二模冗余变电站微机监控系统的可靠性分析

孙　莹　山东工业大学电力系 (250061)

【摘要】 本文介绍了一种二模冗余的变电站微机保护及监控系统, 结合本系统分析了二模冗余系统的可靠度, 讨论了容错技术在提高系统可靠率方面的作用。

【关键词】 冗余　容错　变电站　微机监控

引言

目前, 提高系统可靠性的途径通常有两种, 一是“避错”, 即完善设计, 具体地说: 就是在产品的设计和生产过程中努力将出错、出故障排除在外, 争取尽善尽美; 另一种是“容错”, 即认为保证系统不出故障或不出错是不可能的, 但利用一些外加资源使系统在发生故障时不致瘫痪失效, 避免灾难性损失, 能恢复系统的正常运行或维持系统的准正常运行。

对于变电站微机保护及监控系统这种要求可靠率很高, 无故障运行时间很长的计算机系统, 单靠微机系统的完善设计显然是不现实的, 必须利用冗余容错技术来提高其可靠性。

1　系统结构介绍

变电站微机保护及监控系统主要由电量变送器、隔离继电器、输出继电器、STD 工业控制机、可编程控制器组成, 系统结构如图 1。电力系统线路、变压器等一次设备的二次交流电流、电压经电量变送器变换为与交流量成线性比例的 0～10V 直流电压信号送入工控机的 A/D 板, 断路器辅助触点、瓦斯继电器等触点也经带光隔的开关量板转换为+5V 直流电压信号, 整个变电站的所有模拟量和开关量信号均由工控机的 CPU 集中采集和处理, 当电力系统事故发生时, CPU 发出的继电保护跳闸命令经由开关量输出板启动继电器来实现。

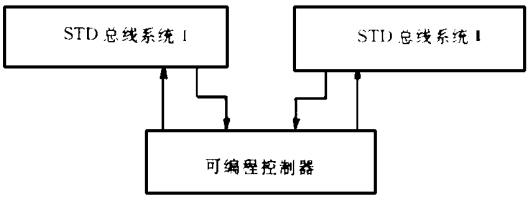

图 1　系统结构图

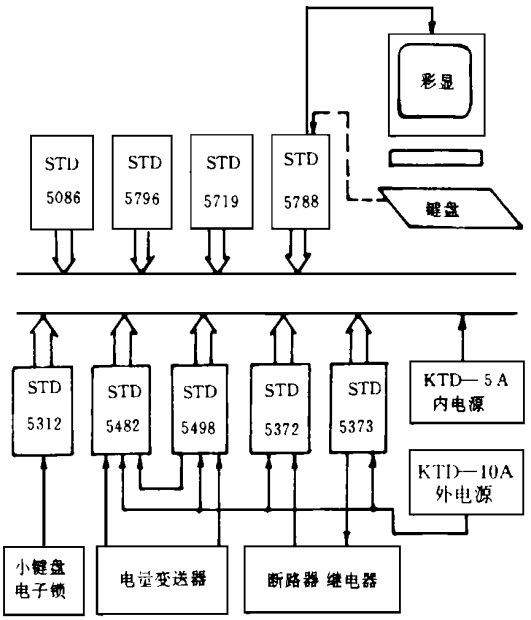

图 2　主机硬件配置图

系统主机采用 STD 5000 工业控制总线, 其硬件配置见图 2。本系统采用的两套主机互为备用, 可编程控制器作为检测和切换部件。工作的主机称工作机, 待命的主机称备用机, 检测和切换部分称为切换部件。工作机的 CPU 对 STD 总线各模板进行自检, 当各模板工作均正常时, CPU 向切换部件定时发出应答信息, 若间隔一定的时间切换部件收不到工作机的应答信息,

收稿日期: 1996—10—28

则将工作机退出运行, 同时让备用机接替工作机的工作。

2 可靠度分析

该系统属于冷储备系统, 系统逻辑图见图 3。

当系统的工作模块失效时, 备份模块接替工作, 被替下的模块不进行修复, 直到备份模块也工作到失效时, 系统才失效; 假设备份单元在储备期间不失效, 并假定切换开关 D 的可靠度 $R_d(t) = 1$。

