ONLINE MONITORING AND FAULT DIAGNOSTICS OF MECHANICAL CONDITIONS OF HIGH-VOLTAGE DISCONNECTOR

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ABSTRACT

The Hidden Markov Model (HMM), normally utilized in the speech recognition domain, is introduced into the mechanical condition monitoring and fault diagnostics of High-Voltage disconnector, and a unique fault diagnosis methodology is thereby developed from a novel view angle.

Online monitoring signals come from both a rotating angular sensor and a current transformer attached to the drive motor of High-Voltage disconnector, which indirectly reflect the dynamic changes of the rotating angles and moments, can effectively indicate the underlying deficiency or potential faults of the mechanical drive system. With combination of several applied algorithms including first-order derivative, instantaneous frequency tracking and wavelet analysis, a feature extraction methodology is presented to evaluate the mechanical condition of the High-Voltage disconnector' drive mechanism, which provides an effective alternative reference to realize fault diagnosis.

By partition, normalization and vector quantization of the power density spectrum of the vibration signals, a feature vector extraction methodology is presented for the discrete spectrums, which can to the farthest extent retain the unique features and difference of all the mechanical modes, and also well meet the requirement for HMM exemplar training. With the sampled data both from experimental simulations and onsite measurements, a trained HMM norm modes database for fault diagnosis is established based on the different mechanical conditions of High-Voltage disconnector. Large quantities of verifications demonstrate that, the new proposed HMM-based mechanical fault diagnosis scheme for High-Voltage disconnector is feasible and applicable, with outstanding behaviour for fault classification.

INTRODUCTION

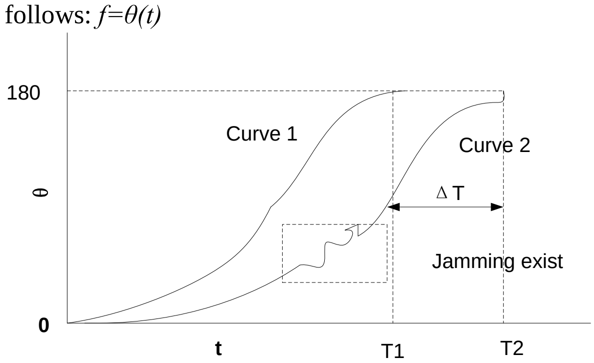
With the rapid development of power industry, power equipment capacity and electricity networks are also increasing in size, the failure of power equipment will lead to huge economic losses and adverse social impact, which gives a higher quality of power supply requirements and unprecedented challenges. Therefore, we must take effective measures to improve the quality of power supply systems, to ensure power equipment and systems operate in a safe, reliable, economic and stable way. Condition Based Maintenance based on Online monitoring and fault diagnosis is the main development trend of the future.

In power systems, disconnector is a mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or equipment from the source of power, In recent years, due to increased power load, power outage caused by disconnector accidents have occurred frequently. There are four fault types of disconnector: insulator contamination, contact overheats, insulator internal injury, transmission parts jamming. According to the record, the principal malfunctions or failures of disconnector are of mechanical type. Outdoor disconnector withstand direct exposure to sun and rain in the atmosphere, the lack of lubrication of bearings and other transmission parts, which cause the operation Jamming happened relatively more often. This has been a serious threat to the safe operation of power system. Hence, online-monitoring of the mechanical characteristics of disconnector is of utmost significance for a safe， stable and reliable operation of the power systems.

PRINCIPLES OF MECHANICAL FAULT DETECTION OF DISCONNECTOR

Rotation angle signal analysis

The rotation angle function of bearing can be expressed as follows: $f=\theta(t)$



Firgue 1 curve of $f=\theta(t)$

Curve 1 represents the standard travel time of the bearing, measured after the first installation; Curve 2 represents the bearing running after a period of time, T1, T2 stands for the whole travel time of bearing. If there are jamming of transmission, the travel time will be extended, so $\triangle$T is a very important feature parameters. Also a twist will produced on the curve shape, as shown in Figure 1.

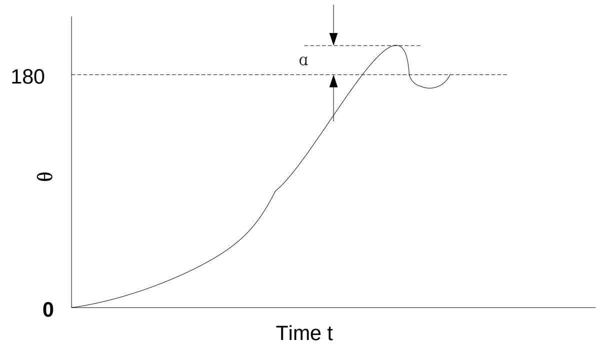


Figure 2 curve of $f=\theta(t)$ with overshoot

If the overshoot exists while the rotation angle less than 180 degrees, indicating that the trip switch cut off too early. If the rotation angle greater than 180 degrees have a overshoot indicates that the trip switch cut off too late, as shown in Figure 2.

Motor drive current signal analysis

The induction motor's drive current reflect the status of disconnector's mechanical systems. Application of current sensors, measure the motor operating current with time to determine whether the jam occurred. A typical current waveform is shown in Figure 3.

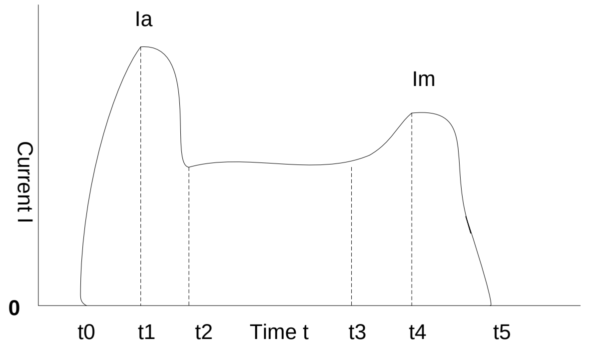


Figure 3 waveform of motor drive current

In Figure 3:
t0~t1: the motor charge, there is a large current pulse (starting current).
t1~t2: the motor starts to rotate, the motor generated counter-electromotive force and current drop.
t2~t3: motor work steady.
At t3, the fixed contact is contacted with moving contact, the load suddenly increases, the current will also rise, the current rise to its peak in the time t4.
t5: current is cut off.

the current parameters at t1-t5 reflect changes in the mechanical transmission system. By attaching a current transformer to the drive motor, which can indirectly reflect the dynamic changes of the rotating angles and moments, as shown in figure 4.

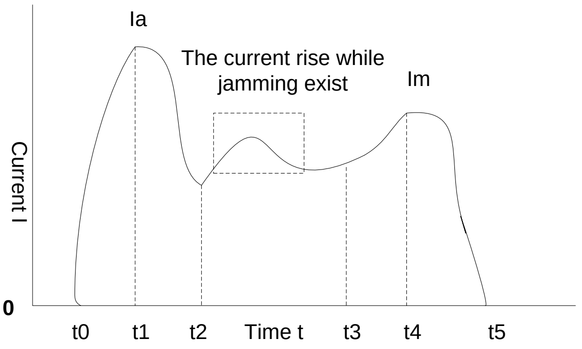


Figure 4 motor drive current

HMM-BASED FAULT DIAGNOSIS

hidden Markov model

A hidden Markov model (HMM) is a statistical Markov model in which the system being modelled is assumed to be a Markov process with unobserved (hidden) states.

Hidden Markov models are especially known for their application in temporal pattern recognition such as speech, handwriting, gesture recognition, part-of-speech tagging, musical score following, partial discharges and bioinformatics.

For a HMM application, three basic questions need to be addressed, and corresponding forming three mature algorithms: the Forward-backward algorithm, Viterbi algorithm, Baum-Welch algorithm.

1) Forward-backward algorithm: There are many circumstances in practical problems where these are not directly measurable, and have to be estimated, this is the learning problem. The forward-backward algorithm permits this estimate to be made on the basis of a sequence of observations known to come from a given set, that represents a known hidden set following a Markov model.

2) Viterbi algorithm: The Viterbi algorithm provides a computationally efficient way of analysing observations of HMMs to recapture the most likely underlying state sequence. It exploits recursion to reduce computational load, and uses the context of the entire sequence to make judgements, thereby allowing good analysis of noise. In use, the algorithm proceeds through an execution trellis calculating a partial probability for each cell, together with a back-pointer indicating how that cell could most probably be reached. On completion, the most likely final state is taken as correct, and the path to it traced back to t=1 via the back pointers.

3) Baum-Welch algorithm: the Baum–Welch algorithm is used to find the unknown parameters of a hidden Markov model. It makes use of the forward-backward algorithm.

It can compute maximum likelihood estimates and posterior mode estimates for the parameters (transition and emission probabilities) of an HMM, when given only emissions as training data.

In our case, HMM-based fault diagnosis is divided into two stages: first, typical feature extracted from fault signals, then get the feature vector to train the typical HMM failure model using Baum-Welch algorithm. Then, have the trained model, the signal will be diagnosed by the feature extraction to form observation vectors for classification, observation vectors into the model library will, through the observation vector Viterbi algorithm to calculate the probability of a different model, the probability of selecting one of the largest Who is the corresponding fault type.

Online monitoring fault diagnosis system

The non-invasion scheme and the multi-sensor measurement technique are applied to design an online monitoring system for disconnector's mechanical characteristics. Without affecting the normal operation of disconnector，the online monitoring system will readily acquire the multiple signals to reflect the operational conditions of the equipment， which facilitates the mechanical feature extraction diverse and much effective.

Online monitoring signals from both a rotating angular sensor and a current transformer attached to the drive motor in a disconnector， which indirectly reflect the dynamic changes of the rotating angles and moments， can effectively indicate the underlying deficiency or even potential faults of the mechanical drive system. With combination of several applied algorithms including firs-order derivative，instantaneous frequency tracking and wavelet analysis，a feature extraction methodology is presented to evaluate the mechanical condition of the disconnector’s drive mechanism，which provides an effective alternative reference to realize fault diagnosis.

By partition，normalization and vector quantization of the power density spectrum of the signals from rotating angular sensor and motor drive current，a feature vector extraction methodology is presented for the discrete spectrums，which can to the farthest extent retain the unique features and difference of all the mechanical modes，and also well meet the requirement for HMM exemplar training. With the sampled data from both experimental simulations and onsite measurements，a trained HMM norm modes database for fault diagnosis is established based on the different mechanical conditions of the disconnector. Large quantities of verifications demonstrate that， the new proposed HMM-based mechanical fault diagnosis scheme for disconnector is feasible and applicable，without standing behaviour for fault classification.

Based on analysis of prevailing faults and their dominant mechanisms specifically for the disconnector，the fault feature changes of the online monitoring signals are summarized. Further，an expert system for synthesized mechanical fault diagnosis of disconnector is established based on a decision tree and integrated analysis of the monitoring signals. The decision tree is preferable for dealing with non-numerical data and rapid reasoning，in addition， multi-angle analysis and synthesized fault diagnosis can be achieved through combination of every diagnosis subprograms and procedures.

CONCLUSION

This paper has presented an HMM-based approach of online-monitoring of the mechanical characteristics of disconnector. An expert system for synthesized mechanical fault diagnosis of disconnector is established based on a decision tree and integrated analysis of the monitoring signals. The experiments show that the HMM-based online-monitoring and fault diagnosis system can detect most of the fault of HV disconnector.

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