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基于 Symphony 的风粉在线监测系统的实现和应用

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摘　要: 介绍了一种基于 Symphony 分布式控制系统的风粉在线监测系统, 通过与单独开发的监测系统相比, 其在安全性、经济性以及投运效果的可视化方面都占有明显优势。本文从系统的功能入手, 简要分析了其实现的基本过程, 以及在此基础上扩展的均衡燃烧控制系统, 可以为其它火电机组实现控制方案优化及充分利用系统资源提供范例和参考。

关　键　词: 一次风; 煤粉; 在线监测; Symphony; 实现
中图分类号: TK39　　文献标识码: A

1　引　言

目前, 国内大部分火电机组缺乏对风速和风量以及煤粉浓度的有效检测, 这样就直接影响了锅炉燃烧的稳定性、安全性和可靠性, 特别是在煤质发生变化或是机组变负荷时, 很难使锅炉按照设计的要求运行。风粉在线监测系统正是应此要求而研究开发的。根据调查, 绝大多数风粉在线监测系统都是独立于机组主控制系统之外单独开发的, 通常模式为工控机采集处理数据加上位机显示方式。笔者认为这并非是解决问题最佳途径。

湖南益阳电厂新建的 2×300 MW 燃煤机组采用了 ABB 公司先进的 Symphony 分布式控制系统(DCS), 对全厂各个过程进行集中监视和控制, 利用其强大的功能算法和数据处理能力以及完备的图形界面组态工具, 成功地实现了风粉在线监测系统的全部功能。这不管是从安全性还是从经济性上讲, 都是另设系统所无法比拟的。本文主要从风粉在线监测系统的功能及特点入手, 浅析其实现过程。

2　系统的功能及特点

2.1　数据测量与处理

为了能准确测量一次风速和煤粉浓度, 选取一种好的测量方法和数据处理方式是其关键。通常测量一次风速选用的是动压法, 即测取一次风动压, 然后根据其与风速的关系计算风速。其公式如下:

$$v = k \times \frac{273 + t_1}{273 + t_2} \sqrt{\frac{2 \times \Delta p}{\rho}},\quad \rho = \rho_0 \times \frac{273}{273 + t_2}$$

式中: v — 风速; Δp — 风速输出动压; ρ — 一次风密度; ρ_0 —0 ℃下风的密度; t_1 — 风粉混合物温度; t_2 — 一次风温度; k — 测速元件的标定系数, 一般在0.7至 1 之间。

对于煤粉浓度的测量, 这里依据热平衡原理采用"温差法", 即混合前的煤粉和一次风的热量等于混合后风粉混合物的总热量。其计算公式为:

$$\mu = \frac{C_{p1} t_2 - C_{p2} t_1}{C_{c2} t_1 - C_{c1} t_3}$$

式中: μ — 煤粉浓度; C_{p1}, C_{p2} 和 C_{c1}, C_{c2} — 空气和煤粉在混和前后的比热容; t_3 — 混合前煤粉温度。需要指出的是煤粉浓度测量的准确性主要依靠上面 4 个比热容计算的准确程度, 其中空气的比热容与温度成非线性关系, 而煤粉的比热容与温度却为线性关系。因此, 获得与实际相一致的比热容与温度的函数关系, 是煤粉浓度测量的关键, 笔者通过参与 300 MW 火电机组风粉在线监测系统的开发, 已获得较理想的比热容与温度的函数关系。另外, 温度采用多点测量取平均值, 使之尽量准确。

2.2　功能及特点

利用所测得的一次风速和煤粉浓度可以很方便地计算出一次风和煤粉的质量流量, 本系统除了具有常规的实时数据显示和报警功能外, 还有记录保存数据, 进行实时或者历史趋势显示的优点。和另

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设一套系统相比，在 Symphony 系统上实现风粉在线监测有以下几个特点：

（1）安全性和可靠性高。由于从数据采集到报警显示都是在 Symphony 系统内进行，没有增设与外界通讯的接口，避免了数据交换所带来的不安全因素，保证了数据格式和通讯协议的一致性。

（2）节省投资。充分利用了 Symphony 系统的软硬件资源，体现了经济性原则。因为利用现有条件完全可以实现控制策略组态和监视画面的组态，另外在系统的维护以及扩展方面，也具有明显的优势。

（3）通讯速度快，数据实时刷新率高，完全实现了远程的实时监控。

3　系统实现

3.1　控制方案组态

由于 Symphony 系统在控制功能组态方面拥有内容丰富的功能码库，一个功能码就是一种控制功能的模块化表现形式，利用功能码可以非常方便地实现实时数据处理及报警显示功能。下面以 Symphony 系统为例，简要介绍一次风速运算组态。应用上述一次风速的计算公式，当系统采集到一次风动压、一次风温以及风粉混合物温度时，将自动按图 1 方式计算出一次风速。

