Improved Operational Availability Evaluation Algorithm for Meteorological Observation Equipment

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***Abstract*—Operational availability, Ao, is a comprehensive evaluation index of stable and reliable operation ability, maintenance support ability and data quality of meteorological equipment. The current Ao evaluation algorithm fails to make effective use of the operational status parameter information of various kinds of equipment, and it fails to establish the correlation mechanism between equipment maintenance and equipment operational capability assessment. In order to scientifically measure the stable and reliable operation of meteorological observation equipment and to provide reference for equipment manufacturers, decision makers, business managers and users, this study improved the Ao evaluation algorithm in China meteorological observation equipment support from three aspects, namely, the operation parameter information of key components of equipment, the equipment fault form filled manually by support personnel and the quality of observation data. Taking the weather radar as an example, the influence factors and evaluation results of the old and new algorithms on Ao are compared and analyzed. The results show that the new algorithm can more correctly reflect the operation ability of meteorological observation equipment and the level of meteorological observation support. This paper also discusses the processing of maintenance state, the utilization of equipment operating parameters, the processing of overlapping periods corresponding to each equipment status, and the data quality control in the new algorithm, and forecasts the future development direction of the operation evaluation service of meteorological observation network.**

Keywords—Meteorological observation, Equipment support, Operational availability, Evaluation, Improvement

I. INTRODUCTION

Meteorological observation is the basis of weather forecast and meteorological services [1]. At present, China has built the ground-based, the air-based and the space-based Integrated Meteorological Observation System, IMOS. The total number of national observation equipment is more than 60,000 stations. Ensuring stable and reliable operation of the observation system is the fundamental goal of the meteorological observation support business. The assessment and evaluation is the important way to measure the strength of meteorological security and the ability of equipment to operate, and the scientificity of the evaluation algorithm will directly affect the meteorological support business and thus influence decision-making.

II. AVAILABILITY INTRODUCTION

A. Equipment running time division

The equipment operation states are generally divided into two: working and no working. The operation availability is reflected by the time corresponding to different states. The evaluation of the meteorological equipment is counted from the time of its business operation, until the end of the equipment component is scrapped. The life time TT of the business operation meteorological equipment is divided into the operable time T_{yes} and the inoperable time T_{no}, as shown in Fig. 1 below:

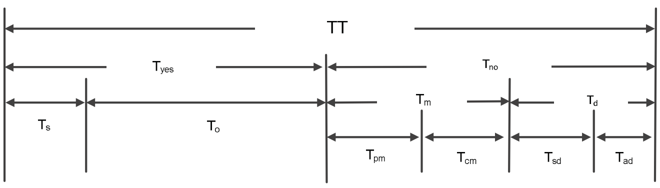

Fig. 1. Life cycle profile of meteorological equipment

The operable time T_{yes} includes the working time T_o and the standby time T_s. The standby time is the standby state time when the equipment is working and not working.

The inoperable time T_{no} includes the repair time T_m and the delay time T_d. The repair time mainly refers to the time when the equipment has been faulty, downtime, test time, etc., which are specifically divided into the corrective maintenance time T_{cm} and the preventive maintenance time T_{pm}. The delay time is divided into the guarantee delay time T_{sd} and the management delay time T_{ad}.

B. Availability definition

In reliability engineering, availability is an important indicator to measure equipment performance and the level of post-guarantee [2-4]; in the field of meteorological observation, Meng Zhaolin et al consider availability as a framework [5], which is a comprehensive parameter that reflects the reliability, maintainability and supportability of equipment or systems.

Availability is the degree to which a meteorological device is operational or serviceable during observation at random times:

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$$X_i = \begin{cases} 0, & \text{(time t, the equipment is available)} \\ 1, & \text{(time t, the equipment is not available)} \end{cases} \quad (1)$$

The availability A at time t is:

$$\mathrm{A}(t) = \mathrm{P}\{\mathrm{X}(t) = 0\}$$

$\mathrm{A}(t)$ I is instantaneous availability and is a comprehensive reflection of reliability, maintainability and supportability. If the equipment is less likely to break down at time t, or if the fault is repaired quickly with less guaranteed resources, the availability is high. It is more appropriate to use average availability for meteorological equipment [6].

