应用技术

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1 000 MW 机组高、低压旁路系统可靠性分析及改造策略

马　旭,白广臣,邱　杨
(神华广东国华粤电台山发电有限公司,广东 台山 529228)

摘　要: 为了提高 1 000 MW 机组在厂用电全部失去的情况下高、低压旁路系统的可靠性,通过分析高、低压旁路系统在机组跳闸过程中存在的问题,实施技术改造措施,将油动机控制电源接至 UPS,并将原双侧进油油动机改造成带安全模块单元和关闭弹簧的油动机。改造后的试验验证达到了油站电源失去关闭低压旁路阀的预期效果。通过此次技术改造,消除了高、低压旁路系统运行中存在的安全隐患,提高了高、低压旁路系统的可靠性。

关　键　词: 厂用电全部失去; 机组跳闸; 旁路系统; 可靠性; 试验验证; 改造
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引　言

1 000 MW 机组高、低压旁路系统的可靠性在很大程度上取决于控制系统和油动机能否正确动作,当高、低压旁路阀油站失去动力电源和控制电源时,将出现高、低压旁路阀不受控制以及低压旁路阀无法关闭等恶性设备事故,严重时将威胁汽轮发电机组的安全运行。因此,提高 1 000 MW 机组高、低压旁路系统的安全可靠性显得尤为重要。

以某 1 000 MW 机组为例,分析机组跳闸、厂用电全部失去的情况下,高、低压旁路阀的动作情况,并对存在的问题提出了技术改造方案,取得了预期的效果。

1　概述

1.1　高、低压旁路系统

某 1 000 MW 机组配备 100% 锅炉最大连续蒸发量的高压旁路和 65% 锅炉最大连续蒸发量的低压旁路组成的两级串连旁路系统。高压旁路阀包括 4 套,低压旁路阀包括 2 套,高、低压旁路阀各配 1 套液压油站(以下简称油站) 控制高、低压旁路阀的开关,旁路系统如图 1 所示。

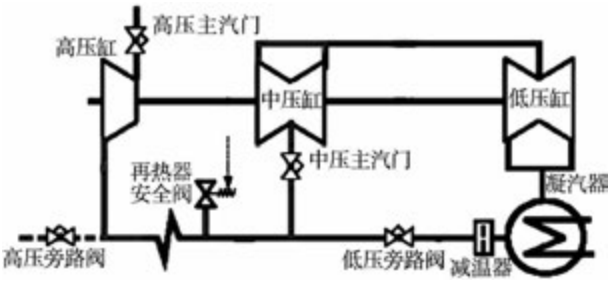

图 1　旁路系统示意图
Fig. 1 Schematic diagram of a by pass system

1.2　高、低压旁路阀油站的电源设置

高、低压旁路阀油站电源由机组保安段提供,保安 A 段、B 段各引一路电源分别接至高、低压旁路阀油站。

机组正常运行时保安段电源由厂用变压器提供,厂用变压器失去后由备用变压器提供,备用变压器失去后由柴油发电机提供,柴油发电机失去后则 380 V 电源全部失去。

1.3　机组跳闸前设备运行状态

机组负荷 660 MW,各系统参数均在正常运行范围内,厂用电由厂用变压器提供,备用变压器、柴油发电机均在备用状态,高、低压旁路阀处于全关位置。

1.4　机组跳闸过程中高、低压旁路阀动作情况

2010 年 11 月 12 日,机组主变压器重瓦斯保护动作,主变压器跳闸导致机组跳闸。机组跳闸后厂用变压器电源失去,6 kV 厂用电失去。备用变压器启动不成功,启动柴油发电机过载跳闸,380 V 保安 A、B 段电源失去。厂用电全部失去后,辅机全部跳闸。

机组跳闸过程中,高压旁路阀动作全部开启,

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作者简介: 马　旭(1983 -) ,男,辽宁铁岭人,神华广东国华粤电台山发电有限公司工程师.

