K-out-of-n Model to Calculate the Availability of a Business System

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***Abstract*—This paper shows a model to calculate the availability of a business system. K - out - of - n model is a system consists of n parts. When there are at least k parts during normal work, the system can work normally. Also, the paper gives a MTBF usability testing method to test the availability.**

***Keywords*—availability; k out of n model; MTBF**

I INTRODUCTION

Because of the informatization, all kinds of network infrastructure, application system constantly improve and upgrade. There is a growing dependence on information grid system. With the deepening of the process of informatization, informatization gradually entered a period of application and network integration development from the basic network construction, application system construction. The traditional information management can no longer meet the needs of the automation and standardization of information management. There is an urgent need for effective means of scientific management to realize the operation maintenance function, and realize the maximization of interests [1].

In environment of the smart grid, the establishment of an information system for operational monitoring actively monitoring platform is very important, which can realize the management of the information system of the safety equipment and security protection, information filtering of the smart grid environment, active operations of the various controlled equipment monitoring management.

Smart grid business involved in power grid dispatching automation, relay protection and safety equipment, power plant control automation, substation automation, distribution network automation, electric power load control, power market, power user information collection, intelligent electricity and other fields. The smart grid system contains many hardware and software technology, involves many manufacturers products. The complex environment of application system integrated use, the different structure and the infrastructure make it difficult to get a unified management. Branches widely distributed in the system and complex equipment take the challenges for unified management. Parallel network and the present situation of the large users bring difficulties to smart grid operations management standardization work. Mass of network devices, the host server, without a unified platform, application system can't formulate unified management strategy, troubleshooting rate is low, the core business is run normally without effective detection means, unpredictable and take measures in advance. And with the continuous development of information construction, the complex huge infrastructure also in unceasingly thorough, in products, network structure, business relationships continually changing [2].

In the information system of power grid enterprise, even if they deploy with a variety of operational monitoring system, but also often have a business system problem how to find the point of failure. Investigate its reason, mainly is the most current operational monitoring system is separated to monitor the working state of the business system component, such as network, server, database, etc., and the operational monitoring level is low. Especially in the network environment, if only know presented according to a switch port throughput or grouping, it is difficult to find cause of abnormal operation [3]

To solve this problem, an effective way is the construction of an integrated operational monitoring management platform: it is able to run with the organization's current environment matching effectively, help the managers to master the complex information system running state, at the same time, provide management personnel with concise and effective operation monitoring system, help the organization to enhance operational monitoring efficiency. Ensure the effective use of information resources and business operation with high availability, continuity and security [1].

II RELATED WORK

The operational monitoring management information system in early stage focus on individual equipment more such as hardware and network management, mainly take the infrastructure network, then the operational management is through the management of the network devices and monitor and ensure the normal operation of the network. When malfunction come down, system response in time and locate equipment failure. But this kind of system for business system can only carry on the simple management operations. With the mature of enterprise information system, enterprise's focus shifting from the single point of equipment management monitoring to the whole integrated management system [1].

But because the rapid development of technology, IP technology gradually become the key infrastructure of the business for carrying all kinds of data, workflow, the application of interactive, multimedia information. On the one hand, all service in the information system of organization's core business, must depend on IP technology to realize the connectivity, on the other hand, IP technology for access to these complex information system and management provides a good consistency, real-time performance management channel. Based on the IP based network, various network, computing, storage, and application of integrated management become possible.

In the early 1980's, the British government commerce (OGC) in order to improve the efficiency of information equipment and systems, to guarantee the healthy operation of information system of effective service outsourcing management, computer and communications agency is designated to research a kind of method, which is used to guide the efficient and economic operation of the national government department information equipment and systems. And Library of information Infrastructure (IT Infrastructure Library, ITIL) comes out. It brings together the best practices of IT service industry. ITIL is to guide how to define in operations management personnel, process, service, activities and the relationship between guiding framework mouth [4].

