变工况下汽轮机反动度的统一表达式

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[摘要]　对变工况下汽轮机反动度的统一表达式,以及影响反动度的诸因素进行了论述,还讨论了反动度变化的全增量性质等问题,对反动度的内容提出了比较完整和简明的解释。

关键词　汽轮机　变工况　反动度
中图分类号　TK26

1　前言

级的反动度是汽轮机重要的特性参数,反动度的大小是随着工况而变化的,因此,从某些侧面反映了级和汽轮机的工作状态。一个级的反动度数值不仅仅表示能量转换中级的理想焓降在喷嘴和动叶的分配关系,而且对汽轮机的轴向推力以及零部件的受力有直接的影响,更重要的是反动度在汽轮机的热力计算中起主导作用,是进行热力计算的基础数据。因此,正确理解反动度的内涵和性质以及正确地确定反动度的数值,不仅是保证热力计算准确性的前提条件,也是了解汽轮机工作状况的重要内容。

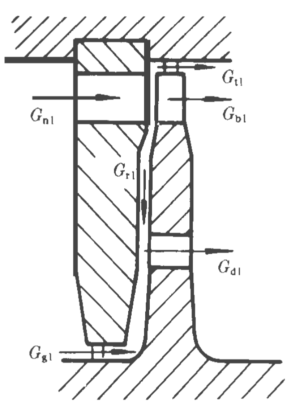

图 1　级的通流部分

2　变工况下汽轮机反动度的统一表达式

图 1 表示蒸汽在一个级内的流动情况 G_{n1}, G_{b1} 为喷嘴叶栅和动叶栅的流量, G_{t1}, G_{r1} 则表示叶顶和叶根间隙的漏汽量,因此有:

$$G_{n1}=G_{b1}+G_{t1}+G_{r1} \tag{1}$$

现首先讨论设计条件下的工作,根据连续方程:

$$\begin{cases} G_n=\dfrac{\mu_n A_n C_{1t}}{V_{1t}} \\ G_b=\dfrac{\mu_b A_b w_{2t}}{V_{2t}} \end{cases} \quad pe \quad 所以 \begin{cases} G_{1t}=\dfrac{G_n V_{1t}}{\mu_n A_n} \\ w_{2t}=\dfrac{G_b V_{2t}}{\mu_b A_b} \end{cases} \tag{2}$$

在等熵条件下,喷嘴出口及动叶出口的汽流速度为:

$$\begin{cases} C_{1t}=\sqrt{2(1-\Omega_0)\Delta h_t^*} \\ w_{2t}=\sqrt{2\Omega_0\Delta h_t^*+w_1^2} \end{cases} \tag{3}$$

式中 Ω_0, Δh_t^*—设计条件下,级的反动度及滞止理想焓降。

式(3)中,两式相比得:

$$\left(\frac{w_{2t}}{C_{1t}}\right)^2=\frac{2\Omega_0\Delta h_t^*+w_1^2}{2(1-\Omega_0)\Delta h_t^*}=\frac{\Omega_0+(w_1/C_a)^2}{1-\Omega_0} \tag{4}$$

式中　C_a—设计条件下,级的假想速度。

图 2 为进口速度三角形图,在变工况下,有:

$$w'_{11}=w_{11}\cos(\beta_{11}-\beta_1)=C_{11}\cos(\beta_1-\alpha_1)-u\cos\beta_1$$

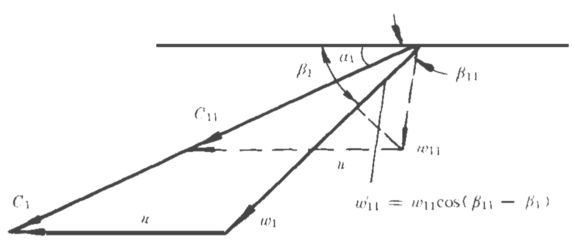

图 2　变工况下的速度三角形

在设计工况下,则有:

$$w_1=C_1\cos(\beta_1-\alpha_1)-u\cos\beta_1$$

则由上式得:

$$\left(\frac{w_1}{C_a}\right)^2=\left[\frac{C_1\cos(\beta_1-\alpha_1)-u\cos\beta_1}{C_a}\right]^2$$

$$=\left[\frac{\varphi\sqrt{2(1-\Omega_0)\Delta h_t^*}\cos(\beta_1-\alpha_1)}{\sqrt{2\Delta h_t^*}}-x_{ao}\cos\beta_1\right]^2$$