A、B 侧低压旁路阀保护动作，A 侧低压旁路阀开到 11% 后关到零，并且反馈消失，B 侧低压旁路阀自动调节从 35% 关到 25% 后，开度反馈 25% 消失。保安段电源恢复后，B 侧低压旁路阀人工关到零位。A、B 侧低压旁路阀动作曲线如图 2 所示。

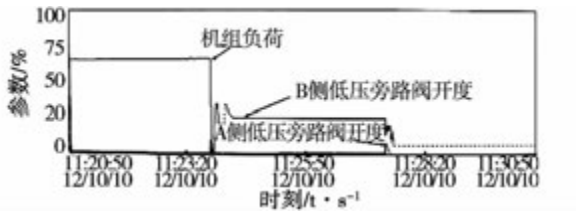

图 2 厂用电全部失去 A、B 侧低压旁路阀动作曲线

Fig. 2 Action-taking curves of the low pressure bypass valve at the side A and B at a loss of all the plant service power supplies

机组跳闸过程中，由于低压旁路阀油站电源全部失去导致 A、B 侧低压旁路阀失去控制无法操作，保持了一定的开度。同时由于 6KV 厂用电失去，凝结水泵跳闸失去减温水，大量高温高压蒸汽直接进入凝汽器，导致低压缸部分动、静叶片处的径向汽封片局部脱落并被加热到熔融状态，冷却后汽封片熔融物凝固在低压缸动、静叶片径向汽封处，发生了低压缸与转子抱死的恶性设备事故。

2 存在的问题及改造措施

高、低压旁路阀油站电源包括动力电源和控制电源，动力电源为 380 V 交流电，控制电源为 24 V 直流电；高、低压旁路阀油站的内部电源分为两路，一路 380 V 电源接至油站动力油泵（以下简称油泵），一路 380 V 电源经过变压器转换成 24 V 直流控制电源，控制油站的油泵和各油动机的三位四通电磁阀及安全模块的电磁阀，从而控制各阀门的开关状态。

高、低压旁路阀油站的外部电源设计时接在机组保安段，当保安段电源失去后，动力电源和控制电源全部失去，造成高、低压旁路阀失去控制。因此，高、低压旁路阀油站电源在设计之初便存在一定的安全隐患，未充分考虑到厂用电全部失去的恶劣工况。

高、低压旁路阀油站分别设计有 4、6 个 50 L 的蓄能器，蓄能器内气囊上部充有 10 MPa 的氮气，油泵正常运行时蓄能器气囊被压缩压力为 17 – 18 MPa，根据 1 000 MW 机组高、低压旁路阀的设计，当油泵失去后蓄能器能保证高、低压旁路的所有阀门开关一次，因此只要保证任何工况下控制电源不失去，便可保证对高、低压旁路阀的控制。

改造措施：保持原高、低压旁路阀油站控制电源不变，从 220 V UPS 电源引一路经过变压器转换成 24 V 直流控制电源备用，以保证即使保安段电源失去，高、低压旁路阀油站控制电源不失去，确保高、低压旁路阀随时可控。

低压旁路阀油动机的设计为双侧进油型，依靠三位四通电磁阀控制油动机上下腔室进油、回油，从而控制阀门的开关状态，这种类型的油动机通常提升力大、时间常数小、可靠性较高。但是，当油动机控制电源失去或低压旁路阀油站发生故障时，阀门将失去控制无法操作，给设备的安全运行带来了隐患。

与双侧进油油动机相比，单侧进油油动机即使失去油动机控制电源或油站发生故障时，阀门依靠油动机的关闭弹簧，仍然可以保证正常关闭。同时，为保证当控制电源失去时油动机下部腔室的存油不影响阀门的关闭，需要设置安全模块单元，如图 3 所示。

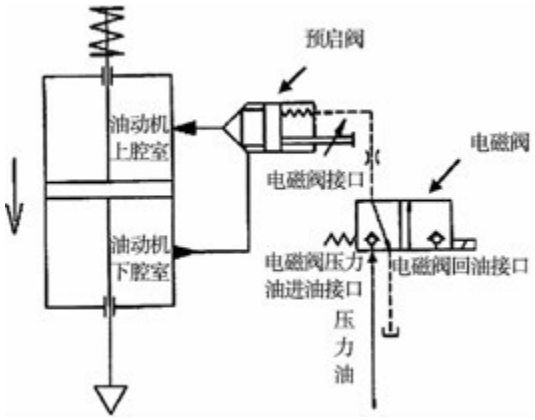

图 3 安全模块单元

Fig. 3 The security module unit

安全模块单元的电磁阀工作时常带电，电磁阀接口连到电磁阀压力油进油接口，预启阀依靠压力油关闭。电磁阀不带电时激活安全模块单元，这时电磁阀回油接口和电磁阀接口相连，预启阀依靠弹簧力打开，此时油动机的上腔室和下腔室连通，油压相互平衡。

