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Electric Site Survey to Explore Elevator Parameters

通过电气现场调查考察电梯参数

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Abstract

The need to modernize vertical transportation systems in old tall buildings is growing very rapidly. Modernization using state of the art Permanent Magnet motors and the latest control technologies will provide highly improved traffic performance and up to 50-60% energy savings. The environmentally optimal solution is to maximize the reuse of the existing installed material. Car acceleration and the hoisting motor power will reveal existing parameters when state of the art sensors, measurement, modelling and optimization techniques are applied. The developed KONE ESiteSurvey™ method provides a comprehensive set of elevator system parameters readily after a round trip test run and out-of-service time less than 30 minutes. The parameters include masses, frictions, balancing, compensation, hoist motor and hoist way efficiencies.

Keywords: Modernization, Systems Analysis, Modelling, Optimization, Energy

摘要

旧高层建筑更新改造垂直运输系统的需求增长非常迅速。利用最先进的永磁驱动技术和最新的控制对旧电梯系统进行更新改造，可以极大地改进运输性能，同时可节约高达50-60%的能源。从环保角度出发，最佳解决方案是最大限度地再利用现有安装材料。当采用最先进的传感器、测量、建模和优化技术时，轿厢加速度以及曳引驱动功率将显示现有的电梯系统参数。通力电梯开发的ESiteSurvey™ 方法可以在经过往返试运行和不超过30分钟的停止运行之后提供一整套电梯系统参数。这些参数包括质量、摩擦、平衡、补偿、曳引驱动和曳引方式的效率。

关键词：更新改造、系统分析、建模、优化、能源

Introduction

The number of old tall buildings that need major elevator modernization is growing globally by more than 5% per annum, even by 15% in some markets. New buildings appear around the old buildings and it is a challenge to keep the old buildings competitive to attract tenants. Typical reasons to make a major modernization to the building's People FlowTM systems is usually poor reliability due to the main components wear and tear and/or poor traffic handling performance due to old controls systems and probably a change of the building usage or increased population.

For a major modernization there are three main different approaches: (1) keep the old motor and hoisting system, (2) keep the hoisting system but change the motor and (3) make a full replacement.

The full replacement is obviously the most expensive one and disturbs for long time the building operations. On the other hand, if the old hoisting system and the DC motor are kept, it is less disturbing but energy efficiency and long term reliability are sacrificed. Reused DC motors involve reliability risks, like insulation damage due to the higher excitation stress of present drive technologies,

引言

全球需要进行大型电梯更新改造的旧高层建筑数量每年增长超过5%，在有些市场，每年增长甚至达到15%。旧建筑物周围不断涌现新建筑物，对于旧建筑物来说，要在吸引租房客方面保持竞争力十分具有挑战性。对建筑物的People FlowTM 系统进行大型更新改造的典型原因一般包括因主要零部件磨损而导致系统可靠性变差，和/或者因旧的控制系统和建筑用途变化或人口增加而导致系统的运输处理性能变差。

要实施大型更新改造，主要有三种不同的方法：（1）保留旧的驱动和曳引系统；（2）保留曳引系统但更换驱动系统；和（3）全部更换。

很显然，全部更换的费用最昂贵，并且对建筑物的运行造成长时间干扰。另一方面，如果保留旧的曳引系统和直流驱动系统，虽然带来的干扰较少，但却牺牲了能源效率和长期可靠性。直流驱动系统再利用存在可靠性风险，例如，因现有驱动技术的较高激发应力而导致的绝缘损坏、轴承损坏甚至驱动轴故障均出现过。

由于直流驱动技术一般也是处于其生命周期的最后阶段，因此，大型更新改造的最佳选择方案是保留旧的导轨和曳引系统，而采用高效、可靠的永磁同步驱动技术取代现有的驱动系统。从环保角度来看，这

broken bearings or even motor shaft breakdowns.

Since the DC-motor technology in general is also at the end of its life cycle, the most optimum alternative for the major modernization is to keep the old guide rails and hoisting system but replace the existing motor with the highly efficient and reliable Permanent Magnet Synchronous Motor technology. This approach is environmentally sustainable because it produces the least amount of waste and is the most energy efficient and reliable long-term solution.