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$$=[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{ao}\cos\beta_1]^2 \quad (5)$$

式中 x_{ao}—设计速度比，$x_{ao}=u/C_a$

将式(5)代入式(4)，得到：

$$(\frac{w_{2t}}{C_{1t}})^2=\frac{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2}{1-\Omega_0} \quad (6)$$

同理，对于变动工况，可推导得：

$$(\frac{w_{2t1}}{C_{1t1}})^2=\frac{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{a1}\cos\beta_1]^2}{1-\Omega_{01}} \quad (7)$$

式中 Ω_{01}，x_{a1}—变工况下，级的反动度与速度比。

式(7)除以式(6)则得：

$$(\frac{w_{2t1}}{C_{1t1}})^2/(\frac{w_{2t}}{C_{1t}})^2=\frac{(1-\Omega_0)\{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{a1}\cos\beta_1]^2\}}{(1-\Omega_{01})\{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2\}} \quad (8)$$

由式(2)知：$(\frac{w_{2t}}{c_{1t}})^2=(\frac{G_b V_{2t}\mu_n A_n}{G_n V_{1t}\mu_b A_b})^2$ (9)

同理，对变工况有：$(\frac{w_{2t1}}{c_{1t1}})^2=(\frac{G_{b1} V_{2t1}\mu_{n1} A_{n1}}{G_{n1} V_{1t1}\mu_{b1} A_{b1}})^2$ (10)

将式(9)、(10)代入式(8)，得：

$$\frac{(1-\Omega_0)\{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{a1}\cos\beta_1]^2\}}{(1-\Omega_{01})\{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2\}}=(\frac{G_{b1}A_{n1}V_{2t1}\mu_{n1}}{G_{n1}A_{b1}V_{1t1}\mu_{b1}})^2/(\frac{G_b A_n V_{2t}\mu_n}{G_n A_b V_{1t}\mu_b})^2 \quad (11)$$

上式中，令 $g_0=G_b/G_n$，$g_{01}=G_{b1}/G_{n1}$，$f_0=A_n/A_b$，$f_{01}=A_{n1}/A_{b1}$，$q_0=V_{2t}/V_{1t}$，$q_{01}=V_{2t1}/V_{1t1}$，$r_0=\mu_n/\mu_b$，$r_{01}=\mu_{n1}/\mu_{b1}$，则式(11)可写为：

$$\frac{1-\Omega_{01}}{1-\Omega_0}=(\frac{g_0f_0q_0r_0}{g_{01}f_{01}q_{01}r_{01}})^2\frac{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{a1}\cos\beta_1]^2}{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2} \quad (12)$$

从式(12)可以看出，变工况下的反动度是速度比 x_a、面积比 f、流量比 g、比容比 q 及流量系数比 r 的函数，也是 φ、α_1、β_1 的函数，该式就是确定变工况下，汽轮机反动度的统一表达式。

现在假设：(1)在各种工况下，φ、α_1、β_1 及 μ_n、μ_b 保持为常数不变，则上式中 $r_0/r_{01}=1$；(2)各种工况下，叶顶及叶根间隙都不发生吸汽或漏汽，故喷嘴流量等于动叶流量，$G_n=G_b$；$G_{n1}=G_{b1}$。(在此条件下的反动度称为理论反动度 Ω_{th})，则上式中 $g_0/g_{01}=1$。

在此条件下，式(12)可简化为：

$$\frac{1-\Omega_{01}}{1-\Omega_0}=(\frac{f_0q_0}{f_{01}q_{01}})^2\frac{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{a1}\cos\beta_1]^2}{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2} \quad (13)$$

式(13)表明，汽轮机的理论反动度仅是速度比、面积比和比容比的多元函数，即：

$$\Omega=f(x_a,f,q)$$

这就是说，当工况偏离设计条件时，级反动度的变化是一个全增量，即：

$$\Delta\Omega=\frac{\partial\Omega}{\partial x_a}\Delta x_a+\frac{\partial\Omega}{\partial f}\Delta f+\frac{\partial\Omega}{\partial q}\Delta q \quad (14)$$

