Research on driving current prediction method based on ARIMA

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Abstract. The abnormal driving current of DC measuring device is sometimes covered by the fluctuation of normal monitoring signal, which is difficult to identify by traditional operation and maintenance monitoring panel and abnormal alarm means. In order to solve the above problems, a prediction and trend analysis algorithm model of ARIMA is proposed to predict the change trend of driving current, realize the prediction of driving current in the next 8 hours, and analyze whether there is a growth trend of driving current by using the change rate. The practicability of the proposed method is verified by the analysis of the actual operation monitoring data of converter station, which can be applied to the trend analysis of driving current in DC measurement system.

Keywords: DC measuring system; drive current; ARIMA fault warning.

1. Introduction
The abnormal DC measurement is an important factor affecting the safe operation of the HVDC system in UHV DC transmission projects. DC measurement includes DC voltage measurement and DC current measurement. The accuracy of the measurement determines the output and performance of the entire DC control and protection system. The photoelectric sensor has been widely used in the DC transmission system of China Southern Power Grid\cite{1}, the large deviation of the driving current or voltage measurement may cause the protection system to operate to affect the normal operation of the converter station\cite{2}. The sampling situation of the DC measurement system is mainly monitored through data monitoring of operation and maintenance personnel, abnormal alarms, etc. in the daily operation and maintenance of the DC converter station. However, there may be abnormal fluctuations in the DC measurement current due to factors such as the ambient temperature of the screen cabinet, the external environment, and fiber defects. The abnormal alarm has certain limitations based solely on the threshold. And when it does not exceed the alarm value, the abnormality of the drive current (such as a slow increase trend) may be hidden in the fluctuation of the normal monitoring signal, which is difficult to identify under the condition of manual monitoring. Therefore, it is necessary to carry out prediction and analysis of the driving current trend to provide auxiliary basis for the operation and maintenance and status evaluation of the DC measurement device.
At present, the analysis of the status of the DC measurement device is mostly focused on the identification of the abnormal cause[3]-[4] and the impact on the control and protection system[5], there is little research on the prediction and analysis of the future trend of drive current. Under the above background, this paper introduces the ARIMA method to predict the driving current, and realizes the abnormal analysis of the driving current through the driving current data collected by different measuring devices, combined with time series prediction and trend warning algorithms.

2. Principle analysis of dc measuring device

The architecture diagram of the DC optic-electric measurement system of the converter station is shown in Figure 1. The remote module, optical fiber loop and merging unit form a DC optic-electric measurement system. The DC measurement system generally collects and transmits signals with a photoelectric hybrid method which converts the collected current signals into optical signals, and transmits them to the control and protection center in time using optical fibers as the transmission path. The working state of the remote module, the on-off of the optical fiber loop and the working state of the merging unit play a decisive role in the working state of the entire measurement system, any problems in these will cause measurement abnormalities, so that leading to failure of the converter station control and protection system.

![Diagram of DC optic-electric measurement system](image_url)

**Fig. 1** The architecture diagram of DC optic-electric measurement system in converter station

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3. Driving current trend prediction algorithm based on arima

ARIMA uses a mathematical model to approximate a random sequence formed by a data sequence over time. The data model can be used to predict future values through historical data under similar conditions. The forecasting process not only considers the periodic influence of the data sequence, but also eliminates certain random fluctuations, which accurately predicts the periodic trend of the data, and has a wide range of applications for short-term forecasting. The superiority of the ARIMA algorithm and the feasibility of its application in the trend analysis of UHV equipment monitoring state quantities have been verified[6]-7).

ARIMA consists of an autoregressive model and a moving average model, it usually expressed as ARIMA(p,q,d), where p represents the order of the autoregressive model (AR), q represents the order of the moving average model (MA), and d represents difference order of time series.

Autoregressive model (AR) is a description of the relationship between a certain time t and the sequence of first p moments before it, in the sequence \{x_t\}:

$$x_t = \varphi_1 x_{t-1} + \cdots + \varphi_p x_{t-p} + \epsilon_t$$  \hspace{1cm} (1)

Among them, the random sequence \{\epsilon_t\} is white noise and is irrelevant with the previous sequence \{x_k\} (k<t), denoted as AR(p).

Moving average model (MA) represents the weighted average sum of several white noises, in the sequence \{x_t\}:

$$x_t = \epsilon_t + \theta_1 \epsilon_{t-1} + \cdots + \theta_q \epsilon_{t-q}$$ \hspace{1cm} (2)

Among them, the random sequence \{\epsilon_t\} is white noise, denoted as MA(q).

Combine AR(p) and MA(q):

$$x_t = \varphi_1 x_{t-1} + \cdots + \varphi_p x_{t-p} + \epsilon_t$$
$$\hspace{3cm} - \theta_1 \epsilon_{t-1} - \cdots - \theta_q \epsilon_{t-q}$$ \hspace{1cm} (3)

Among them, t is a time variable; \varphi_1, \varphi_2 ..., \varphi_p and \theta_1, \theta_2 ..., \theta_p are non-zero undetermined coefficients; \epsilon_1, \epsilon_2 ..., \epsilon_p are independent error terms.

The Bayesian information criterion is used to determine the order of the model. The criterion is defined as:

$$V = -2M + d \log N$$ \hspace{1cm} (4)

Among them, M represents the best log-likelihood value, d represents the number of estimated parameters, and N represents the number of samples.

Generally, the enumeration method is used to select (p, q) model type for final prediction, but the scope is generally limited in practical applications. In the engineering field, the waveform trend can be predicted well within 6 steps.

The driving current prediction and analysis process based on time series is:

- Judge the stationarity of the input drive current sample sequence, if it is not stable, perform the difference operation until the sequence is stable;
- Import the stationary series into ARIMA models with different (p, q) models;
- Compare the order of the models under different (p, q) values, select the group with the smallest order as the optimal parameter and output the predicted drive current sequence;
- Judge whether the predicted drive current exceeds the alarm threshold. If it does not exceed the limit, then use the growth rate to further analyze the change trend of the drive current. The calculation formula is shown in formula (5):

$$I\% = \frac{I - I_{\text{START}}}{I_{\text{START}}} \times 100\%$$ \hspace{1cm} (5)

Among them, I% is the drive current change rate, I is the drive current monitoring value at the predicted time, and I_{\text{START}} is the historical average. When the growth rate I% ≥ 30%, it prompts that the drive current monitoring quantity is abnormal, and the operation and maintenance measures should be taken in advance. The specific algorithm flow chart is shown in Figure 2.
4. Example verification
This paper takes the historical data of the drive current of a set of 1A1-RTU1 units of a DC measuring device with a pole height of 1 in a converter station as an example for analysis. The sample data contains the driving current monitoring data from December 2019 to May 2020, with a sampling interval of 15 minutes, and a total of 17,280 data. Build an ARIMA prediction algorithm on this data set.

4.1. Data analysis
The trend of driving current is shown in Figure 3, which shows the driving current still has large fluctuations in a short time and the numerical range is basically maintained in the range of 530–590mA, with an average value of 554.68mA. In a short period of time, the data fluctuates significantly and the speed of change is relatively fast. On the whole, the data fluctuates relatively smoothly, with a peak value of 592mA and a valley value of 527mA.
4.2. Stationarity and non-white noise
The ARIMA model requires the time series to meet the stationarity requirements, so the difference method is used to achieve the stationarity operation of the time series. The data shown in Figure 4 can already meet the sequence stationarity requirements in the first-order difference.

![Fig. 4 Data processing diagram of first-order difference and second-order difference](image)

4.3. Time series ordering
The result of the order is displayed in the form of a heat map. The darker the color, the better the position, as shown in Figure 5. Taking (3,1) for p and q can get better prediction results and is relatively simple.

![Fig. 5 Heat map of the order result](image)

4.4. Construction of ARIMA model
Divide the data into a training set and a test set. Take the data from December 2019 to April 2020 as the training set, and the data from May 2020 as the test set. Then input the data into the model for training. The prediction result is shown in Figure 6. The true value and the predicted value curve have a high degree of coincidence. The predicted value is slightly lower than the true value at the peak of the wave, and slightly higher at the trough, and the forecast error is 2.6089%.
4.5. Prediction
Predict the driving current change in the next 8 hours based on the June 2020 data of the DC measurement model of the converter station and the trained ARIMA model. The prediction result is shown in Figure 7. Predict the change trend of drive current on the basis of historical monitoring values. The predicted value does not exceed the alarm threshold (700mA), and the maximum growth rate is 5.6%, which also does not exceed the threshold.

5. Conclusion
A forecast and trend analysis algorithm model is proposed in this paper which can predict the change trend of driving current and warning before failure occurs based on ARIMA for the trend analysis of the driving current measured by the DC measuring device. It provides reference for timely and reasonable formulation of maintenance plans. According to the results of trend analysis, we can focus on the abnormal measurement device, guide the maintenance of field equipment, and realize the transition from the full inspection of the optical fiber to the targeted partial inspection.

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