The challenge in replacing the motor while keeping most of the old system is to become familiar with the main key parameters of the existing system to engineer a safe and reliable new solution. The most critical parameters are the masses of the existing key components and the balancing hoisting system. Occasionally, weight information can be found from the plates attached to the components, but experience has shown that this information is unreliable due to possible undocumented changes made to the system over the years.

Until today, most of the main components have been surveyed with considerable on-site effort. The efforts sometimes even include dismantling the system to subcomponents and weighing them separately to obtain accurate information. This means long out-of-service periods. This paper describes an innovative procedure for determining the key parameters accurately from traction elevators with minimum disturbance to the elevator availability, only about 30 minutes out-of-service, enabling safe and reliable solutions.

Operation Principle

Commonly in the elevator industry, in order to achieve an understanding of the elevator system, the outputs of the system, like acceleration or speed, are recorded and analyzed (Ebeling 2011), (Lorsbach 2010). This approach provides some view of the system operations, conditions and behavior. However, when the system is controlled with a feedback loop, the monitored output behavior may remain unaffected, although there were significant abnormalities in the system parameters, for example in balancing of the car/counterweight system or in hoistway friction.

In order to obtain a more comprehensive view of the objective system, the input excitation and output response signals together with the system model identification and estimation techniques are required (Ljung 1999), (The MathWorks 2011). The traditional way to form a system model for a mechanical system is based on force balances acting on the system (Lehtinen et al. 1998). The drawback is that it essentially requires a priori information about the objective system. In this application the motor current-to-torque characteristics should be known beforehand. Generally, and particularly in modernization projects, it is not possible to obtain this information about an arbitrary, old elevator system being modernized.

Instead of the ordinary force model, a power or energy balance model approach has been adopted here. The fundamental principle of energy preservation omits the need of any prior knowledge of the investigated system. In fact, it is possible to compute many characteristics of the system while post-processing the energy model outputs, including the mentioned current-to-torque operating curve of the motor.

Figure 1 illustrates how KONE Electric Site Survey or KONE ESiteSurvey^{TM} exploits the power balance approach.

Motor electrical power, P_{me}, and car acceleration, a, are recorded during a test round trip run from top floor to bottom floor and back.

种方法具有可持续性，因为其提供的是一个浪费程度最低、能源效率和可靠性最佳的长期解决方案。

更换驱动系统同时最大限度地保留旧的系统，其挑战是要了解现有系统的主要关键参数，以便能够设计出一个安全、可靠的新方案。最关键的参数是现有关键零部件的质量和曳引系统平衡。少数情况下，重量信息可从零部件随附的铭牌上找到，但是经验表明，这类信息并不可靠，其原因是，过去数年来，系统可能发生了一些没有记录在案的变化。

直到今天，主要零部件的质量仍需通过大量的现场调查工作获知。现场调查工作有时甚至包括将系统拆解成各个子组件，并分别称重，以获取足够的准确信息。这始终意味着系统长时间的停止运行——甚至长达数周时间。本文描述了一种能够准确获取任何牵引电梯的关键参数的创新程序，对电梯的可用性仅造成最小干扰，停止运行时间仅需30分钟左右，从而能够给出安全、可靠的解决方案。

运行原理

在电梯行业，为了获取对电梯系统的了解，通常需要记录并分析系统的输出，如加速度或速度，例如（伊贝玲，2011年）、（骆巴，2010年）。这种方法可以提供一些关于系统的运行、状况和行为的视角。但是，当系统使用反馈回路进行控制时，尽管系统参数有显著的异常情况，例如轿厢/配重系统的平衡或者井道摩擦，但所监控的输出行为仍可能保持不变。

为了对目标系统有一个更全面的了解，需要有输入激发和输出响应信号以及系统模型识别和估测技术（李军，1999年）（MathWorks公司，2011年）。构建机械系统的系统模型的传统做法是根据作用在系统上的力平衡（雷提依等，1998年）。这种方法的缺点是，其要求必须有目标系统的先验信息。在这种应用中，必须事先知晓驱动系统的电流转矩比特征。一般而言，尤其是在更新改造项目中，是不可能获得任意一个需要更新改造的旧电梯系统的这一信息。