ITIL has experienced more than 30 years of development. In 2005, the international organization for standardization based on ITIL made the IS02000 international standards of IT service management. According to the demand of government departments, business groups and the energy industry enterprise development, ITIL can ensure the effect of the IT resources and low cost. Large IT companies and relevant government departments make ITIL get continuous growth and rich. ITIL eventually becomes internationally recognized best practices [5]. And now, ITIL standard is widely used in companies such as Microsoft, HP, IBM, CA, and is put into practice. On the basis of practice, ITIL forme the respective ITSM (information technology service management, IT service management) method theory and products, and become their IT services market brand. Based on ITIL processes and philosophy, user can establish a reasonable working process, reasonable arrangement of personnel, clear responsibilities, avoid fault mutual shuffle. It can help the relevant person in charge of business find and solve the problem, quickly resume business. With the unified monitoring platform, the various monitoring resources are centralized to display and alarm for unified management, overall comprehensive, fast, understand the running status of the current system help operations staff to quickly locate the fault, shortening the time of screening [6].

III K - OUT - OF - N SYSTEM MODELING

K - out - of - n model is a system consists of n parts. When there are at least k parts during normal work, the system can work normally. If there are n - k parts malfunctioned, it will enter a state fault system. K - out - of - n models are common descriptions and fault-tolerant computing research and engineering design model of the redundant system, which can be widely used in fault-tolerant technology of information system. For a given k - out - of - n system, the system will run to the system failure. There is a sequence of failure parts. Every failure of components effect the remaining parts of survival. When the first n - k + 1 components fail, while the rest of the k - 1 parts or normal, the whole system has failed. If we ignore the possible correlation between target system components, it is possible to underestimate the failure rate of the whole system, and to overestimate the analysis of the system availability indicator.

For the normal work of the k - out - of - n system, assumed to satisfy the following conditions:

1) k - out - of - n system, which all the parts are in good condition in the beginning, when the work parts number is less than k or failure parts number is greater than n - k + 1, will enter a state of failure;

2) n component failure events are independent of each other. Assuming failure can immediately be detected, multiple component failure probability is zero at the same time;

3) r maintenance personnel can only repair one part at the same time a part. The events that $1 \le r \le n-k+1$ parts can be repaired are independent of each other. And repair time obey exponential distribution parameter for μ;

4) the system state depends on the number of components in the system failure, such as the system is in state i said i have a component failure;

5) during the system running, all load borne by the current live parts evenly, foe example if the system is in state i, which means there are i components in failure state, then the full system load will be split by residual n -i the parts.

6) when system is in i state, the single component obeys exponential distribution parameter λ_i, α_i indicates the failure rate of system in the state i, μ_i says the system is the repair rate in state i.

When the system is in state 0, the failure rate of each parts is λ0. There are n possible components failed at this time, so the probability of state 0 to state 1 is $\alpha_0 = n\lambda_0$; When the system is in state 1, the failure rate for each component is λ_1.The component failure may occur n – 1 conditions, so the probability of state 1 to state 2 is $\alpha_1 = (n-1)\lambda_1$, and the rest of n - 1 parts divide all load. The transition probability of state 0 to the state 1 is $\mu_1 = \mu$;When the system is in state i, component failure has n – i conditions, failure rate for live parts is λ_i, the system will have probability of $\alpha_i = (n-i)\lambda_i$ into the i+1 state, and n - i live parts divide all loads.

Given a random variable N (s) stands for the number of failure parts in the interval (0, s), and N (0) = 0. Apparently random process {N (s), s acuity 0} independent increment, and does not occur at the same time two component failure, therefore {N (s), s≥0} is an independent increment, and it won't happen that there are two failed parts at a same time.

Given Ti which stand for the time staying in each state. It is a set of random variables of two parameter weibull distribution. The correlation of the time Ti of system in state i-1 with the time after system state i, is the affect of the ith falied part to the rest parts. Given Si stand for the time point of ith part failed, and there are $S_t = \sum_{j=1}^{t} T_j$. The Copula function of multidimensional random variables (T1, T2,..., Tn - k) which are composed with the above a set of random vector , is a marginal distribution function F1 (t1), F2 (t2),...(tn, Fn - k - k) of the multivariate distribution function, and has the Gumbel copulas connect functional form.

