并联离心压缩机防喘振控制系统的研究及应用

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[摘要]文中介绍了新研制的四台并联运行的煤气离心压缩机组的防喘振控制系统所采用的防喘振控制方法 ,并对并联离心压缩机机组的防喘振控制系统的原理、功能及在煤气压缩站的应用作了描述。

关键词　离心压缩机组　喘振　防喘控制系统
分类号　TK473. 82

0　概述

在石油、化工、冶金等工业生产中 ,离心压缩机以它平稳高效得到了广泛应用 ,并在生产中起着重要作用。喘振现象是离心压缩机的固有特性 ,它在压缩机入口流量低于最小流量时发生 ,轻则造成压缩机停机 ,中断生产过程造成经济损失; 重则造成压缩机叶片损坏 ,引起压缩机设备报废造成人员伤害。因此 ,喘振现象具有严重的破坏性。如何在离心压缩机的运行过程中 ,能有效保证其正常运行 ,防止喘振现象的产生具有重大意义。我们查阅了有关的文献 [1] [2] [3]等。传统的防喘振方法一般采用最小流量法 ,其缺点是不能充分使压缩机工作在其工况区 ,过早起动防喘阀浪费了能源 ,降低了经济效益。且控制系统一般均采用模拟仪表构成 ,在压缩机的喘振线发生变化时不能及时修正 ,对不是直线的喘振线不能较好控制。报导多台并联或串联的离心压缩机组的防喘振控制的文献很少。而对并联与串联机组进行有效的防喘振控制又更具有难度与重要意义。我们对北京石景山煤气储配厂的四台并联运行的煤气压缩机组进行控制的实践中采用了集散控制系统的设计方法和上下位机结构为此机组设计了防喘振控制系统。同时设计了防喘控制算法*。该方法可以对各种喘振线进行模拟 ,可随时按照规定的喘振裕度设计防喘振控制线 ,对喘振现象达到有效控制。实验室试验和现场实时控制的运行结果 ,均表明我们研制的防喘振控制系统能成功地对喘振现象进行控制 ,保障生产过程的安全运行。该系统已通过由机电部组织的专家鉴定 ,并获北京市科技进步三等奖。

1　控制系统的构成

防喘振控制系统采用集散控制系统的结构 ,采用上位机下位机的方式 ,四台下位机分别控制四台离心压缩机。上位机通过通信网络同下位机联结 ,对下位机进行管理与协调。图 1给出了控制系统的结构方框图。

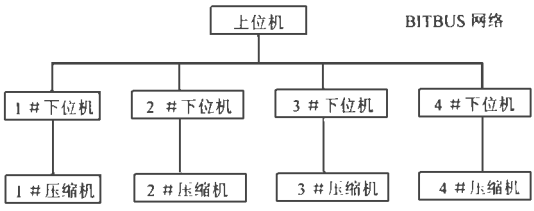

图 1　控制系统结构示意图

* 本文为国家“七五”技术攻关推广项目之一
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上位机: 采用台湾研华工控机 IPC- 610 286微机及 49厘米大屏幕彩色显示器。上下位机之间通过 BITBUS网络联接。上位机主要完成四台下位机采集的时数据显示,工况点图形显示,实时数据存储,报警显示与存储,数据报表打印,对下位机控制线参数的在线修改等任务。

下位机: 采用 STD总线工控机。其显示与操作由面板上的八位 LED显示及三十个控制功能键组成。下位机完成对离心压缩机在线工况参数的实时采集,防喘振控制算法的在线运算,对各种情况的报警,对防喘阀、入口阀、出口阀的实时控制,实现防喘振功能。下位机可以显示实时数据,工况点,可以在线修改控制、显示参数。下位机可以独立工作,在上位机故障或通信网失败时,下位机仍可独立地对压缩机进行正常控制。下位机可以随时进行手自动切换,从而保证了控制系统的可靠性。

通信网: 采用 BITBUS通信网完成上下位机之间的控制参数传输,实时参数的传输,报警信号传送功能。

2 防喘振控制算法及其实施

2.1 单台离心压缩机控制系统

图 2表示的是单台离心压缩机的控制系统的结构示意图。

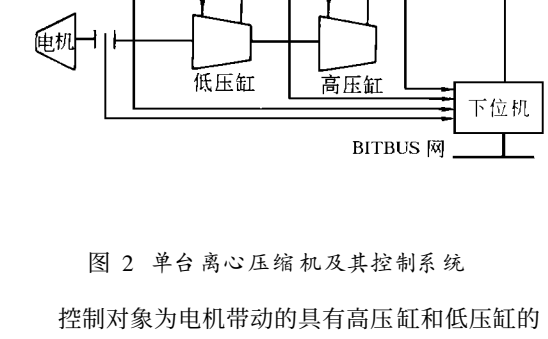

图 2 单台离心压缩机及其控制系统

控制对象为电机带动的具有高压缸和低压缸的多级离心压缩机。下位机分别对电机的转速、低压缸(入口压力、入口温度、出口温度、出口压力)、高压缸(入口压力、入口温度、出口温度、出口压力)、母管压力等现场脉冲量、模拟量进行数据采集。对入口阀、出口阀的阀状态进行开关量输入采集。根据煤气组份及实时采集数据按照防喘振控制算法计算喘振裕度,阻塞裕度。判别压缩机的工况点位置。分别进行报警、控制处理。控制信号分别控制压缩机的入口阀、出口阀、防喘阀达到防喘振的目的。图 3给出的是压缩机喘振线及控制线的示意图(喘振线由实验测得)。

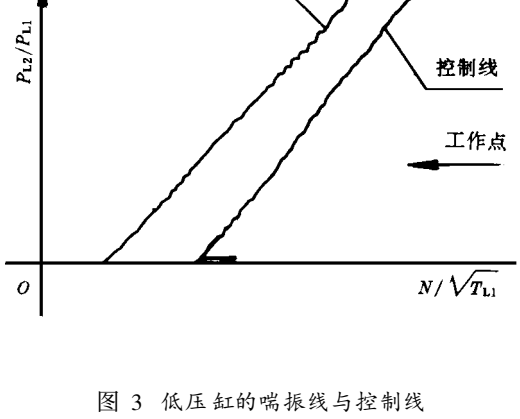

图 3 低压缸的喘振线与控制线

2.2 防喘振控制算法

2.2.1 输入煤气成份确定该成份下的喘振线、控制线参数。

2.2.2 下位机分别对上文所述的 AI量及 DI量进行实时数据采集。

2.2.3 用下面公式计算低压缸、高压缸、母管的喘振裕度。

$$X_{ikjo}= A_{ikj}(N/\overline{T_{ik}})^2+ B_{ikj}(N/\overline{T_{ik}})+ C_{ikj} \quad (1)$$

式中: $i=$ 1表示低压缸参数,$k=$ 1表示喘振参数。

$i=$ h表示高压缸参数,$k=$ 2表示阻塞参数。

$i=$ m表示母管参数。

$j=$ 1, 2, 3, 4分别表示压缩机 1, 2, 3, 4

N 表示电机转速。

T表示温度。

A, B, C表示压缩机喘振线、阻塞线参数。

$$X_{1j}= P_{12j}/P_{11j} \quad (2)$$

$$X_{hj}= P_{h2j}/P_{h1j} \quad (3)$$

式中: X_{1j}表示低压缸压比。$P_{12j}P_{11j}$表示低压缸出口

压力,入口压力。

X_{hj}表示高压缸压比。 P_{h2j} P_{h1j}表示高压缸出口压力,入口压力。

$$S_{lj} = (X_{1ljo} - X_{lj}) / X_{1ljo} \quad (4)$$

$$S_{hj} = (X_{h1jo} - X_{hj}) / X_{h1jo} \quad (5)$$

式中: S_{lj}表示低压缸喘振裕度。

S_{hj}表示高压缸喘振裕度。

$$Z_{lj} = (X_{lj} - X_{12jo}) / X_{12jo} \quad (6)$$

$$Z_{hj} = (X_{hj} - X_{h2jo}) / X_{h2jo} \quad (7)$$

式中: Z_{lj}表示低压缸阻塞裕度。

Z_{hj}表示高压缸阻塞裕度。

$$S_{mj} = (X_{mj} - X_{lj}) / X_{mj} \quad (8)$$

式中: S_{mj}表示母管喘振裕度。

2.2.4 用上面计算结果同报警设定值、控制设定值比较得出对应的报警与控制量,用得到的控制量控制防喘阀,达到对压缩机进行防喘控制的目的。

3 实时控制结果

该套离心压缩机防喘振控制系统于 1992年在现场投入运行,运行情况良好。为压缩机正常运行、保证供气起了重要作用。有效防止了喘振现象的产生,受到了用户的好评,该项目通过了机电部仪表司组织的专家鉴定。

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先进燃机的研制

据"火力原子力发电"1996年 7月号报道,日本东北电力公司与国内三家燃机制造公司(东芝、三菱重工和日立公司)已开发了用于下一代 1500℃级高效率燃气轮机的关键技术。研制的目标是要在燃用液化天燃气的联合循环电站中达到超过 55% (低发热值)的热效率。

在这项研究中,已经研制了 (1)先进的冷却方式,包括采用全面积覆盖气膜冷却、拟用于 200 MW级燃机第一级静叶的蒸汽冷却; (2)用于第一级静叶和动叶的耐热材料,包括开发拟用于 200 MW级燃机的定向凝固合金和单晶合金,并给叶片喷涂上 0.3~ 0.5 mm的热障涂层; (3)高温干式低 NO_x燃烧室。

将把这些关键技术应用于东新泻火力发电站 4号系列机组(4台 270MW的燃气轮机和 2台 265MW的汽轮机,总输出功率为 1610 MW, LHV /HHV 热效率为 55% /50%),该系列将在 1999到 2000年开始商业营运。 (思娟 供稿)

旋流煤粉燃烧技术的发展= **Evolution of Swirling-Flow Pulverized-Coal Combustion Technologies**〔刊,中〕/ Qin Yukun, Li Zhengqi, Wu Shaohua(Harbin Institute of Technology) //Journal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 241~ 244

A review is conducted of the evolution of the swirling-flow pulverized-coal combustion technologies both at home and abroad. On the basis of the difference in the feeding mode of the secondary air and the pulverized-coal concentrations of primary air-coal mixture the above-cited technologies may be classified into three types, i.e. common type, staged combustion type and fuel-rich type. The latter can in its turn be divided into the high pulverized-coal concentration type and the fuel bias type. Summarized are the features of various types of burners in terms of flame stability, combustion efficiency, NO_X emissions, slagging, high-temperature corrosion and control characterisitics, etc. It is pointed out that the fuel-bias swirl burners are to be preferred for further development in the area of swirling-flow pulverized-coal combustion technology. **Key words**: swirl burner, classification, bias combustion, staged combustion.

"洁净煤技术"的烟气净化系统最新概况及工艺选择= **The Latest Survey of the Gas Purification System of "Clean Coal Technology" and its Technological Selection**〔刊,中〕/Hu Guoxin, Luo Zhongyan, et al (Zhejiang University) //Jorunal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 245~ 249

Flue gases of coal-burning emit a huge amount of pollutants, such as powder/dust, SO_2 and NO_X, etc, causing serious consequences to environment ecology. In view of this it is essential to develop coal-fired boiler flue gas purification technology. The authors give a brief description of the present status and latest developments in the above-cited technology, analysing the merits and defects of various technological processes, some influencing factors and the results of thier applications. In addition, proposed are the method of system selection and key points to be taken into account during technological design, etc. **Key words**: coal-fired boiler, gas purification, desulfurization and denitration, technological design

关于离心压缩机防喘振控制系统的研究及应用= **The Study and Application of Anti-surge Control System for Parallel-connected Centrifugal Compressors**〔刊,中〕/Zhang Zhijun, Xu Xiangdong (Tsinghua University) // Journal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 250~ 252

This paper mainly describes the algorithm of anti-surge control method used in an anti-surge control system for four parallel-connected centrifugal gas compressors. The use of this algorithm can lead to an effective prevention of surge phenomena. With respect to different parallel-connected centrifugal compressor units the surge margin and design parameters can be conveniently revised and it is only necessary to make some proper changes so that the algorithm can be applicable to a variety of cases, including a single compressor. A detailed description is given of the anti-surge control of the parallel-connected centrifugal compressor units, presenting the control system structural drawing, its configuration principles and functions. A total distributed control system has been adopted for the anti-surge control system, which consists of one upper computer and four lower computers. The latter can independently perform the real-time acquisition of on-site signals and implement the control algorithm, realizing the control of the four centrifugal compressors. The upper computer by way of a bitbus is connected with the lower computers, carrying out the management and coordination with respect to the lower computers. The upper computer has the following functions: real-time data display, operating condition point graphic display, real-time data storage, alarms display and storage, print-out of data sheets, etc. Also described in this paper is the result of practical use of the said control system in a gas compressor station. The control system has been successfully applied to the centrifugal compressor unit of Beijing Shijingshan coal gas storage and distribution plant, playing a significant role in ensuring the safe operation of the production process. It has also passed an expert appraisal organized by the State Ministry of Electro-me-

chanical Industry. **Key words**: surge, anti-surge control system

太阳能吸附式空气取水器和太阳能制冷结露法空气取水器的热性能分析比较= **An Analytical Comparison of Thermodynamic Performance of Solar-energy Adsorption-based Water Collector from Air and Solar Energy Refrigeration Dewfall-based Water collector from Air**[刊,中]/Chou Qiaoli, Liu Zongyan, et al. (China National University of Science & Technology) //Journal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 253~256

A thermodynamic performance is conducted of an adsorption type water collector from air and a refrigeration dewfall based water collector from air with a water collection expression being given. On the basis of the said expression a comparison has been made of the water collection rate of the above-cited two methods. **Key words**: water collector from air, adsorption refrigeration, refrigeration dewfall method, water collection rate

泥炭燃烧的研究= **A Study on Peat Combustion**[刊,中]/Zhang Jingbo, Li Xueheng et al (Northeast Electrical Engineering Institute) //Journal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 257~260

On the basis of peat basic combustion tests and the development and operation practice of a 1 t/h peat-fired fluidized boiler this paper proposes a method of firing peat by utilizing fluidized bed combustion technology. A detailed description is given of the peat combustion characteristics with some key issues in the design of such boilers being pinpointed. **Key words**: boiler, fluidized bed, peat, combustion

煤粉粒子的发射率= **The Emissivity of Pulverized-Coal Particles**[刊,中]/Liu Linhua, Yu Qizheng, Tan Heping (Harbin Institute of Technology), Xu Wanli (Harbin University of Science & Technology) //Journal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 261~266

On the basis of the classical Lorentz-Mie electromagnetic theory for isotropic and homogeneous spherical particles and by utilizing the experimentally measured complex refractive indices of pulverized-coal particles determined are the emissivity of pulverized-coal particles of twenty kinds of Chinese coals for power generation. The results of calculation show that the full wave-length emissivity of pulverized-coal particles is dependent on particle diameter, particle temperature and coal type and within a wide range of particle diameters radically deviates from the assumed value of 0.8 often given in technical literature. It has also been found that within a particle diameter range of 1~20 μm the emissivity of the pulverized-coal particles is often greater than 1.0. The reason why some pulverized-coal particles have an emissivity greater than 1.0 is given with an explanation of its physical meaning. For engineering calculation purposes the curves showing the variation of emissivity with particle diameter and temperature are given for twenty kinds of typical Chinese coals. **Key words**: emissivity, particles, coal, electromagnetic theory

一类不可逆卡诺热机最佳效率和功率间的关系= **Relationship between the Optimum Efficiency and Output Power of a Kind of Irreversible Carnot Heat Engine**[刊,中]/Lu Ying, Tian Xinquan (Luoyang Teachers College) //Journal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 267~269

Through the use of an irreversible Carnot heat engine model of Dulong-Petit nonlinear heat transfer rate and heat leakage derived is its basic optimization relation with the issue of the heat engine efficiency during its maximum output power being also discussed. **Key words**: finite-time thermodynamics, Carnot engine, thermal resistance, heat leakage, basis optimization ralation, optimum efficiency

斜齿圆柱齿轮瞬时啮合刚度及齿廓修形的研究= **A Study on the Momentary Meshing Rigidity and Tooth Profile Modification of Helical Cylindrical Gears**[刊,中]/Chand Shan, Xu Zhenzhong, Huo Zhaobo (Harbin No. 703 Research Institute) //Journal of Engineering for Thermal Energy & Power. - 1997, 12(4). - 270~274

The paper presents a high-efficiency gear calculation model with gear basic effects being taken into ac-