Average availability refers to the average availability of the product over a certain period of time [3]:

$$\overline{A} = \frac{1}{t}\int_0^t A(\tau)\, d_\tau \quad (2)$$

$0 \leq \mathrm{A} \leq 1$, which represents the proportion of time that the product is in a usable state during long-term operation. In the equipment business, the average calculation and the average inoperable time in a certain period of time are expressed in the specific calculation:

$$\overline{\mathrm{A}} = \frac{\overline{T_{yes}}}{\overline{T_{yes}}+\overline{T_{no}}} \times 100\% \quad (3)$$

The average available time T_{yes} and average unavailability time T_{no} of meteorological equipment are the mathematical expectation of working time and non-working time, respectively, which need to be obtained by their corresponding time density functions, which is difficult to carry out in actual work. The indicators used in the actual support management of large-scale equipment and more instructive for the actual support work are mainly the intrinsic availability A_i, the reachable availability A_a and the use availability A_o. The emphasis of the three is different and the calculation method is different as well.

Usability A_o is the estimated percentage of time that the equipment can be put into use at any random time in a given time and logistics support and usage environment. The calculation method is:

$$A_o = \frac{MTBM}{MTBM+\overline{MDT}} \times 100\% \quad (4)$$

Among them, Mean Down Time, MDT, is the average downtime, including MTTR, preventive maintenance time and delay time.

A_o is a comprehensive parameter of reliability, maintainability and supportability, and is a quantitative measure of equipment integrity and equipment operation capability.

In the actual support business evaluation analysis, corresponding to the stages in Fig. 1, the calculation methods of A_o is:

$$A_o = \frac{T_o+T_s}{T_o+T_s+T_{cm}+T_{pm}+T_{sd}+T_{ad}} \times 100\% \quad (5)$$

III. EXISTING ALGORITHM

The A_o is an important index that CMA regularly evaluates and reports to various regions and equipment manufacturers [7]. The business availability calculation is directly related to the equipment running state determination. However, the operating state determination mode has the following defects: (1) the operating parameters of the device are limited; (2) the observation data quality control algorithm is subject to the local weather process and the characteristics of the underlying surface's impact of specific factors, there are often misjudgments; the normality of the observation data and the operating state of the observation equipment cannot be completely equated; (3) the business form data that is guaranteed to be filled by business personnel often has the phenomenon of incorrect filling, irregular filling, and sometimes pseudo-filling.

Therefore, if the operational state of the equipment is judged solely on the basis of limited equipment state parameters, observed data quality or fault form, there will often be a big difference between the result and the real state of the equipment, which cannot truly reflect the running capacity of the equipment

IV. IMPROVED ALGPRITHM

In order to solve the problem above, Li Yan et al. proposed a comprehensive judgment method of equipment running state based on information of each equipment's own running state, information of meteorological observation elements, and information reported in the form of maintenance and support business [8]. Based on this idea, the operational availability algorithm in meteorological equipment support can be redefined as,

$$A_o = \frac{TT-T_s-T_{\mathrm{no}}}{TT-T_s} \times 100\% \quad (6)$$

Or

$$A_o = \frac{TT-T_s-T_{\mathrm{bad\_parameter}}-T_{\mathrm{down}}-T_{\mathrm{bad\_data}}}{TT-T_s} \times 100\% \quad (7)$$

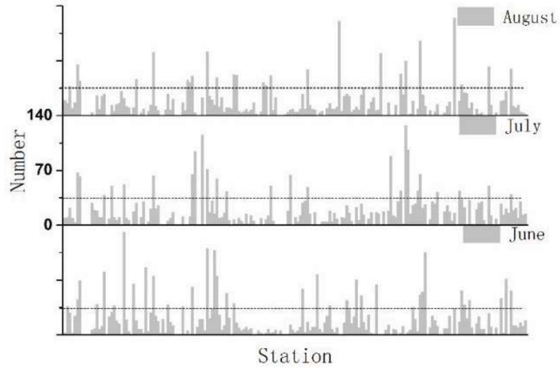
Among which, $T_{\mathrm{bad\_parameter}}$, T_{down} and $T_{\mathrm{bad\_data}}$ respectively correspond to equipment parameter anomaly time or unavailable time, fault duration in the fault form and data error time determined by the quality control result, which are the three times in Fig. 1 inoperable time T_{no}.