改造措施：保留油动机上、下 2 个腔室，在油动机上部增加关闭弹簧，对低压旁路阀油动机加装安

全模块单元，改造后的油动机油路原理图如图 4　　所示。

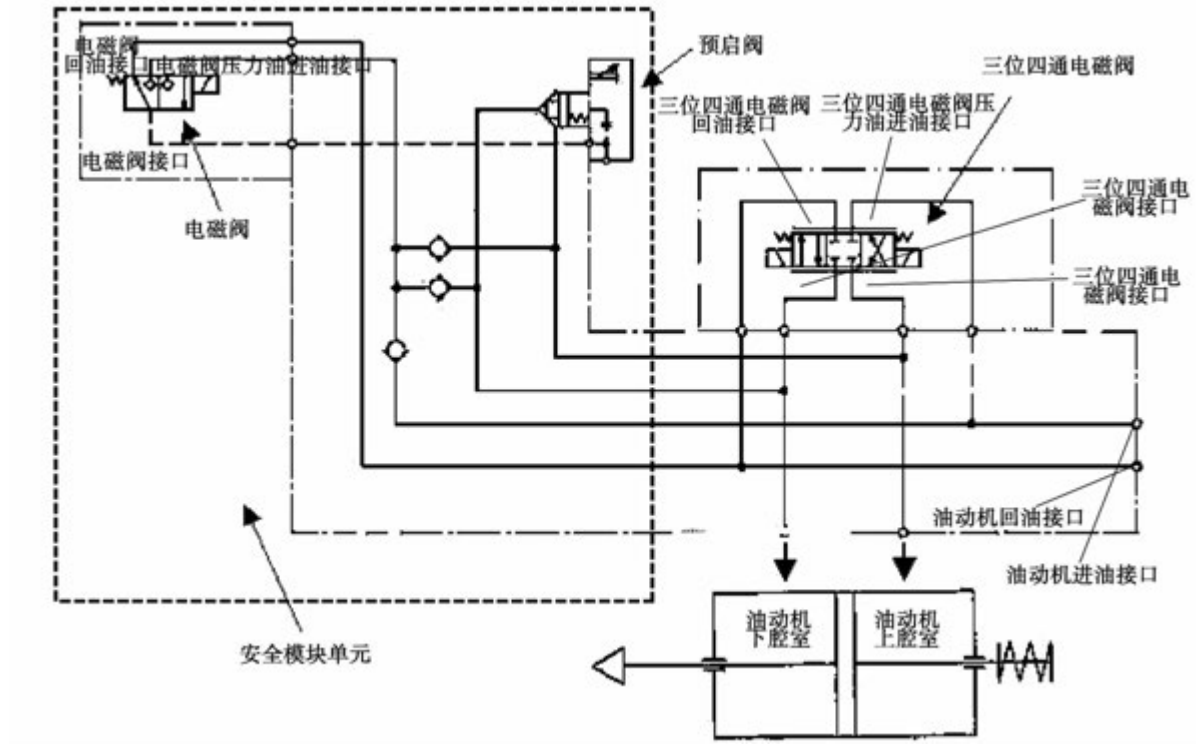

图 4　低压旁路阀油动机改造后原理图

Fig. 4 The principle diagram of hydraulic oil cylinder after transformed

低压旁路阀关闭时，三位四通电磁阀压力油进油接口和三位四通电磁阀接口 A 导通、三位四通电磁阀回油接口和三位四通电磁阀接口 B 导通，油动机进油接口通过三位四通电磁阀压力油进油接口和三位四通电磁阀接口 A 与油动机上腔室连接，油动机回油接口通过三位四通电磁阀回油接口和三位四通电磁阀接口 B 与油动机下腔室连接。安全模块单元的电磁阀工作时常带电，电磁阀接口连到电磁阀压力油进油接口，预启阀被关闭。压力油进入油动机上腔室推动活塞将阀门关闭。低压旁路阀开启时，三位四通电磁阀压力油进油接口和三位四通电磁阀接口 B 导通、三位四通电磁阀回油接口和三位四通电磁阀接口 A 导通，油动机进油接口通过三位四通电磁阀压力油进油接口和三位四通电磁阀接口 B 与油动机下腔室连接，油动机回油接口通过三位四通电磁阀回油接口和三位四通电磁阀接口 A 与油动机上腔室连接。安全模块单元的电磁阀工作时常带电，电磁阀接口连到电磁阀压力油进油接口，预启阀被关闭。压力油进入油动机下腔室推动活塞将阀门开启。阀门处于开启状态油站电源失去时，安全模块单元的电磁阀电源失去激活安全模块单元，电磁阀回油接口和电磁阀接口相连，预启阀依靠弹簧力被打开，此时低压旁路阀油动机的上腔室和下腔室连通，通过油动机上部的弹簧实现低压旁路阀快速关闭，改造前、后油动机结构对比图如图 5 所示。