这里采用一种功率或能量平衡模型方法，而不是普通的力模型。能量守恒基本原理不要求事先了解被调查的系统。事实上，其可以计算系统的诸多特征，同时后期处理能量模型输出，包括所提及的驱动系统的电流转矩比运行曲线。

图1显示了通力电梯的电气现场调查或通力电梯的ESiteSurvey™如何利用功率平衡法。

在从顶层到底部并从底部返回顶层的往返试运行期间，记录驱动系统的电功率P_{me} 和轿厢的加速度a。驱动系统有内部损耗，例如因电流经过电枢和磁场绕组而导致的铜线损耗。在驱动系统牵引

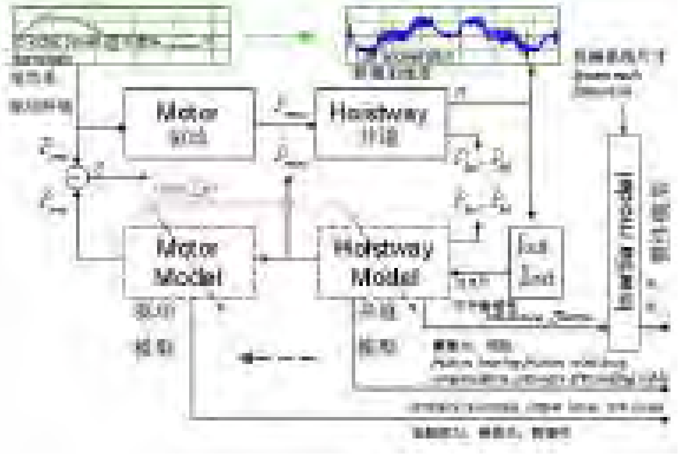

Figure 1. KONE ESiteSurveyTM block diagram
图1. 通力电梯ESiteSurveyTM框图

The motor suffers internal losses, such as copper losses due to the current through the armature and field windings. The mechanical power, P_{mm}, obtainable at the motor traction sheave, is the electrical power, P_{me}, minus the motor internal losses. The mechanical power, P_{mm}, at the motor's traction sheave acts as an excitation signal to the hoistway system. The P_{mm} transforms in the hoistway partially into useful conservative potential and kinetic energies, P_{hc}, and partially is lost in friction type losses, P_{hl}. The consequence and indication of these energy transformations is car acceleration, ***a***. It is obvious that from real elevator systems it is not possible to directly measure by any reasonable means either the traction sheave instantaneous mechanical power or the powers inside the hoistway.

In order to dig into the motor-hoistway system, a model based on power terms is formed. The information flow in the model is reverse - the motor electrical power, P_{me}, is estimated based on the car state vector ***(a, v, h)T***. Further, the estimation error, ***e***, is minimized over the set of motor power and car acceleration samples ***K*** collected during the round trip test run:

$$e(\mathbf{P})=\sum_{k\in K}(\hat{P}_{me}(a_k,v_k,h_k,\mathbf{P})-P_{me k})^2=\min .$$

In the optimization problem (1) velocity ***v*** and position ***h*** of the car are obtained by integrating the measured acceleration ***a***. The vector ***P*** represents all the parameters for partial power terms included for the motor and hoistway models. For example, the models for potential and kinetic power terms P_P and P_K in the hoistway model are:

$$\hat{P}_P(a,v,h,m_B(h))=m_B(h)\cdot g\cdot v$$
$$\hat{P}_K(a,v,h,m_I(h))=m_I(h)\cdot a\cdot v$$
$$\hat{P}_{hc}=\hat{P}_P+\hat{P}_K$$

where m_B is the mass difference between the car-counterweight system and other shaft components affecting it, m_I is the equivalent total inertia mass of all moving or rotating components in the system, both are in kilograms and dependent of car location in the hoistway. Symbol ***g*** is the gravitational acceleration ~9.81 m/s^2.