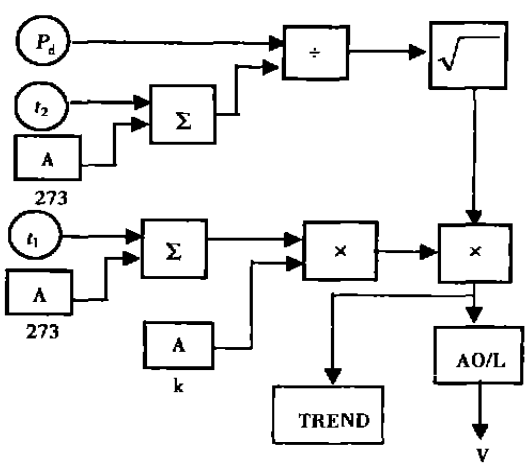

图 1　一次风速组态实例

从图 1 我们可以看出，其运算过程和计算公式稍有不同，这是一次风速公式经过简化后的表达式。现场所测的一次风动压、一次风温以及风粉混合物温度经过加法块、乘法块、除法块和开方运算块处理后，计算出一次风速送入模拟例外报告块和趋势块。例外报告是 Symphony 通讯系统中使用的一种有效的通信技术，它是过程控制中产生的一些涉及测量数据、操作和报警信息经过一定技术处理后，而形成的一种反映信息值的专门报告，是系统内部进行数据交换的基础。一次风速经过例外报告功能块后，直接送到 OIS 操作员站进行显示和报警。趋势功能块作用是记录一次风速历史数据，它可以用两种方式采集趋势数据，正常方式为每 60 s 一次，而快速方式为 15 s 一次。与此类似，煤粉浓度的计算值也可以根据其计算公式通过组态轻松实现。

3.2　监视界面显示

除了可以进行控制组态外，Symphony 系统还有功能强大的画面组态工具。根据风粉在线监控的需要，可实现以下显示功能：

（1）棒图显示：显示 20 个燃烧器一次风速及 20 个粉管的煤粉浓度。

（2）趋势显示：显示每个测点的状态及 20 路燃烧器一次风速和 20 路粉管的煤粉浓度，并可调用两个月内任意时段这些参数的历史曲线。

（3）燃烧偏心图显示：通过四角燃烧器一次风速的平衡状况，计算各层燃烧中心的偏离状况，并以图形形式直观动态地显示出来。

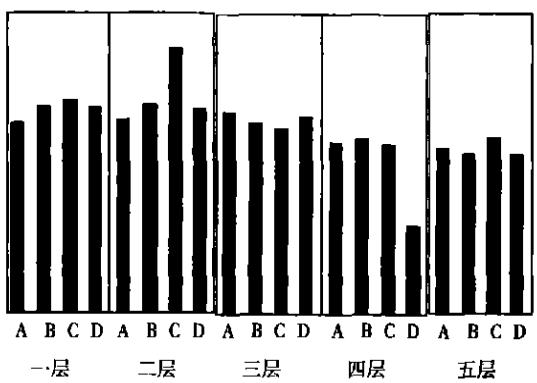

图 2　煤粉浓度监视棒图

益阳电厂应用基于 Symphony 的可视化风粉在线监测系统，为操作员调整燃烧提供了直观的监视画面，取得了良好的效果。正常运行时，一次风速为 13.5～21.5 m/s，煤粉浓度为 0.39～0.65 kJ/kg，超过此范围一定程度系统将发出报警，一次风速的高低报警为 50 m/s 和 10 m/s，煤粉浓度的高低报警为 0.85 kJ/kg 和－1 kJ/kg。以煤粉浓度监视画面为例，在运行过程中通过对煤粉浓度的监视，可以及时调

整燃烧,防止断粉、堵粉故障的发生,同时还可以判断给粉机的运行状态,如图 2 所示。

根据图 2 分析,第二层 C 角煤粉浓度明显偏高,因此判断可能发生了堵粉;而第四层 D 角的煤粉浓度明显偏低,因此判断给粉机可能发生故障,导致了断粉。另外棒状图上还具有上下限报警,提醒运行人员及时调整。

4 系统应用及扩展

目前,基于 Symphony 系统开发的风粉在线监控系统已经在湖南益阳电厂 300 MW 火电机组上成功实现,整个系统取得了预期的效果,这对提高锅炉运行的可靠性、经济性及故障诊断方面都具有重要的意义。该系统为锅炉运行中的燃烧调整提供了准确而直观的数据,已成为运行人员监视燃烧工况和判断设备故障重要手段之一。