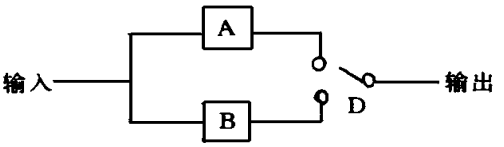

图 3 系统逻辑图

设两个模块的寿命分布服从指数分布; 失效率分别为 λ_1 和 λ_2, 模块的可靠度分别为 $R_1(t) = e^{-\lambda_1 t}$ 和 $R_2(t) = e^{-\lambda_2 t}$; 概率密度函数分别为

$$f_1(t) = \lambda_1 e^{-\lambda_1(t-x)} \tag{1}$$

$$f_2(t) = \lambda_2 e^{-\lambda_2 t} \tag{2}$$

根据卷积公式, 则系统的寿命分布密度函数为

$$\begin{aligned} f_s(t) &= \int \lambda_1 e^{-\lambda_1(t-x)} \lambda_2 e^{-\lambda_2 x} dx \\ &= \lambda_1\lambda_2 e^{-\lambda_1 t} \int e^{-(\lambda_2-\lambda_1)x} dx \\ &= \lambda_1\lambda_2 e^{-\lambda_1 t} \int \frac{1}{-(\lambda_2-\lambda_1)} e^{-(\lambda_2-\lambda_1)x} d[-(\lambda_2-\lambda_1)x] \\ &= \lambda_1\lambda_2 e^{-\lambda_1 t} \frac{1}{-(\lambda_2-\lambda_1)} [e^{-(\lambda_2-\lambda_1)x}]_0^t \\ &= \lambda_1\lambda_2 \frac{e^{-\lambda_1 t} - e^{-\lambda_2 t}}{\lambda_2-\lambda_1} \end{aligned} \tag{3}$$

系统的可靠度为

$$\begin{aligned} R_s(t) &= \int_t^\infty f_s(t)\,dt = \int_t^\infty \lambda_1\lambda_2 \frac{e^{-\lambda_1 t} - e^{-\lambda_2 t}}{\lambda_2-\lambda_1} dx \\ &= \frac{\lambda_1\lambda_2}{\lambda_2-\lambda_1} \int_t^\infty (e^{-\lambda_1 t} - e^{-\lambda_2 t})\,dx \\ &= \frac{\lambda_1\lambda_2}{\lambda_2-\lambda_1} \left(-\frac{1}{\lambda_1} e^{-\lambda_1 t} + \frac{1}{\lambda_2} e^{-\lambda_2 t}\right) \\ &= \frac{\lambda_2}{\lambda_2-\lambda_1} e^{-\lambda_1 t} + \frac{\lambda_1}{\lambda_1-\lambda_2} e^{-\lambda_2 t} \end{aligned} \tag{4}$$

如果 $\lambda_1 = \lambda_2 = \lambda$, 则有概率密度分布函数

$$\begin{aligned} f_s(t) &= \int \lambda e^{-\lambda(t-x)} \lambda e^{-\lambda x} dx \\ &= \lambda^2 e^{-\lambda t} \int 1 \cdot dx \\ &= \lambda^2 t e^{-\lambda t} \end{aligned} \tag{5}$$

系统可靠度

$$\begin{aligned} R_s(t) &= \int_t^\infty \lambda^2 x e^{-\lambda x} dx = \lambda^2 \int_t^\infty x e^{-\lambda x} d(-\lambda x) \\ &= -\lambda \int_t^\infty x e^{-\lambda x} d(-\lambda x) \end{aligned} \tag{6}$$

用分部积分法, 得

$$R_s(t) = -\lambda\{[xe^{-\lambda x}]_t^{\infty} - \int_t^{\infty} e^{-\lambda x}dx\}$$

$$= -\lambda\{-te^{-\lambda t} - \frac{1}{\lambda}e^{-\lambda t}\}$$

$$= (1+\lambda t)e^{-\lambda t} \tag{7}$$

当 $\lambda = 6.25\times10^{-5}$ 时, 则双机容错系统可靠度 $R_s(t)$ 与单机系统可靠度 $R_1(t)$ 比较见图 4。由图可见, 采用双机容错系统可大大地提高系统的可靠性。

3　切换开关不完全可靠的系统可靠度分析

上面推导可靠性数学模型时, 都是在假定切换开关百分之百的可靠, 即 $R_d(t) = 1$ 的前提下进行的, 而实际上, 绝对可靠的元器件是没有的。如果假定切换开关的可靠度 $R_d(t)$ 不是 1, 而是 $e^{-\lambda_d t}$, 当两个模块的可靠度分别为 $e^{-\lambda_1 t}$ 和 $e^{-\lambda_2 t}$, 则系统的可靠度

$$R_s(t) = e^{-\lambda_1 t} + \frac{\lambda_1}{\lambda_d+\lambda_1+\lambda_2}[e^{-\lambda_1 t} - e^{-(\lambda_1+\lambda_2+\lambda_d)t}] \tag{8}$$

当 $\lambda_1 = \lambda_2 = \lambda$ 时, 则系统的可靠度为

$$R_s(t) = e^{-\lambda t} + \frac{\lambda}{\lambda_d}[e^{-\lambda t} - e^{-(\lambda_d+\lambda)t}] \tag{9}$$