Once the optimization problem (1) is completed, the hoistway and motor parameters have been found as well as numerous additional parameters, figures of merits and performance indicators can be calculated. For example, based on the readily available estimates for the traction sheave power and hoistway conservative powers , it is possible to calculate estimation for the motor and hoistway efficiencies at any point k of the test run:

$$\hat{\eta}_{mk}=(\hat{P}_{mm_k}P_{me_k}{}^{-1})^{sign(P_{me_k})}\qquad \hat{\eta}_{hk}=(\hat{P}_{hc_k}\hat{P}_{mm_k}{}^{-1})^{sign(P_{hc_k})}$$
$$\left|\hat{P}_{mm}\right|>0\quad \left|P_{me}\right|>0\quad \left|\hat{P}_{hc}\right|>0$$

Equation (3) says that the real mechanical powers, impossible to measure on site, have been substituted with their estimates from the model. The efficiency figures from equation (3) are realistic in a way that they illustrate the real operating conditions and performance of the elevator. Typically the motor efficiencies are obtained in a torque test bench in a laboratory environment and are given at a certain nominal operating point.

Obtaining The Hoistway Parameters

For the high-rise modernization projects one of the most interesting

滑轮处可获得的机械功率P_{mm} 等于电功率P_{me}减去驱动系统内部损耗。在驱动系统牵引滑轮处的机械功率P_{mm} 反过来作为到曳引系统的激发信号。曳引系统中的P_{mm} 部分转化为有用的保守势能和动能P_{hc}，部分以摩擦损耗P_{hl}的形式损耗。所有这些沿着功率传输链进行的能量转化的结果和指示是轿厢加速度***a***。很明显，在实际电梯系统中，要通过任何合理的方法直接测量牵引滑轮的瞬时机械功率或曳引系统中的功率是不可能的。

为了深入了解驱动-曳引系统，特别构建了一个基于功率术语的模型。在该模型中，信息流是逆向的——驱动系统的电功率P_{me}根据轿厢状态向量 ***(a, v, h)T***进行估测。此外，估测误差***e***在往返试运行期间收集的驱动系统功率和轿厢加速度样本集***K***中获得了最小化。

$$e(\mathbf{P})=\sum_{k\in K}(\hat{P}_{me}(a_k,v_k,h_k,\mathbf{P})-P_{me k})^2=\min .$$

在最优化问题（1）中，速率***v***和轿厢的位置***h***通过对所测加速度***a***求积分获得。向量***P***代表驱动和曳引模型中包括的部分功率术语的所有参数。例如，曳引模型中的势能和动能功率术语P_P和P_K的模型是

$$\hat{P}_P(a,v,h,m_B(h))=m_B(h)\cdot g\cdot v$$
$$\hat{P}_K(a,v,h,m_I(h))=m_I(h)\cdot a\cdot v$$
$$\hat{P}_{hc}=\hat{P}_P+\hat{P}_K$$

在上式中，m_B是轿厢配重系统和对其有影响的其他转轴零部件之间的质量差，m_I 是系统中所有移动或旋转零部件的等量总惯性质量，两者都以千克为计量单位，取决于轿厢在井道中的位置。符号***g***是重力加速度~9.81m/s^2。

一旦最优化问题（1）完成，即找到了曳引和驱动参数，并可以计算多个其他参数、优良指数和性能指标。例如，根据对牵引滑轮功率和曳引保守功率的现有可用估计值，可以计算试运行中任何一点k处的驱动和曳引效率的估计值：

$$\hat{\eta}_{mk}=(\hat{P}_{mm_k}P_{me_k}{}^{-1})^{sign(P_{me_k})}\qquad \hat{\eta}_{hk}=(\hat{P}_{hc_k}\hat{P}_{mm_k}{}^{-1})^{sign(P_{hc_k})}$$
$$\left|\hat{P}_{mm}\right|>0\quad \left|P_{me}\right|>0\quad \left|\hat{P}_{hc}\right|>0$$

等式（3）表明在现场无法通过测量获得的实际机械功率被模型中获得的估计值替代。通过等式（3）获得的效率数据在某种程度上是实际数据，反映了电梯的实际运行状况和性能。例如，一般在实验室环境中，通过转矩试验台获得某个额定运行点的驱动效率。