V. DISCUSSION

A. Reposition of equipment maintenance

Maintenance is the combination of repair and maintenance, which is a technical management measure to keep the equipment in the prescribed technical state according to the pre-specified plan or the corresponding technical conditions [9].

In the previous availability algorithm, the daily maintenance time T_{pm} is classified as the working time T_{yes}, but the nature of this work is to reduce the auxiliary measures of the fault, which should be classified as repair, inoperable time T_{no} category; in addition, because the current evaluation business doesn't contain the number of maintenance and duration, and the equipment's daily, weekly, monthly, annual maintenance and pre-examination inspection maintenance are counted as available, resulting in the current Maintenance work is not thorough but too frequent, as shown in Fig. 2,



Note: The horizontal dot lines are the maximum monthly maintenance numbers of equipment; the horizontal coordinates are different radar stations, and the vertical coordinates are the total monthly maintenance times corresponding to each station; the maintenance includes daily, weekly, monthly, quarterly maintenance and annual

Fig. 2. Maintenance numbers of 190 weather radars from July-August in 2017

According to the weather radar observation specification [10], the maximum number of monthly average maintenance times of weather radar is 35. However, statistics show that from June to August, the number of sites with more than 35 maintenance times accounted for 19.5%, 13.2% and 13.7% of the total station points respectively, with an average of more than 15%, eight stations for more than 100 times and 55 stations for more than 50 times. The maintenance status of the current evaluation algorithm is calculated according to the available equipment, so, in order to improve the evaluation results of equipment operation and assessment in some stations, when the equipment fails, the status of the equipment is reported as maintenance in ASOM[7], resulting in a false high evaluation index (Fig. 3).

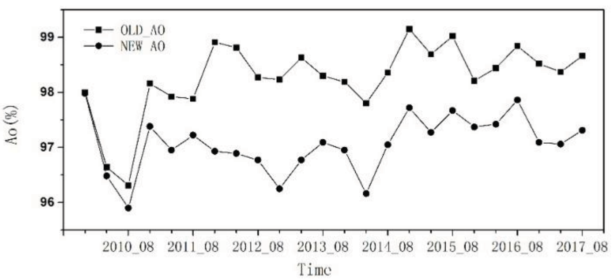


Fig. 3. Comparison of the operational availability of the new and old algorithms from June-August of the national weather radar network from 2010-2017.

As can be found that the operational availability index of the old algorithm in each month of the analysis period is higher than that of the new algorithm, and the old average algorithm is 1.2% higher than the new algorithm. Although preventive maintenance can increase the average maintenance interval of the equipment, if it is too frequent, it will affect the reachable availability of the system.

B. .Utilization of instrument operational parameters

In the current equipment state availability determination method, except for the weather radar and lightning positioning system, the other equipment is reflected by the quality of observation data. At present, there are regularly cases in meteorological equipment observations, that is, when the equipment performance parameters deviate far from the normal range, the observation data is still uploaded and used by the users. Even if the data quality is not yet unavailable, device performance is already unavailable. The peak power of the weather radar transmitter is the main performance parameter of the transmitter, which can reflect the most basic operating conditions of the weather radar to a certain extent, as an example (Fig. 4).

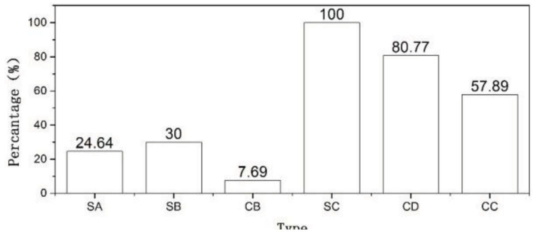


Fig. 4. Peak power anomaly statistics of all types of weather radar transmitters in March 2016.

It can be seen that the number of abnormal peak power parameter stations of 174 operational weather radar transmitters accounts for 45.40% of the total.

Abnormal operation parameters of the equipment means that it is working with disease, and its observation status is evaluated by the observation data obtained under its sub-health state, which is bound to overestimate the actual combat capability of the equipment. Therefore, it is necessary to effectively use the equipment's own operational status information.

