composed of a series of indexes or standards to measure the safety level of power grid construction. Based on the general characteristics of the criteria system, the design of the criteria system is studied with data tools and other theoretical results. Finally, the research content is applied to power grid construction and the safety evaluation criterion system of power grid construction is reconstructed.

The reconstruction of the safety system for power grid construction projects is shown in Table 1. The target layer U is the evaluation of the safety system for power grid construction. The index layer U_i and the criterion layer U_{ij} :

Table 1. Power Grid Construction Safety Evaluation System

Target layer	Indicator layer	Criterion layer
Power grid construction safety evaluation system (U)	Human Factors (U1)	U11: Average Education Level
		U12: Safety Production Inspection
		U13: Average Age and Length of Service
		U14: Safety Education and Training
		U15: Professional Quality of Employees
		U16: Management Organization and Staffing
	Mechanical Equipment Factor (U2)	U21: Construction Facilities
		U22: Electricity for Construction
		U23: Equipment Maintenance
		U24: ease of operation
	Material factor (U3)	U25: Construction Equipment and Vehicles
		U31: Power Grid Materials
		U32: Construction Quality
		U33: Detection of Protective Equipment
	Technical Factors (U4)	U34: input of safety protection articles
		U41: Safety Inspection
		U42: Emergency Measures
		U43: Site Hazard Source
	Environmental Factors (U5)	U44: Various Acceptance Forms
		U45: Project Complexity
		U51: Operating Space
		U52: Lighting Intensity
		U53: Construction Site Layout
		U54: Noise and Dust Pollution
		U55: Safety Signals and Labels
		U56: Seasons and Weather Conditions

3. PSO-SVM based early warning model for power grid construction safety.

3.1. Support Vector Machine (SVM) Theory

According to specific input data x , through regression analysis by the system, the output data y can be obtained. the input sample x and the output result y (x, y), called training sample, are input to the learning machine. the learning machine finally obtains the prediction result through a series of machine learning and outputs the result y , as shown in fig. 3.

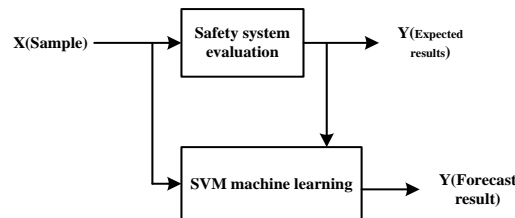


Figure 3. SVM machine learning

Support vector machine regression can be divided into linear SVM and non-linear SVM. In this paper, only non-linear SVM is involved. The basic idea of non-linear SVM includes: SVM model uses kernel function to map linearly indivisible sample data into high-dimensional space, and constructs an optimal hyperplane in high-dimensional space to partition the mapped sample data, thus realizing classification problem, i.e. transforming non-linear problem into high-dimensional linear problem. Mapping is realized by kernel function. The specific mapping transformation process is shown in the formula:

$$x \rightarrow \Phi(x) = \{\alpha_1 \Phi_1(x), \alpha_2 \Phi_2(x), L, \alpha_n \Phi_n(x)\} \quad (1)$$

The kernel function is in the form of $K(x_i, x_j) = \Phi(x_i) \bullet \Phi(x_j)$. In SVM model, Mercer kernel conditions need to be satisfied when the input nonlinear samples are mapped into multi-dimensional feature space. The properties of the algorithm are different and need to adapt to different types of kernel functions. Generally, the kernel functions have three forms, including polynomial kernel function, radial basis function (RBF) and Sigmoid kernel function, as follows:

- Polynomial Kernel Function

$$K(x, x_i) = [(x \bullet x_i) + 1]^q \quad (2)$$

Where q is the polynomial order.

- Radial Basis Function (RBF)

$$K(x, x_i) = \exp[-|x - x_i|^2 / \delta^2] \quad (3)$$

- Sigmoid kernel function

$$K(x, x_i) = \tanh[v(x \bullet x_i) + c] \quad (4)$$

According to the above kernel function, the optimal classification function can be obtained as shown in formula (5):

$$f(x) = \text{sgn}\left\{\sum_{j=1}^l \alpha_j y_j K(x_j \bullet x) + b\right\} \quad (5)$$

The parameters of SVM model in practical application have a very important influence on its classification accuracy, and the most obvious influence on prediction regression accuracy should be the values of kernel function parameter G and penalty factor C. The key to the construction of SVM model lies in the selection of kernel function and the selection of the best kernel function parameters and penalty factor [14].