获得井道参数

对于高层更新改造项目，最有趣、最相关的问题之一是轿厢和配重质量m_{car}和m_{cwt}。从框图中可以看到，基本系统模型没有将等量线性总惯量分到机械系统零部件中。该模型只提供了线性惯量总质量m_I和系统平衡质量m_B。为了获得轿厢和配重质量，必须知晓其他移动零部件的惯性质量，这样就可以根据所确定的质量m_I和m_B计算得出。

当系统功率模型适当制定出来时，则可以定义以下关系：

$$\begin{cases}m_B=m_{car}-m_{cwt}\\ m_I=m_{car}+m_{cwt}+m_{IC}\end{cases}$$

在上式中，m_{IC}包括除轿厢和配重之外的所有其他移动零部件的线性惯性质量。如果零部件***c***有旋转惯量，首先必须通过转换公

and relevant questions are the car and counterweight masses m_{car} and m_{cwt}. As visible in the block diagram the basic system model does not divide the total equivalent linear inertia to mechanical system components. The model provides only the total linear inertia mass m_I and the system balancing mass m_B. In order to access the car and counterweight masses, the inertia masses of the other moving components have to be known so that they can be counted out from the identified masses m_I and m_B.

Once the system power model has been properly formulated, the following relationship can be defined:

$$\begin{cases} m_B = m_{car} - m_{cwt} \\ m_I = m_{car} + m_{cwt} + m_{IC} \end{cases}$$

where m_{IC} holds the linear inertia masses of all other moving components other than car and counterweight. If a component c has rotational inertia, it has to be transferred first to its equivalent linear inertia with a transformation $m_{Ic} = J_c / r_c^2$, where J_c is the rotational inertia and r_c is the radius of the rotating element through which the component is connected to the system. If the roping ratio differs from 1:1, it has to be considered as well.

In the following example, an office building in Paris (KONE 2012), illustrates the accuracy of the obtained results. The building is under modernization. The existing DC motors are replaced with KONE EcoDisc® permanent magnet synchronous motors whereas the car and counterweight are reused. ESiteSurveyTM was made as part of the standard site survey during the tendering phase. The main goal was to find out the masses of the car and counterweight in order to ensure a safe, reliable and economical new hoisting solution. The inertias of the hoisting system components were defined based on the measured dimensions and information from the rope plates. After receiving the modernization project one of the elevators was weighed in a traditional way to verify the results from the ESiteSurvey™.

Rope inertia masses are simple to define based on rope lengths and information from rope plates or diameter of the ropes. The pulleys and especially the motor are, more challenging. Fortunately the construction of the DC-motor is normally such that the rotating parts can be split up into three main inertia components: armature, traction sheave and brake drum. Each of these three components can be modelled as a set of hollow cylinders with outer diameter D and inner diameter d having a rotational inertia:

$$J(D,d,l,\rho) = \frac{l}{2}\pi\left[\left(\frac{D}{2}\right)^4 - \left(\frac{d}{2}\right)^4\right] \cdot \rho$$

where l is the length of the cylinder and ρ is the density of material. As inertia increases in power to 4 with the diameter, usually only the outer main brim is enough to consider. If more accuracy is needed then also the body structure can be modelled as a cylinder with $d=0$ and $D=d_{brim}$.

Figure 2 shows the measured and estimated motor power from a unit with 1,600 kg capacity, 5 m/s nominal speed, 1:1 roping and 127 m travel. The EsiteSurvey model explains again the general behavior of the hoisting system very well; the average error is 0.5kW over the round trip while the peak power is ~90kW. Part of the error comes from the vibration caused by the vertical jerking of the car acceleration. The model does not even try to explain this. The results of applying the inertia model are shown in the Table 1.