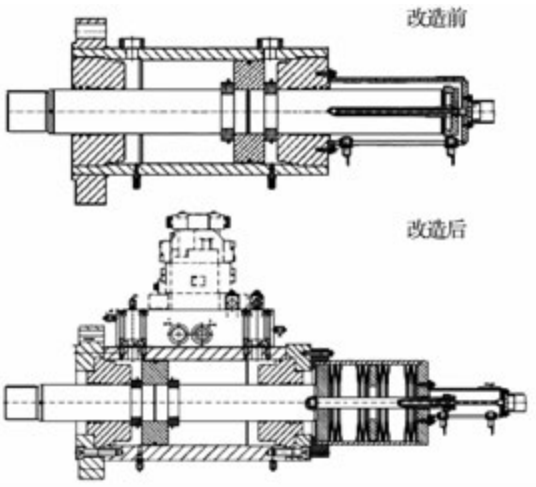

图 5　改造前、后油动机结构对比图

Fig. 5 The contrast figure of hydraulic oil cylinder structure before and after transformed

3 改造后的试验验证

由于本次技术改造针对低压旁路阀油站电源全部失去导致低压旁路阀无法操作,因此改造后模拟低压旁路阀油站电源全部失去的工况进行试验是检验本次改造是否成功的关键。试验前,低压旁路阀油站正常运行,A、B 侧低压旁路阀开至 50%。试验采取同时断开低压旁路阀油站动力电源开关和控制电源开关的方法进行。断开 2 个开关后,即低压旁路阀油站电源全部失去,A、B 侧低压旁路阀从 50%开度关闭至零位,证明本次技术改造是成功的。

4 结 论

1 000 MW 机组高、低压旁路阀油站外接电源设计和低压旁路阀油动机设计时,未充分考虑到当高、低压旁路阀油站失去电源后阀门失去控制无法操作的极端恶劣工况,因此造成了汽轮机低压缸与转子抱死的恶性设备事故。

改造后采用对高、低压旁路阀油站增设控制电源,对低压旁路阀油动机增加关闭弹簧和安全模块单元的方式,通过改造后的试验验证,证明了这种改造方法满足当低压旁路阀油站电源全部失去时关闭低压旁路阀的要求,进一步提高了汽轮发电机组运行的安全性。

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(单丽华 编辑)

新技术、新工艺

西伯利亚油田 12 台基本负荷功率 501 – KB7 燃气轮机

DOI:10.16146/j.cnki.rndlgc.2015.03.042

据《Gas Turbine World》2013 年 11 – 12 月刊报道,Centrax 公司已 5.2 MW 501 – KB7 燃气轮机的试运行,这些燃气轮机发电机组被安装在莫斯科以东约 1 600 公里西西伯利亚平原秋明地区乌斯基特古斯油田的电站。

秋明地区整个一年的平均温度约为 1.3 ℃,并且一年的大部分时间是处在冰点以下。燃气轮机机组利用从钻井作业回收的煤气为原料,这些煤气通常作为火炬气被白白地燃烧掉。

燃气轮机发电机组的模块设计和制造也有助于迅速和方便地安装、试运行和维护。

在 15 ℃海平面现场条件下,利用天然气作为燃料,501 – KB7 燃气轮机发电机 ISO 条件下基本负荷的额定输出功率为 5 245 kW,热耗率为 11 445 kJ/kWh(31.5%效率)。

(吉桂明 摘译)

半纤维素高温纯蒸汽气化微观反应机理研究 = **Study of the Mechanism Governing the Microscopic Gasification Reaction of a Hemi-cellulose Pure Steam at a High Temperature**[刊,汉]XIONG Jia-jia,TIAN Hong,CAO Xiao-ling (College of Energy Source and Power Engineering,Changsha University of Science and Technology,Changsha,China,Post Code: 410004),DENG Sheng-xiang (College of Energy Science and Engineering,Central South University,Changsha,China,Post Code: 410083) //Journal of Engineering for Thermal Energy & Power. -2015,30(3). -466 -473

By adopting the method in the density function theory (DFT),studied was the mechanism governing the gasification reaction of the high temperature steam of hemi-cellulose xylan in its typical temperature range (700 ~ 1500K) which serves as the object modeled. A total of eight reaction approaches were designed and the xylan in the form of open rings formed its chain type structure IM1 and through a series of process such as dewatering and degradation etc.,2-furfural,acetic acid,methane and CO etc. products were eventually obtained. It has been found that in a certain temperature range,the Gibbs free energy variations in various reaction approaches will increase with an increase of the temperature,however,when the temperature exceeds 1 300 K,the Gibbs free energy will begin to gradually decrease. At a same temperature,the Gibbs free energy variation in the approach No. 4 is less than those of other approaches and the reaction potential barrier in approach No. 4 is the minimum,being only 183 kJ/mol,hence,the reaction approach No. 4 is deemed as the optimum approach for the gasification of xylan. **Key Words**: hemi-cellulose,density extensive function theory,pure steam gasification at a high temperature,microscopic reaction mechanism

1 000 MW 机组高、低压旁路系统可靠性分析及改造策略 = **Analysis of the Reliability of the HP and LP By-pass System of a 1 000 MW Unit and Its Reconstruction Tactics**[刊,汉]MA Xu,BAI Guang-chen,QIU Yang (Shenhua Guangdong Guohua Yuedian Taishan Power Generation Co. Ltd.,Taishan,China,Post Code: 529228) //Journal of Engineering for Thermal Energy & Power. -2015,30(3). -374 -477

To enhance the reliability of a HP and LP bypass system of a 1 000 MW unit in the case of a total loss of the plant service power supplies,through analyzing the problems existing in the tripping process of the unit,by adopting a technical reconstruction method,the control power supply of the oil servo-motor was connected to a UPS and the original oil servo-motor supplied with oil at both sides was modified into one with a safety modular unit and closing spring. The verification test after the reconstruction had achieved the expected effectiveness to close the LP bypass valve when a failure to the power supply for the oil station occurred. Through this technical modification,the hidden safety troubles existing in the operation of the HP and LP bypass system were eliminated,thus enhancing the relia-

bility of both systems. **Key Words**: total loss of plant service power supplies, unit tripping, bypass system, action process, reconstruction, reliability, verification test

1 036 MW 超超临界燃煤机组锅炉等离子点火系统的设计及应用 = **Design and Applications of a Plasma Ignition System for a 1 036 MW Ultra-supercritical Coal-fired Boiler Unit**[刊,汉]ZHONG Bin, LI Geng, QIAN Feng, LIU Yan-tao (Shenzhen Orient Boiler Control Co. Ltd., Shenzhen, China, Post Code: 518057) //Journal of Engineering for Thermal Energy & Power. -2015, 30(3). -478 -481

Described were the principles for the plasma ignition technology. For the Boiler No. 4 of a 1036 MW ultra-supercritical coal-fired unit in a domestic power plant, a plasma ignition system equipped with low NO_x plasma pulverized coal burners was designed. On this basis, the authors made it realized that the flow field formed by using plasma pulverized coal burners and the pulverized coal concentration distribution is controllable. The simulation calculation results by using the software Fluent and the practical operation effectiveness show that when the plasma pulverized coal burners serve as the ignition ones, the plasma ignition system can maintain a stable operation and has a high burn-out rate of the pulverized coal, the temperature and pressure rise speed of the boiler meeting the requirements stipulated in the operation specifications. When the plasma pulverized coal burners serve as the primary ones, the flow field and the pulverized coal concentration distribution originally designed for the boiler can be restored very well, thus guaranteeing that the performance of the boiler can meet the design requirement. **Key Words**: plasma ignition, pulverized coal burner, plasma generator, oil-free start-up

火电厂循环水泵节能提效研究 = **Study of the Enhancement in the Efficiency of a Circulating Water Pump in a Thermal Power Plant**[刊,汉]CUI Chuan-tao, CHANG Hao, WANG Bao-yu, ZHUANG Zhao-yi (Huadian Electric Power Science Research Institute, Hangzhou, China, Post Code: 310030) //Journal of Engineering for Thermal Energy & Power. -2015, 30(3). -482 -486

In the light of the problem that the efficiency of circulating water pumps in thermal power plants is universally on the low side, the authors analyzed its causes and proposed a method for enhancing the operation efficiency of circulating water pumps. Through taking such measures as an optimized design of the flow path of a circulating water pump and optimization of the operation mode of the pump according to the actual operating conditions and others, the authors have made the operation efficiency of the pump increased by 20%. After the modification, using the pump can save millions of kilowatt-hour electricity each year, thus achieving a good power-saving result. **Key Words**: circulating water pump, plant service power, optimization modification