由 9 式可以看出, 切换开关的可靠性是个很重要的因素, 为此, 我们选取了可靠度很高的可编程控制器作为切换装置。

4　结语

通过对二模冗余系统的可靠度分析可以看出, 对于要求可靠性很高、无故障运行时间很长的系统, 利用二模冗余容错技术是提高系统可靠性的重要途径。将有故障的模块脱离系统, 修复后再恢复运行, 又可使双机系统无故障运行时间大大延长。我们利用该技术设计了 110kV 变电站微机保护及监控系统, 运行实践表明, 可靠性大大提高。

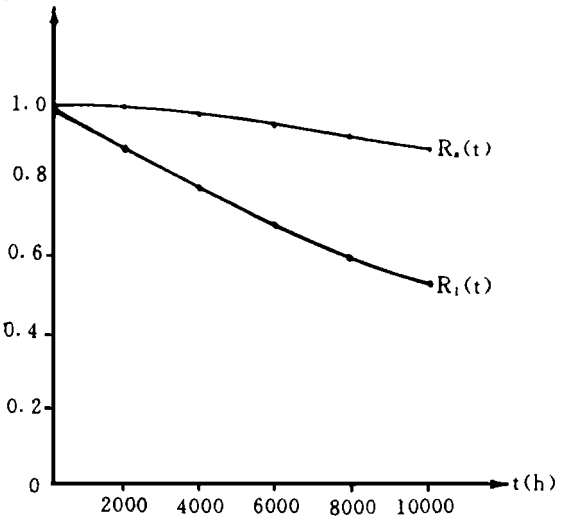

图 4　双机容错系统与单机的可靠率比较

参考文献

1　唐永洪 . 系统可靠性、故障诊断及容错 重庆: 重庆大学出版社, 1990

2　巍庆福 . STD 总线工业控制机的设计与应用 . 北京: 科学出版社, 1991

3　段际杰等。遥测系统中的软件容错设计 . 电子测量与仪器学报, 1992, No. 2, 56～65

RELAY

Vol. 25 No. 4 August 1997

CONTENTS AND ABSTRACTS (Partial)

THEORETICAL STUDY AND CALCULATION

The Influence of Capacitance Current to differential Protection and Its Compensation Scheme ..... **Wu Yekai, Zou Dongxia** (4)

The influence of distributed Capacitance of UHV distant transmission line to current differential protection is analyzed and the corresponding capacitance current compensation scheme is presented in this paper. The scheme is simple and practical, not only increasing security during short- circuit beyond protected zone but also improving sensitivity at fault within the protected zone.

Key words: Distributed capacitance Current differential protection Capacitance current compensation

Feasibility Study on Whole Line Fault High Speed Clearing Protection for Distribution Power System ..... **Pan Zhencun et al** (9)

A new concept of whole line fault high speed clearing protection is introduced according to the structure of urban distribution power system and requirement of power supplying. Feasibility study on this protection is carried out. A practical implement scheme of this protection, which measures the electrical signal on both sides of the protected line is presented.

Key words: Distribution power system Line protection High speed relay Feasibility

One Convenient Method for Modifying Bus- Impedance Matrix in Open Circuit State ..... **Wang Chun et al** (12)

The computating formulas for modifying bus- impedance matrix in open circuit state are derived in this paper. They are convenient to calculate and easily programmed. They have been used in fault- calculating program.

Key words: Open circuit fault Bus- impedance matrix Line with zero- sequence mutual impedance

The Method of Deriving Magnetization Curve When Using Magnetic Characteristic to Discriminate Energization Inrush of Transformer ..... **Zhang Yan et al** (16)

A new method of deriving magnetization curve of transformer- - the approximating function optimization is presented to meet the requirement of using magnetic flux characteristic to discriminate the energization inrush current in transformer. Actual calculation shows that the magnetization curve derived by the method is of high accuracy and its error is within 1%, thus it can meet the requirement of transformer differential protection.

Key words: Power transformer Magnetization curve Energization inrush

NEW TECHNICAL RESEARCH AND APPLICATION

Reliability Analysis on The microcomputer Supervisory Control System for Substation by Using Two- Model Redundancy Technology ..... **Sun Ying** (19)

A microcomputer protection and supervisory control system for substation by using the two- model redundancy technology is briefly described. With reference to the system, the reliability of the two- model redundancy system is analyzed and effect of fault- tolerant technique in improving the reliability of the system is also discussed.

Key words: Redundancy Fault- tolerant Substation Microcomputer supervisory control

A New Method to Realize the Digital Impedance Relay ..... **Jin Ming** (22)

A new method to realize the digital impedance relay based on microcomputer is described in this paper. The new method utilizes ANN (artificial neural network) and is available for all kinds of relay characteristics which are used in power system. Some examples are used to test the new algorithm and the results show the algorithm performs well.

Key words: ANN Impedance relay Distance protection

Microcomputer Based Single Phase Earthed Protection of Generator stator Winding of Secondary Harmonic Mould ..... **Yan Zhuosheng et al** (26)

A single phase earthed protection of generator stator winding is presented in this paper. It is realized by de-