式$m_{Ic} = J_c / r_c^2$转化为等效线性惯量。在该转换公式中，J_c为旋转惯量，r_c是将该零部件连接到系统的旋转元件的半径。如果悬挂比不等于1:1，也必须予以考虑。

在下面的例子中，法国巴黎的一座办公楼（通力电梯2012年）说明了所得结果的准确性。该建筑目前正在进行更新改造。采用通力电梯的EcoDisc® 永磁同步驱动系统取代现有的直流驱动系统，并再利用现有的轿厢和配重。在投标阶段，ESiteSurvey®是作为标准现场调查的一部分。其主要目的是找到轿厢和配重的质量，以确保设计出一个安全、可靠和经济的全新曳引方案。曳引系统零部件的惯量根据所测的维度和钢索铭牌上提供的信息确定。在获得该更新改造项目之后，我们采用传统方法对其中一台电梯称重，验证了通过ESiteSurvey® 获得的结果。

根据钢索长度和钢索铭牌上的信息或钢索的直径可以直接确定钢索的惯性质量。滑轮，特别是驱动系统，则更具挑战性。幸运的是，直流驱动系统的结构（如旋转零部件）通常可以分成三个主要惯量零部件：电枢、牵引滑轮和制动轮。这三个零部件都可以建模为一组空心圆柱体，外径D和内径d的旋转惯量为：

$$J(D,d,l,\rho) = \frac{l}{2}\pi\left[\left(\frac{D}{2}\right)^4 - \left(\frac{d}{2}\right)^4\right] \cdot \rho$$

在上式中，l是圆柱体的长度，ρ是材料的密度。当功率中的惯量随着直径增加到4时，通常只有主要的外边缘足以考虑。如果需要更高的准确性，那么主体结构也可以建模为一个圆柱体，其中$d=0$和$D=d_{brim}$。

图2显示了载重量为1600kg、额定速度为5m/s、悬挂比为1:1、行程为127米的系统单元的测量和估算驱动功率。EsiteSurvey™ 模型再次很好地解释了曳引系统的一般行为。当峰值功率为~90kW时，每个往返运行的平均误差是0.5kW。部分误差来自轿厢加速度垂直抖动引起的振动型噪音，对此该模型甚至没有试图解释。应用该惯量模型的结果如表1中所示。

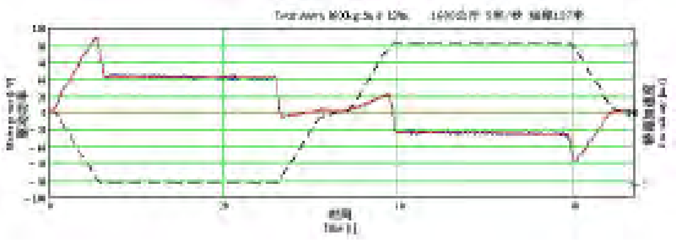

Figure 2.Office tower in Paris, measured and calculated motor power vs. time
图2. 巴黎办公楼，测量和计算所得的驱动功率vs. 时间

	ESiteSurvey[kg] [千克]	Weighed [kg] 重量[千克]	D [kg] 差值[千克]	D [%] 差值[百分比]
Car 轿箱	2783	2813	-30	-1.1
	3638	3675	-37	-1.0

Table 1. Office tower in Paris, car and counterweight masses
表1. 巴黎办公楼，轿厢和配重质量

Other interesting main parameters found from the hoisting system include: slight under compensation -0.6 kg/m, travelling cable unit weight 2.7 kg/m and middle of the shaft balancing -850 kg / -53%.

The results of the example above show that it is possible to gather component inertia information based on the dimensions and to replace the laborious, tedious, obtrusive and lengthy traditional weighing procedure with the more convenient and less disruptive KONE ESiteSurveyTM method.

Motor And Hoistway Efficiencies

The efficiency of the motor and shaft in the office tower in Paris is shown in Figure 3 as calculated according to equation (3). The instantaneous efficiency can be seen at every stage of the round trip. Consequently the efficiency could be called "operational" or "dynamic" efficiency, since it shows the true operating performance of the system.

One interesting point to mention is that when the system accelerates to heavy direction, it is beginning to change from the acceleration state to the nominal speed state. This point is the highest positive peak power on the motor efficiency graph. The inferior efficiency at this point, when compared to constant speed efficiency, is due to the copper and iron losses in the motor. At this point the motor current has its maximum value while the armature commuting frequency is also close to the maximum frequency just before the nominal speed has been reached.