为了实现电站锅炉的优化燃烧,对大型锅炉来说,只有每个燃烧器按照一定的风煤比向炉膛送入煤粉和空气,才能在炉内建立良好的空气动力场,才能稳定燃烧并使锅炉达到最佳燃烧效果。但这光靠手动调整是很难实现的,在风粉在线的基础上可以扩展实现均衡燃烧控制系统。所谓均衡燃烧是指通过适当的手段来保证:

(1)同层切圆燃烧的四角出口射流动量相等,煤粉浓度相等。

(2)同层助燃二次风四角出口射流动量相等。

(3)四层喷燃器出口煤粉浓度及助燃二次风量按照运行要求达到最佳比例分配。

系统实现主蒸汽压力闭环控制,并且系统内回路采用每个燃烧器出口的煤粉浓度或煤粉量反馈,保证了控制系统投自动时,燃烧器出口煤粉浓度均衡,主蒸汽压力稳定。

5 结束语

将风粉在线监测系统嵌入到分布式控制系统中,具有资源共享,控制与保护协调,节约投资等优点。笔者认为,在分布式系统中设计风粉在线监测,其投运的灵活性、修改的便利性以及投运效果的可视性,仍是其它装置或方法难以达到的。可以为其它火电机组实现控制方案优化及充分利用系统资源提供范例和参考。

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阵方程不需任何改变,即可得到工况变动后的热力系统计算结果。对于不同的热力系统可以改变表示热力系统和回热加热器特征的逻辑变量直接应用该模型。该逻辑—矩阵模型构造容易,各项含义明确,通用性强。不仅为编制通用的热力系统计算程序提供了依据,而且为实时测试、控制和优化提供了方便的工具。

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ty, Chongqing, China, Post Code: 400044), CAO Hong (Huaneng Chongqing Gas Turbine Power Plant, Chongqing, China, Post Code: 400044) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(6). —617 ~ 619, 637.

By adopting a method combining theoretical analysis with historical operating data an off-design performance calculation was conducted of a combined cycle power plant. Through an evaluation of calculation results one can ascertain whether there is a lowering in performance of any one system. Moreover, on the basis of a graded fault classification to utilize BP algorithm-based sensitivity analytical method, it is possible to perform an on-line diagnosis of the causes triggering a performance deterioration, thus accumulating the experience of combined cycle plant operation and enhancing management level. **Key words**: combined cycle. off-design operation, BP algorithm

一般传热规律下广义不可逆卡诺热机的构形优化= **Configuration Optimization of a Generalized Irreversible Carnot heat Engine under a General Heat Transfer Law** [刊, 汉] / ZHANG Xiao-hui, YANG Mo (College of Power Engineering under the Shanghai University of Science & Technology, Shanghai, China, Post Code: 200093) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(6). —620 ~ 623.

On the basis of a generalized irreversible Carnot heat engine model and in conjunction with a general heat transfer law the characteristics of heat engine configuration optimization under the condition of finite construction materials were obtained, namely, a new relation of quantitative allocation of optimum heat conductivity. An analysis was conducted of the impact of such factors as the internal irreversibility and heat transfer laws, etc on the characteristics of heat engine configuration optimization. It has been found that the conclusions given in some now available literature pertain to a special case of the relation obtained by the authors. The conclusion reached herein can serve as a theoretical guide for the optimized design of heat engines. **Key words**: heat engine, general heat transfer law, optimization, allocation of thermal conductivity

催化裂化余热锅炉的技术特点= **Technical Features of Waste Heat Boilers Used in a Fluid Catalytic Cracking Unit** [刊, 汉] / SUN Kai-hong (SINOPEC Engineering Construction Corp., Beijing, China, Post Code: 100011), WANG Heng (Thermal Energy Engineering Department, Beijing University of Science & Technology, Beijing, China, Post Code: 100083) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(6). —624 ~ 627.

In comparison with conventional boilers, waste heat boilers destined for catalytic cracking units have some specific features, such as a wide range of superheated steam temperature regulation and operating conditions subject to changes in step with the working conditions of a fluid catalytic cracking unit. In light of the different conditions of catalytic cracking regeneration technology and flue gases the authors have focused on such problems as the avoidance of superheater overheating and low-temperature corrosion of economizers, as well as the alleviation of ash deposits. Some measures are proposed for ensuring the stable control of feedwater regulating valves. Furthermore, in connection with the production of high-parameter steam by high-temperature waste heat from a large-sized oil refinery unit, it is recommended to realize the utilization of steam on a graded basis. **Key words**: oil refinery, catalytic cracking unit, waste heat boiler, technical features

基于 Symphony 的风粉在线监测系统的实现和应用= **Realization and Application of a Symphony-based On-line Air and Pulverized Coal Monitoring System** [刊, 汉] / SHENG Sai-bin, LI Guo-qiang (Automation Department, Wuhan University, Wuhan, China, Post Code: 430072) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(6). —628 ~ 630.