At present, the information design of operating state detection of meteorological equipment in China is uneven, but overall, the design of this aspect is not very perfect, more importantly, the utilization rate of existing information is very low (Table. 1).

TABLE 1. STATISTICS OF STATE ALARM POINTS OF WEATHER RADAR

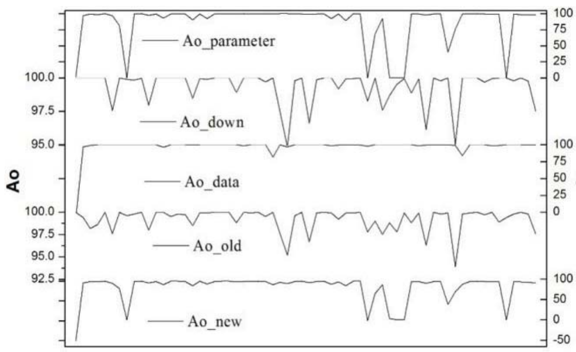
Position (large system)	*Code*	*Number*
Transmitting system	XMT	17
Receiver/signal processor	RSP	47
Servo System	PED	36
Control system	CTR	20
Power distribution system	UTL	27
Archive A	ARCH	6

Note: 115 other (N/A) status alarm points are also provided.

Table. 1 shows the design of the new generation weather radar state information monitoring points in China. At present, there are 153 effective state detection points, among which, only 15 are actually used for equipment state positioning in the current observation equipment operation support service

C. .Processing of overlapping operational status

According to the new algorithm, the equipment operating state is composed of the state determined by the equipment parameters, the state determined by the observed data quality, and the state determined by the equipment fault. The overall service availability of the equipment can be considered as the operational availability $A_{\mathrm{o\_parameter}}$, determined by the state parameters, and the fault-determined availability $A_{\mathrm{o\_down}}$, and the availability of the observed data $A_{\mathrm{o\_data}}$. In the actual business work, the abnormal time of these three often overlap in time or in various combinations, that is, data errors when the equipment parameters are abnormal. At the same time, the station equipment support business personnel reported the fault form. In this case, the comprehensive operational availability A_{o} of the equipment is low or even negative. Weather radar as an example as follows (Fig. 5).



Note: The data period is from June to August 2017

Fig. 5 Operational availability affected by various factors

It can be seen that some operational parameters of weather radar equipment lead to low availability, which is very serious, because the operational parameters of equipment are abnormal for a long time[11]; though equipment normal operation in some weather radar, the poor quality of its acquisition of data, resulting in its low $A_{\text{o\_data}}$; From $A_{\text{o\_parameter}}$, $A_{\text{o\_down}}$, $A_{\text{o\_data}}$ and $A_{\text{o\_new}}$ comparison can be seen that equipment failure, equipment operation parameters and the observation data quality situation of the influence degree of the whole equipment operation ability. In addition, from the results of $A_{\text{o\_new}}$, it can be found that the availability evaluation results of some stations have a negative value because the equipment failure time, equipment parameter abnormal time and data abnormal time overlap in the overall A_{o} calculation, and the calculation is repeated. The time that the device can be used is longer than the time that should be run. Therefore, in order to avoid this, in the back-end evaluation calculation, a strict logical relationship needs to be established between the three

VI. Conclusions and Prospects

Meteorological support is an important means to ensure the stable and reliable operation of the observation system. Availability is a comprehensive reflection of the equipment's own performance, maintenance capabilities and level of assurance.

Based on the current situation of meteorological observation support in China, this study improved the A_{o} evaluation algorithm in China meteorological observation equipment support from three aspects: the operation parameter information of key components of equipment, the equipment fault form filled manually by support personnel and the quality of observation data. The improvement of the operational availability assessment algorithm is in line with the concept of socialization of meteorological support, and also meets the development requirements of smart weather.

The meteorological observation quality management system is designed from the whole process and the whole process. It includes basic business and business technology support, as well as business management [12]. Therefore, the promotion and implementation of China's meteorological observation quality management system (QMS-O-CMA) is an important guarantee for the improvement of the operational capability of meteorological observation equipment and the maximization of operational benefits.

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