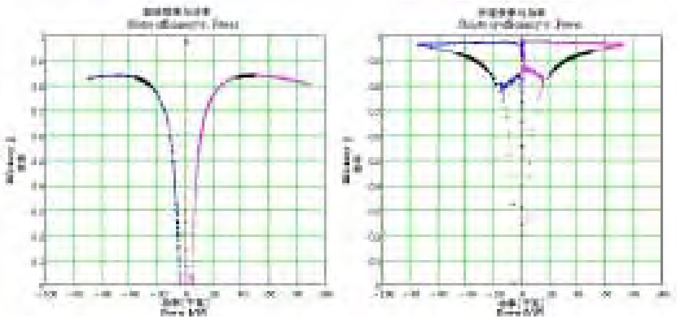

Figure 3.Office tower in Paris , motor and hoistway efficiencies over Round Trip
图3. 巴黎办公楼，往返运行中的驱动和曳引系统效率

In addition to the instantaneous efficiencies, overall average efficiencies can be calculated over the round trip. In this case, the motor round trip efficiency is 0.68, which is a typical low value for a DC-motor from this era. The overall shaft efficiency 0.91 is very good. It is necessary to bear in mind that the obtained efficiency figures always depend on the operating point of the system – the results here are for the empty car full travel round trip. Different loads and different trips will yield different efficiencies. Nevertheless, performing the test always in the same manner will provide comparable results from one system to another.

Measurement Gear And Procedure

Figure 4 demonstrates the data capturing hardware that can be used for both the AC and DC motor systems. There are two subsystems for logging the data.

For motor power there is a small laptop-PC and an USB-based data acquisition box which measure the currents and voltages. DC-

从曳引系统中可找到的其他有趣的主要参数有：略低于补偿-0.6kg/m，运行电缆单位重量2.7kg/m和转轴平衡中项-850kg / -53%。

上述例子的结果表明可以采用更便捷、更少运行中断的通力ESiteSurveyTM方法，根据尺寸大小收集零部件的惯量信息，取代费力、繁琐、令人厌烦、费时的传统称重程序。

驱动和曳引系统效率

图3显示了根据公式（3）计算所得的安装在法国巴黎办公楼中的驱动系统和转轴的效率。在往返运行的每个阶段都可看到瞬时效率。因此，该效率可以称作“运行”或“动态”效率，因为其显示了系统的真实运行性能。

值得一提的非常有趣的一点是当系统朝着较重的方向加速、正要开始从加速状态转变为额定速度状态的那个时刻。该时刻是驱动效率图上的最高正峰值功率。但与常速效率相比，该时刻的效率较低，原因是驱动系统中的铜和铁损耗。在该时刻，驱动电流达到最大值，就在达到额定速度之前，电枢往返频率也接近了最大频率。

除了瞬时效率之外，整体平均效率也可以在往返运行中计算获得。在这种情况下，驱动系统的往返运行效率是0.68，对于当前的直流驱动系统来说，这是一个典型的低值。相反，驱动系统转轴的整体效率0.91则是一个很好的状态。必须记住的是，所获得的效率数字始终取决于系统的运行点——这里获得的结果是对空轿厢完整往返运行而言。不同的载重和不同的行程会产生不同的效率。但是，始终以同样的方式在不同的系统上进行该测试将会得出类似结果。

测量工具和程序

图4显示了可同时用于交流和直流驱动系统的数据采集硬件。有两个子系统可用于记录数据。

对于驱动功率，采用一种小型笔记本电脑和USB接口型数据采集箱测量电流和电压。需要使用直流电流钳和隔离差分探头，以确保测量安全，无失真。对于轿厢加速度，采用一种独立的数据采集箱，在试运行期间放置在轿厢地面，将数据存储到存储卡中。所有测量设备可以装进一个小型携带箱中，重量只有几公斤而已。这可以与传统的系统质量称重法所需的实际硬件相比较，也可以与采用一堆笨重的测试法码确定曳引系统平衡的传统方法相比较。