关系式诸变量中，速度比 x_a，面积比 f 是可以单独变化的，但比容比不是独立变量，而是随着 x_a 及 f 的变化而变化，即：

$$q=\psi(x_a,f)$$

则有 $\Delta q=\frac{\partial q}{\partial x_a}\Delta x_a+\frac{\partial q}{\partial f}\Delta f$

所以 $\frac{\partial\Omega}{\partial q}\Delta q=\frac{\partial\Omega}{\partial q}\frac{\partial q}{\partial x_a}\Delta x_a+\frac{\partial\Omega}{\partial q}\frac{\partial q}{\partial f}\Delta f$ (15)

将式(15)代入式(14)，得

$$\Delta\Omega=(\frac{\partial\Omega}{\partial x_a}+\frac{\partial\Omega}{\partial q}\frac{\partial q}{\partial x_a})\Delta x_a+(\frac{\partial\Omega}{\partial f}+\frac{\partial\Omega}{\partial q}\frac{\partial q}{\partial f})\Delta f$$
$$=\frac{\partial\Omega}{\partial x_a}\Delta x_a+\frac{\partial\Omega}{\partial f}\Delta f+(\frac{\partial\Omega}{\partial q}\frac{\partial q}{\partial x_a}\Delta x_a+\frac{\partial\Omega}{\partial q}\frac{\partial q}{\partial f}\Delta f)$$

由上式可见，反动度的全增量也是 x_a，f 二者单独变化引起的反动度变化值以及 x_a，f 引起比容比 q 变化而产生的附加反动度变化值的总和，将上式写为：

$$\Delta\Omega=\Delta\Omega_{xa}+\Delta\Omega_f+(\Delta\Omega_q^{xa}+\Delta\Omega_q^f) \quad (16)$$

3　速度比、面积比及比容比诸因素对反动度的影响

3.1　速度比 x_a 单独变化引起的反动度变化值 $\Delta\Omega_{xa}$

在此情况下，式(13)中 $f_{01}=f_0$，$q_{01}=q_0$（由 x_a 变化引起的比容变化对反动度的影响，另作计算），则该式可写为：

$$\frac{1-\Omega_{01}}{1-\Omega_0}=\frac{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{a1}\cos\beta_1]^2}{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2} \tag{17}$$

由于　$\Omega_{01}=\Omega_0+\Delta\Omega_{xa}$，$x_{a1}=x_{ao}+\Delta x_a$ 以及 $(1-\Omega_{01})^{1/2}\approx\sqrt{1-\Omega_0}\left(1-\frac{1}{2}\frac{\Delta\Omega}{1-\Omega_0}\right)$，将这些关系式代入式(17)，经展开，推导、消项、合并，整理后，可得出下式：

$$\frac{\Delta\Omega_{x_a}}{1-\Omega_0}=A\,\frac{\Delta x_a}{x_{ao}} \tag{18}$$

式中 $A=\dfrac{2\varphi\sqrt{1-\sqrt{1-\Omega_0}\dfrac{\cos(\beta_1-\alpha_1)}{\cos\beta_1}-2x_{a0}-\Delta x_a}}{\dfrac{1}{\cos^2\beta_1}+x_{a0}^2-\dfrac{\varphi\sqrt{1-\Omega_0}(x_{a0}-\Delta x_a)\cos(\beta_1-\alpha_1)}{\cos\beta_1}}\cdot x_{ao}$

3.2　面积比 f 单独变化引起的反动度变化值 $\Delta\Omega_f$

在此情况下，式(13)中 $x_{a1}=x_{ao}$，$q_{01}=q_0$（由 f 变化引起的比容变化对反动度的影响，另作计算），则该式可写为：

$$\frac{1-\Omega_{01}}{1-\Omega_0}=\left(\frac{f_{01}}{f_0}\right)^2=\frac{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2}{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{a0}\cos\beta_1]^2} \tag{19}$$