An on-line air and pulverized coal monitoring system based on Symphony distributed control system is described. As compared with an independently developed monitoring system, the recommended system enjoys a marked edge in terms of safety, cost effectiveness and the visualization of operation effect. Proceeding from the system functions a concise analysis

is given of the basic process of its implementation and, on this basis, an expanded and balanced combustion control system proposed. The above work can serve as an exemplary case and provide reference for control version optimization in other thermal power plants and for the full utilization of system resources. **Key words**: primary air, pulverized coal, online monitoring, Symphony, realization

煤粉与水煤浆焦炭颗粒燃烧速度的分析和比较＝**Analysis and Comparison of the Combustion Speed of Coal Water Slurry and Pulverized-coal Coke Particles** [刊, 汉] / YU Hai-miao, ZHAO Xiang, CAO Xin-Yu, HUANG Zhen-yu (Education Ministry Key Laboratory on Energy Clean Utilization and Environmental Engineering under the Thermal Power Engineering Institute of Zhejiang University, Hangzhou, China, Post Code: 310027) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(6). —631 ~ 633.

Through the full-load combustion tests of a coal water slurry-fired boiler No. 2 at Maoming Thermal Power Plant and a pulverized coal-fired boiler No. 5 at Banshan Power Plant an analysis and a comparison was conducted of the combustion speed of coal water slurry (CWS) and pulverized-coal coke particles. With the help of a scanning electron microscope and by way of a BET nitrogen adsorption test and by using a granularity analyzer the fly ash samples of the combustion test were studied and analyzed. This is followed by a discussion of the causes, which may have led to the divergence in combustion speed of CWS and pulverized-coal coke particles. **Key words**: pulverized coal, coal water slurry, coke particle, combustion speed

水煤浆代油改造技术在工业采暖锅炉中的应用＝**The Application for Industrial Heating Boilers of a Modification Technology Involving the Conversion from Oil firing to Coal Water Mixture Firing** [刊, 汉] / ZHAO Bao-cheng, ZHU Liu-juan, GU Bo-qin (College of Mechanical & Power Engineering under the Nanjing Polytechnical University, Nanjing, China, Post Code: 210009 // Journal of Engineering for Thermal Energy & Power. — 2004, 19(6). — 634 ~ 637.

The 14 MW heavy oil-fired industrial heating boiler of Beijing Yanshan Petrochemical Civilian Energy Sub-company has been converted to fire coal water mixture. In the light of the specific features of this conversion the authors have expounded the proper adjustment and modification of the boiler system under the condition of retaining the original facilities. The social economic benefits resulting from the above-cited modification are evaluated and analyzed. It can be shown that the coal water mixture as a kind of clean fuel enjoys a high potential of wide applications. **Key words**: industrial heating boiler, coal water mixture, modification

水煤浆技术在吉化炼油厂的应用＝**The Application of Coal Water Slurry Combustion Technology at Jihua Oil Refinery** [刊, 汉] / CAO Xian-bo, TAO Shu-cheng (Jihua Oil Refinery, Jilin, China, Post Code: 132000), LIU Jian-zhong, ZHOU Jun-hu (Zhejiang University, Hangzhou, China, Post Code: 310027) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(6). —638 ~ 641.

The conversion and modification of a 65 t/h oil-fired boiler at Jihua Refinery to fire coal water slurry is described along with a brief account of the latter's discharge, storage and transportation system, the boiler front system components, slag and dust removal system. Moreover, analyzed are the modified-boiler operating conditions, economic and social benefits achieved and future use prospects of such modifications. The actual results of conversion of the above-cited boiler indicate that its load can be higher than 60 t/h, combustion efficiency above 97% and thermal efficiency greater than 88.5%. **Key words**: coal water slurry, combustion, boiler, oil refinery

一种有效的船舶轴系安装新方法＝**A New Effective Method for Installing a Ship Shafting** [刊, 汉] / LI Nan (Mechanical Engineering Institute under the Dalian University of Science & Technology, Dalian, China, Post Code: 116023), NIU Ming-tian (Naval Representative Office Resident at Dalian Shipyard, Dalian, China, Post Code: