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An adaptive online safety assessment method for mechanical system with pre-warning function

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Abstract

The safety status of a dynamic mechanical system is determined by its historical, current and future states together. Therefore the safety assessment process of such system should have dynamic and diachronic characteristics, which helps to track the dynamic states of system and predict future probable danger in advance. In order to overcome the disadvantages of traditional static safety assessment approaches, the results from which are often delayed and prone to produce false alarms, an adaptive online safety assessment method is proposed in this paper, which consists of two steps. A dynamic adaptive weighting method is first introduced and an aggregation scheme based on "3-D" time perspective is further presented to integrate system's historical, current and future safety performance in a unit framework, considering both of assessment and pre-warning functions. The proposed method is able to track and predict the safety status of system dynamically and discover the potential fault in time. Its feasibility and benefits are investigated with a field case study of gas turbine compressor system, which validates that the proposed method improves the accuracy of safety assessment in dynamic conditions, and finally helps to restrain the fault symptom by proactive maintenance successfully.

Highlights

► Mechanical system's safety status is determined by its historical, current and future states. ► We propose an adaptive online safety assessment method considering pre-warning functions. ► It integrates a dynamic adaptive weighting method and an aggregation scheme based on "3-D" time perspective. ► It is able to track and predict the safety status dynamically and discover the potential fault in time. ► It also helps to predict future probable danger in mechanical system in advance.

Keywords

Online safety assessment; "3-D" time perspective; Adaptive weighting method; Aggregation scheme; Pre-warning

Figures and tables from this article:

Fig. 1. Flow chart of AHP-based weighting method.

Figure options

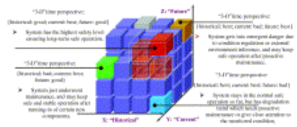

Fig. 2. Classification diagram of integrated safety assessment from "3-D" time perspective.

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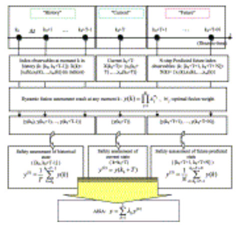

Fig. 3. Calculation flow chart of AOSA from "3-D" time perspective.

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Fig. 4. Implementation steps of the proposed AOSA for application.

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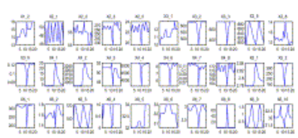

Fig. 5. Observable data corresponding to each safety indicator.

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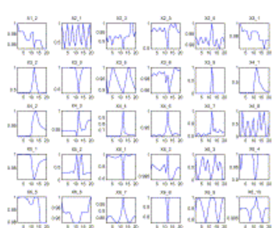

Fig. 6. Preprocessing of indicator observations.

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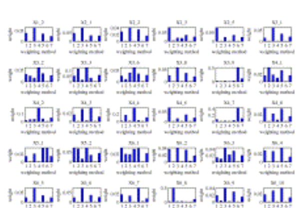

Fig. 7. The weights of each indicator calculated by multi-mechanism weighting methods and optimal fusion weighting scheme.

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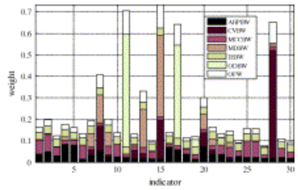

Fig. 8. Comparison of weights of each indicator calculated by various weighting mechanisms.

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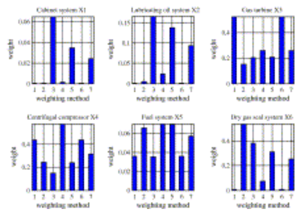

Fig. 9. The weights of each subsystem calculated by multi-mechanism weighting methods and optimal fusion weighting scheme.

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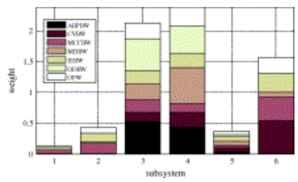

Fig. 10. Comparison of weights of each subsystem calculated by various weighting mechanisms.

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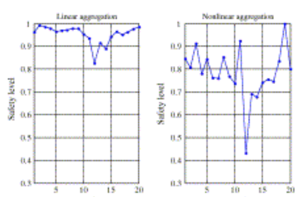

Fig. 11. AOSA of the current state of GTCS.

Figure options

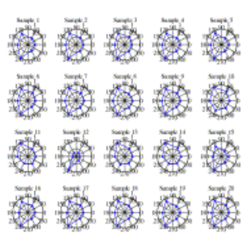
Fig. 12. Radar map of AOSA results for each subsystem.

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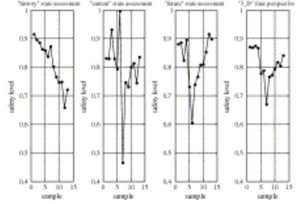

Fig. 13. Detailed safety trends from “ 3-D ” time perspective.

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Table 1. List of historical faults of GTCS.

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Table 2. Initial safety indicator set for AOSA of GTCS.

Notes: (1) Gas turbine speed NGP (expressed as a percentage of the gas generator speed): 100% = 11,220 rmp.(2) Power turbine speed NPT (expressed as a percentage of the power turbine speed): 100% = 8856 rmp.(3) Rotor radial displacement and rotor axial displacement in centrifugal compressor and gas turbine are represented by the average of the observables.

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Table 3. Quantitative refinement of the initial indicators.

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Table 4. Weighted coefficients in optimal fusion weighting scheme.

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Table 5. Safety level calculated by AOSA from the “ 3-D ” time perspective.

Note: (1) safety level is defined according to the alarming standard of AOSA: [0, 0.7) Danger; [0.7, 0.8) Fault; [0.8, 0.9) Good; [0.9, 1] Best.

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