由于 $\Omega_{01}=\Omega_0+\Delta\Omega_f$ 及 $f_{01}=f_0+\Delta f$，将此关系式代入式(19)，经展开、推导、消项、合并、整理后，可得出下式：

$$\Delta\Omega_f/(1-\Omega_0)=B\,\Delta f/f_0 \tag{20}$$

$$B=\frac{2}{1+2\dfrac{\Delta f}{f_0}+\dfrac{(1-\Omega_0)[1-\varphi^2\cos^2(\beta_1-\alpha_1)]+\sqrt{1-\Omega_0}\,\varphi x_{ao}\cos(\beta_1-\alpha_1)\cos\beta_1}{\Omega_0+\varphi^2(1-\Omega_0)\cos^2(\beta_1-\alpha_1)-2\varphi\sqrt{1-\Omega_0}\,x_{a0}\cos(\beta_1-\alpha_1)\cos\beta_1+x_{ao}^2\cos^2\beta_1}}$$

3.3 比容比 q 单独变化引起的反动度变化值 $\Delta\Omega_V$

此情况下，式(13)中 $x_{a1}=x_{ao}$，$f_{01}=f_0$，则该式可写为：

$$\frac{1-\Omega_{01}}{1-\Omega_0}\left(\frac{q_{01}}{q_0}\right)^2=\frac{\Omega_{01}+[\varphi\sqrt{1-\Omega_{01}}\cos(\beta_1-\alpha_1)-x_{ao}\cos\beta_1]^2}{\Omega_0+[\varphi\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)-x_{ao}\cos\beta_1]^2} \tag{21}$$

将 $\Omega_{01}=\Omega_0+\Delta\Omega_u$ 及 $q_{01}=q_0+\Delta q$ 代入式(21)，经展开、推导、消项、合并、整理后，可得到下式：

$$\Delta\Omega_u/(1-\Omega_0)=C\Delta q/q_0 \tag{22}$$

其中 $C=\dfrac{2}{1+\dfrac{2\Delta q}{q_0}+\dfrac{(1-\Omega_0)[1-\varphi^2\cos^2(\beta_1-\alpha_1)]+\sqrt{1-\Omega_0}\,\varphi x_{ao}\cos(\beta_1-\alpha_1)\cos\beta_1}{\Omega_0+\varphi^2(1-\Omega_0)\cos^2(\beta_1-\alpha_1)-2\varphi x_{ao}\sqrt{1-\Omega_0}\cos(\beta_1-\alpha_1)\cos\beta_1+x_{a0}^2 2\cos^2\beta_1}}$

式(22)亦可写为

$$\frac{\Delta\Omega_V}{1-\Omega_0}=C\left(\frac{V_{2t1}/V_{1t1}}{V_{2t}/V_{1t}}-1\right)\approx C\left(\frac{V_{21}/V_{11}}{V_t/V_1}-1\right) \tag{23}$$

需要指出，有些参考文献近似按 $\dfrac{V_{21}/V_{11}}{V_{11}/V_1}=\dfrac{p_{11}/p_{21}}{p_1/p_2}=[1+\Omega_{01}(1/\varepsilon_{01}-1)]/[1+\Omega_0(1/\varepsilon_0-1)]$ 的关系式（式中 ε_0，ε_{01}为级的压力比）计算，由于比容变化引起的反动度变化值，在实际计算中可能引起很大的误差，这是应当加以注意的。建议最好以原始式(23)计算 $\Delta\Omega_V$ 之值，即应以 V_{2t1}，V_{1t1} 或 V_{21}，V_{11}的实际数值代入计算。

4　理论反动度的修正及其统一表达式

以上讨论了当级的叶顶、叶根间隙不发生吸汽或漏汽时反动度随速度比、面积比和比容比的变化，这样的反动度称为理论反动度 Ω_{th}，但汽轮机运行时，叶顶、叶根间隙总是存在吸汽或漏汽的，因此，必须对理论反动度 Ω_{th}进行修正。

现分别列出叶顶及叶根间隙单独发生吸漏汽对反动度影响的关系式如下（限于篇幅，此处略去详细的证明）：

4.1　叶顶间隙漏汽

$$\Delta\Omega_1=\Omega-\Omega_{th}=-kf_t\sqrt{\frac{\Omega}{1-\Omega}} \tag{24}$$

式中 k— 系数, $k=k_1\frac{\mu_t}{\mu_n}$, 对于冲动级 $k_1=0.8\sim0.9$, 计算时可取平均值 0.85, μ_t 为叶顶间隙的流量系数, $\mu_t=0.8$; μ_n 为喷嘴的流量系数, $\mu_n=0.97$.

f_t —叶顶间隙面积 A_t 与喷嘴面积 A_n 的比值, 即 $f_t=A_t/A_n$

4.2　叶顶间隙吸汽

$$\Delta\Omega_2=\Omega-\Omega_{th}=2kf_t\sqrt{\frac{-\Omega}{1-\Omega}} \tag{25}$$

4.3　叶根间隙漏汽

$$\Delta\Omega_3=k_g f_g-k_d f_d\sqrt{\frac{\Omega}{1-\Omega}} \tag{26}$$

式中 $k_g=k_1\frac{\mu_g}{\mu_n}$, μ_g 为隔板汽封的流量系数, $\mu_g=0.8$

f_g —隔板汽封的折合面积比, $f_g=A_g/\sqrt{Z}A_n$

A_g, Z —隔板汽封的漏汽面积及齿数

$k_d=k_1\frac{\mu_d}{\mu_n}$, μ_d 为平衡孔的流量系数, $\mu_d=0.4$

f_d —平衡孔面积与喷嘴面积之比, $f_d=A_d/A_n$

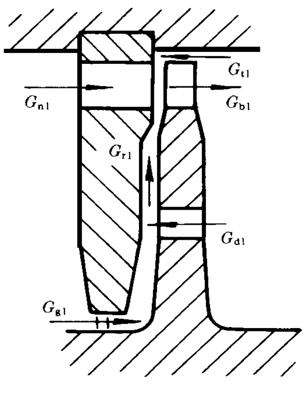

图 3　负反动度较大时的吸汽状态

4.4　叶根间隙吸汽(负反动度)

$$\Delta\Omega_4=2k_g f_g+2k_d f_d\times\sqrt{\frac{-\Omega}{1-\Omega}} \tag{27}$$

4.5　叶根间隙吸汽(叶根正反动度)

$$\Delta\Omega_5=2k_g f_g-k_d f_d\times\sqrt{\frac{\Omega}{1-\Omega}} \tag{28}$$

汽轮机在运行时, 随着工况的变化, 蒸汽在通流部分各处的压力、反动度也随之变化, 级的叶顶、叶根间隙就会呈现出不同的漏汽或吸汽状态, 各种不同的间隙吸、漏汽以及平衡孔处的正、逆向流动都可以看成是上述五种情况中某两种的组合。例如图 1 所示状态, 可看作是情况 4.1 与 4.3 的组合, 由于叶顶和叶根间隙漏汽所引起的反动度总变化值为:

$$\begin{aligned}\Delta\Omega&=\Delta\Omega_1+\Delta\Omega_3\\&=-kf_t\sqrt{\frac{\Omega}{1-\Omega}}-0.5kf_d\sqrt{\frac{\Omega}{1-\Omega}}+kf_g\\&=-k(f_t+0.5f_d)\sqrt{\frac{\Omega}{1-\Omega}}+kf_g\end{aligned}$$

又如图 3 所示状态, 可看作是情况(4.2)、(4.4)的组合, 由于负反动度较大, 使叶项、叶根间隙吸汽, 平衡孔处倒流, 其所引起的反动度总变化值为:

$$\begin{aligned}\Delta\Omega&=\Delta\Omega_2+\Delta\Omega_4\\&=2kf_t+\sqrt{\frac{-\Omega}{1-\Omega}}+kf_d\sqrt{\frac{-\Omega}{1-\Omega}}+2kf_g\end{aligned}$$

在数值计算中, 上述五种情况可以用一个统一的表达式表示, 这就省去了按不同情况编制程序的工作, 使程序变得简单, 修正理论反动度的统一表达式如下:

$$\Omega-(-1)^n sk_1\frac{\mu_t}{\mu_n}f_t\sqrt{\frac{-(-1)^n\Omega}{1-\Omega}}-(-1)^n rk_1\cdot\frac{\mu_d}{\mu_n}f_d\times\sqrt{\frac{-(-1)^n\Omega}{1-\Omega}}=\Omega_{th}+rk_1\frac{\mu_g f_g}{\mu_n} \tag{29}$$

式(29)中, 五种不同情况的 n, s, r 值如下表所示。

情况	n	s	r
(1)	1	1	0
(2)	2	2	0
(3)	3	0	1
(4)	4	0	2
(5)	5	0	2

在选取合适的上、下限后, 就可用迭代法求得满足式(24)~(28)任何一个关系式的叶顶或叶根处的反动度值。

5　结论

(1)变工况下的反动度是速度比 x_a、面积比 f、比容比 q 以及流量比 g 的函数。工况改变时, 反动度的变化具有全增量的性质, 即反动度变化值都是由速度比、面积比、比容比等单独变化所引起的反动度变化的总和。

(2)变工况下, 无须考虑由于叶顶间隙和叶根间隙发生漏汽或吸汽对反动度的影响, 并进行修正。

(3)反动度在汽轮机的热力计算中起着主导的作用, 因此, 正确地确定反动度的数值对于保证热力计算的准确性以及了解汽轮机的工作状态有着重要的意义。

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This paper discusses the unified expression of steam turbine reaction degree under off-design operaling conditions and a variety of factors exercising an influence on such a degree. Also addressed is the problem of total increment character of the reaction degree variation, etc., giving a relatively comprehensive and concise explanation to the contents of the reaction degree. **Key words:** steam turbine, off-design operating condition, degree of reaction

热电联产热电按质分摊数学模型的建立及修正方法＝**The Establishment of a Mathematical Model for Cogeneration Heat and Electricity Apportionment according to Quality and a Correction Method**[刊，中]/Jing Youyin(North China Electric Power University)//Journal of Engineering for Thermal Energy & Power．－1999，14(1)．－51～52

On the basis of a "new conception of cogeneration heat and electricity apportionment" and proceeding from a calorimetric method a mathematical model for heat and electricity apportionment is set up, thus significantly improving the derivation process of actual enthalpy drop method and finding out the relationshiip between the calorimetric method and actual enthalpy drop method. This leads to a more lucid concept of the actual enthalpy drop method and its more clarified physical meaning. To overcome defects of the calorimetric method and actual enthalpy drop method introduced is a concept of the apportionment according to quality of thermification power generation cold source loss. **Key words:** cogeneration, steam extraction power generation, apportionment of heat and electricity according to quality, thermification power generation cold source loss

多媒体技术在汽轮机调速培训系统中的应用＝**The Application of Multi－media Technology in Steam Turbine Speed Governing Training system**[刊，中]/Zhao Hong, Sun Zhaoqiang, Weng Yiwu(Harbin No. 703 Research Institute)//Journal of Engineering for Thermal Energy & Power．－1999，14(1)．－53～55

Multi-media technology is employed in a steam turbine speed governing training system. A brief description is given of the development and realization of a multi-media teaching software for the steam turbine speed governing training system. **Key words:** computer, multi-media, teaching and training

键合图方法在气动系统中的应用＝**The Use of Bonded Diagram Method in an Aerodynamic System**[刊，中]/Li Yan, Zhou Yunlong, et al(North China Electrical Power University)//Journal of Engineering for Thermal Energy & Power．－1999，14(1)．－56～59

Under the assumption that working medium can meet ideal gas state equation and by the use of a dual-channel pseudo bonded diagram method sought out was the description method for an aerodynamic system C field, R field and aerodynamic. I element. With respect to the gas charging process of a gas tank and the speed governing circuit of a cylinder outlet throttling a simulation and experiment was conducted. **Key words:** power output bonded diagram, pseudo bonded diagram, aerodynamic system, dynamic simulation, C field, R field, I element

燃气一蒸汽联合循环无旁通烟囱的分析＝**An Analysis of the Condition under Which No Bypass Stack is Provided for the Gas-Steam Combined Cycle Power Plant**[刊，中]/Yao Tingsheng, Zhuang Jianneng, Wu Laigui (Shenzhen Dapeng Power Plant)//Journal of Engineering for Thermal Energy & Power．－1999，14(1)．－60～62

The features of a gas-steam combined cycle power plant without a bypass stack are analyzed. It is pointed out that during the start-up of such a plant there will be a thermal shock to a heat recovery boiler. The need for the installation of a bypass stack should be determined based on the actual operation conditions of the power plant. What is proposed in the paper may serve as a reference guide to designers of combined cycle plant schemes and operating personnel of such plants. **Key words:** combined cycle, bypass stack, analysis