与传统的称重或平衡检查方法相比，通力电梯ESiteSurvey™ 方法的另一大优点在于其对建筑物人流的干扰最小。当在机房中开

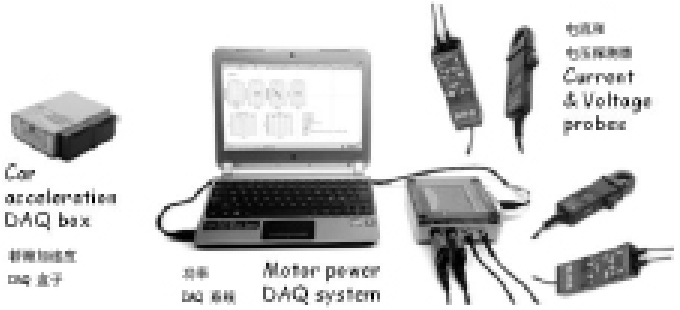

Figure 4. KONE ESiteSurveyTM measurement gear
图4. 通力电梯ESiteSurveyTM 测量工具

current clamps and isolated differential probes are required for safe measurements without distortion. For the car acceleration there is a stand-alone data acquisition box that rides on the car floor during the test run and stores the data in a memory card. All the measuring equipment fits into a small carrying case weighing just a few kilograms. This can be compared to the real hardware needed for the traditional weighing of the system masses and to the traditional way to define the hoisting system balancing with a pile of heavy test weights.

Another vast advantage of the KONE ESiteSurveyTM method is its minimum disturbance to the building's people flow, as compared to the traditional weighing or balancing check methods. The elevator can be in service while the preparation work is going on in the machine room. Once the connection points on the motor have been found and connected, the test run will last less than 10 minutes. Another out-of-service period is required while visiting the car top and collecting the component dimension information. The out-of-service time required for this work is normally around 30 minutes.

Conclusions

A new method to analyze the properties and performance of an existing elevator was presented. The approach is based on state of the art sensor, measurement, modelling and optimization techniques providing a clear insight into an elevator's characteristics. With a light weight measurement system it is possible to substitute the traditional weighing and system balancing measurement procedures. In addition, the method outperforms the traditional approaches in terms of elevator down time and the amount of information that has not been possible to obtain from real elevators so far.

This patented method has shown its power in several real cases. In addition to the reliable hoisting system, the efficiency information obtained from the existing old elevators enables an accurate before–and-after energy consumption analysis. The precise system level, motor and shaft models and efficiencies, along with the round trip energy consumption, can be measured regardless of the brand of the elevator, including Double Deck elevators.

When this professional KONE ESiteSurvey™ method is applied at the early stages of a major modernization, no surprises will arise during the process. The building owner may rely on the solution to be state of the art in terms of performance, energy efficiency and reliability.

展准备工作的时候，电梯可以一直运行。一旦找到驱动系统上的连接点并连接好之后，试运行将持续不超过10分钟的时间。在查看轿厢顶部和井坑以收集零部件的尺寸信息时，需要另一段停止运行时间。该项工作所需的停止运行时间通常在30分钟左右。

结论

本文呈现了一种分析现有电梯属性和性能的全新方法。该方法基于最先进的传感器、测量、建模和优化技术，可以清晰、深入地了解电梯的各种特征。通过一个轻质型测重系统，可以取代传统的称重和系统平衡测量程序。此外，在电梯停机时间以及迄今仍无法从现实电梯中获得的信息量方面，该方法也优于传统方法。

本专利方法多次在实际情况下证明了自身的能力。除了可靠的曳引系统之外，从现有旧电梯中获得的效率信息可以确保在事先和事后进行准确的能源消耗分析。不论哪个品牌的电梯，包括双轿厢电梯，都可以精确测得其系统水平、驱动和转轴模型与效率，以及往返行程的能源消耗。

如果在大型更新改造项目的早期规划阶段采用这种专业的通力电梯ESiteSurvey™ 方法，建筑物业主可以确信在更新改造过程中不会出现任何意外，完全可以依赖这个在性能、能源效率和可靠性方面均属最先进的解决方案。

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