Given a sequence of failure parts, the correlation coefficients between the part i and part j in failure sequence can use rij to measure, correlation coefficients between all the parts can be said as a correlation matrix R = (rij), one of them

$$r_{ij} = \begin{cases} \tau_{ij}, 1 \le i < j \le n-k+1 \\ 1, \quad i = j \\ 0, \quad i > j \end{cases} \tag{1}$$

K - out - of - n system component failure sequence correlation matrix calculation algorithm is as follows

K - out - of - n system component failure sequence correlation matrix calculation algorithm
Input: n, k, the system state set {0, 1,..., n - k}, component failure time sequence T1, T2,...Tn - k + 1, output: related to the matrix R = (r_{ij}) steps: 1. Calculate single component failure rate in system 0 condition 2. Calculate the failure rate system in each state 3. The timing of the system state transition sequences $S_m = \sum_{1 \le m} T_i$,m∈ {1,2, ..., n − k + 1} 4. Ues $\alpha_m = \lambda_0 \gamma S_{m+1}^{\gamma-1}$ to calculate γ 5. Use λ_0 and γ to get the distribution function T_i $u_i = e^{\lambda_0 S_{i-1}^{\gamma}} e^{-\lambda_0 (S_{i-1}+t)^{\gamma}}$,i=1,2,…,n-k 6. The correlation coefficient calculation for i=1:n-k for j=i+1:n-k+1 Kendall rank correlation coefficient calculation end end 7. Return R=(r_{ij}), in which $r_{ij} = \begin{cases} \tau_{ij}, 1 \le i < j \le n-k+1 \\ 1, i = j \\ 0, i > j \end{cases}$

IV OUR EXPERIMENT

We put forward a project based on the threshold of MTBF usability testing method, it can be in a shorter test period and make full use of a small amount of the system under test, test verification system can reach purchase demand for usability metrics

For a given repairable k - out - of - n system, if the system steady-state availability for a given value is a, then you can always find a minimal positive integer minb, when work than B minb or maintenance time, meet

$$(k-1)!\left(\frac{B^{n-k+1}}{n!} + \frac{B^{n-k}}{(n-1)!} + \frac{B^{n-k-1}}{(n-2)!} + \cdots + \frac{B^1}{k!} + \frac{B^0}{(k-1)!}\right) \ge \frac{1}{1-a} \tag{2}$$

In which B=$\frac{MTBF}{MTTR}$

Average trouble-free operation index MTBF (mean time between failure) refers to the repairable k for a given threshold k - out - of - n system, if a single redundant component in the mean times to repair MTTR (mean time to recover) index can be obtained by measuring, the MTBF of the redundant parts of threshold value is defined as min MTBF = minb*MTTR.

And MTBF mean for a given threshold value theorem can repair k - out - of - n system, if a single redundant component in the mean times to repair can be obtained by measuring the MTTR indicators, for a given system steady-state availability forecasts a, we can always find min*MTBF redundant components, as long as the average trouble-free operation time redundant components index MTBF > min*MTBF, there will be established system availability A > a.

It can be seen from the MTBF threshold value theorem, that for a k - out - of - n redundant system, if the MTTR of the redundant components are measurable, we do not need to measure the whole system by using the method of online test for a long time availability index, just in a relatively short period of time of redundant components MTTR and MTBF testing. As long as you can verify its component index MTBF is greater than its MTBF threshold, can explain the given k - out - of - n redundant systems to achieve a given level of usability.

V CONCLUSION

This paper designed and implemented a K - out - of - n system modeling to get the data of a system. In addition, we design a MTBF threshold value theorem to test the system. By using such evaluation model, system can be analyzed, and it can help system manager to evaluate the availability. We hope these works be a theoretical and practical guide for future research.

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