3.2. PSO-SVM model design

SVM often has certain limitations in selecting kernel functions, and the value space range of the best parameter combination is very difficult to determine. In the process of parameter optimization search, all parameter combination methods also lead to low optimization efficiency [15]. PSO is a new artificial intelligence algorithm. Compared with the previous parameter search method, it has the greatest advantage in that it does not need to adjust the parameters one by one, has a faster convergence speed, and is easy to operate [16]. Therefore, we can deal with the limitations of SVM model in parameter selection, replace the traditional method of parameter optimization, and combine PSO and SVM to complement each other, thus forming PSO-SVM prediction model. The idea of optimizing is divided into the following four steps:

- determining an optimization search range of parameters. The function analysis and optimization process according to formula (3) can be expressed as follows:

$$K(x, x_i) = \exp[|x - x_i|^2 / 2g^2] \quad (6)$$

- Particle initialization of PSO
- Calculating the objective function difference between adjacent nodes
- Judgment of Algorithm Termination

As shown in the figure, the PSO-SVM model is completed in two stages, the first stage is the optimization process of PSO algorithm for kernel function parameters and penalty functions, and the second stage is the regression prediction process of SVM model for sample data.

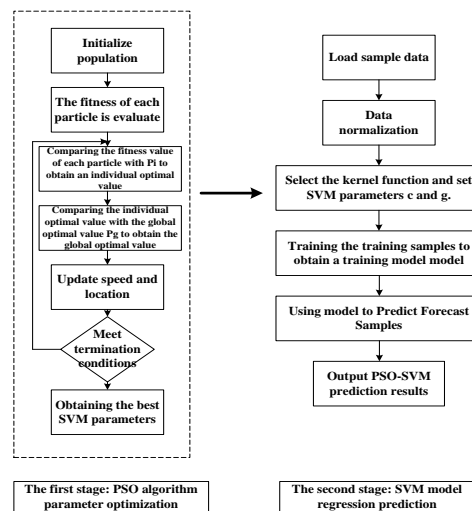


Figure 4. Implementation Steps of PSO-SVM Model

4. Simulation verification

4.1. Traditional SVM security prediction model

In order to verify the prediction effect of PSO-SVM model, the newly constructed PSO-SVM model and the traditional standard SVM model carry out regression prediction on the same set of sample data, and then the obtained results are compared and analyzed. The grid search method is used to search for the optimal combination of c and g parameters of SVM model, where the value range of C is $c \in [2^{-8}, 2^8]$, and the value range of g is $g \in [2^{-8}, 2^8]$. The parameter interval used by grid search method and SVM prediction model make the parameter interval the same. The kernel function adopts radial basis kernel function formula (3) and the regression classification function is formula (5).

The criterion for parameter optimization is the minimum root mean square error MSE. The grid search method is used to search and optimize the penalty factor C and the kernel function parameter G . The parameter optimization is completed through matlab programming. The parameter adjustment results are as follows

The traditional SVM model uses the grid search method to optimize the parameters, and the optimal $c=0.125$, $g=0.25$.

The normalized sample data is imported into the libsvm toolbox of matlab program, and the optimal SVM parameters c and g obtained from previous grid search are brought into the SVM model for prediction. the obtained results are shown in the following figure:

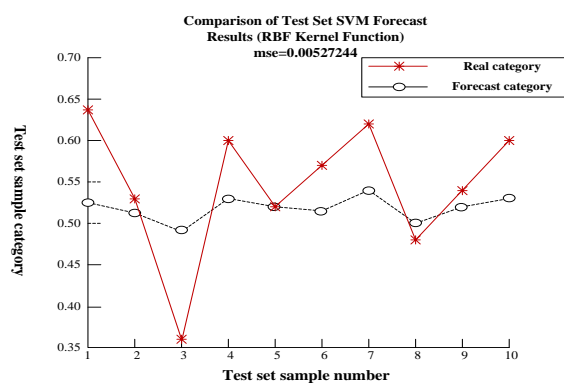


Figure 5. SVM prediction results of parameter optimization by grid search method

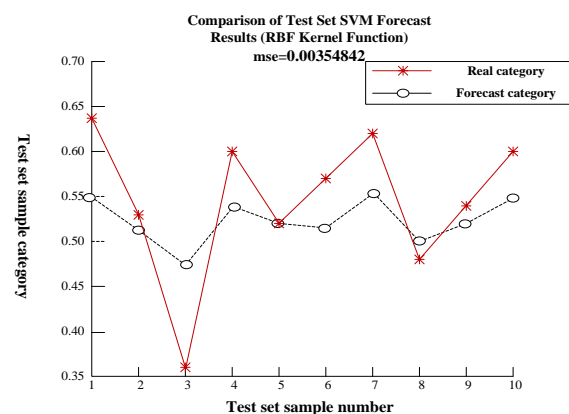


Figure 6. prediction results of PSO-SVM model

4.2. Improved PSO-SVM safety prediction model

The PSO-SVM model uses PSO algorithm to optimize the parameters, and the optimal $c=18.0784$, $g=0.25$.

4.3. Results and Analysis of Safety Early Warning

In order to check the prediction accuracy of SVM model, the methods of relative error and mean square deviation are generally adopted. Relative error refers to the ratio of absolute error and actual value (the expected value is assumed to replace the actual value here), while absolute error refers to the difference between predicted value and actual value.

The mean square deviation is used to measure the degree of data dispersion. It is often used to measure the accuracy and also to predict the overall effect of the model. The calculation formula of the error test function is as follows:

$$MSE = \sqrt{\frac{1}{n} \sum_{n=1}^N [x(n, expect) - x(n, pred)]^2} \quad (7)$$

Where $x(n, expect)$ and $x(n, pred)$ are the actual and predicted values of the n th test sample respectively.

Table 2. Error Comparison between Predicted Values of Traditional SVM Model and PSO-SVM Model

Sample number	Expected value	SVM predictor	Relative error value	Expected value	PSO-SVM prediction value	Relative error
31	0.6346	0.5235	0.1111	0.6346	0.5433	0.0913
32	0.5300	0.5136	0.0164	0.5300	0.5139	0.0161
33	0.3584	0.4887	0.1303	0.3584	0.4704	0.1120
34	0.5978	0.5293	0.0685	0.5978	0.5517	0.0461
35	0.5135	0.5154	0.0019	0.5135	0.5188	0.0053
36	0.5700	0.5097	0.0603	0.5700	0.5146	0.0554
37	0.6225	0.5337	0.0888	0.6225	0.5524	0.0701
38	0.4783	0.5023	0.0240	0.4783	0.4925	0.0142
39	0.5395	0.5155	0.0240	0.5395	0.5201	0.0194
40	0.5288	0.4580	0.0758	0.5288	0.5444	0.0602
MSE=0.00527			MSE=0.00354			

As shown in Table 2, the MSE of the traditional SVM model using grid search method MSE=0.00527, and the MSE of the SVM model optimized by PSO algorithm MSE=0.00354. It can be seen that the MSE of PSO-SVM model is smaller than that of the traditional model, which indicates that PSO-SVM has smaller error.

According to the actual situation of the power grid construction project, the security situation is divided into the presence of police or the absence of police, and the security risk level is divided into four levels, namely high level, intermediate level, low level and lower level. According to the scoring situation of power grid construction projects in this paper, the scoring interval is corresponding to four risk levels, as shown in Table 3:

Table 3. Classification of Risk Levels and Alert Situations

Score interval	Risk level	Alarm condition
[0,0.3]	High	alarm
(0.3,0.5]	medium	alarm
(0.5,0.7]	Low	No alarm
(0.7,1]	Lower	No alarm

Table 4. Comparison of Safety Early Warning Results of Two Forecast Models

Sample number	Actual risk level	Alarm condition	SVM risk level	Alarm condition	PSO-SVM risk level	Alarm condition
31	low	No alarm	low	No alarm	low	No alarm
32	low	No alarm	low	No alarm	low	No alarm
33	medium	alarm	medium	alarm	medium	alarm
34	low	No alarm	low	No alarm	low	No alarm
35	low	No alarm	low	No alarm	low	No alarm
36	low	No alarm	low	No alarm	low	No alarm
37	low	No alarm	low	No alarm	low	No alarm
38	medium	alarm	low	No alarm	medium	alarm
39	low	No alarm	low	No alarm	low	No alarm
40	low	No alarm	low	No alarm	low	No alarm

As can be seen from the table, in the 38th sample, SVM has errors, while PSO-SVM is normal. After overall comparison, PSO-SVM model has better effect and accuracy.

5. Conclusion

In this paper, the combination of particle swarm optimization (PSO) and support vector machine (SVM) is used to improve the power grid security early warning model. Based on the data, the traditional SVM model and the improved PSO-SVM model combined with particle swarm algorithm are respectively used to carry out empirical tests in the field of power grid construction safety, which proves that the improved prediction accuracy of the model is improved.

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