The Development of a Low- to Mid- Rise Energy Efficient, Green Lift System

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Abstract. This paper explains and discusses the drivers, aims and the design process applied in a research and development project to develop a low- to mid- rise green lift system. The particular technologies that have been in this work include a new lift car design, adjustable counterweight system, lift control system, energy efficient drive system, lift monitoring system, belt suspension and improvements in lift installation technique.

1 INTRODUCTION

In the modern built environment there is a strong need and continued demand for the design of efficient and environmentally friendly ('green') vertical transportation systems. In this context, the green lift system design is undertaken within the framework of Knowledge Transfer Partnership scheme. The paper summarizes the research which has been carried out to develop a novel, efficient Machine Room-Less (MRL) low- to mid- rise lift system incorporating a number of modern technologies.

A new MRL system that addresses the inherent problems brought about by economics, current lift practices, environmental challenges and safety standards has been designed. The design of the system is optimized to achieve better efficiency. The lift installation process and the issue of reducing its energy consumption have been investigated in the paper.

2 GREEN LIFT

2.1 Energy efficiency

Although the topic of improving energy efficiency of a lift system was investigated recently on numerous occasions [1], the state of the industry in the UK, particularly in the low- to mid- rise applications, often concentrates on economics rather than constant improvement. This paper is aimed at changing this perception and proposes new solutions that might challenge the current state.

Many people in the industry, primarily lift engineers and lift operators, consider that lifts are already very efficient and account for 5% energy used in offices [2], and according to CIBSE guide F for between 5% and 15% of energy used in some buildings [3] (Other authors quote figures between 3-5% for lifts, escalators and moving walks combined [4] and between 3-8% for lifts according to Asvestopoulos and Spyropoulos [5]). This point of view is understandable for a practitioner, who concentrates on main principles such as economics, mechanical and electrical performance of the system. This is, however, not justified when taking a holistic approach to the energy usage and sustainability of a country. A study presented in the recent work [6] estimates energy saving potential in the European residential sector for 62% of current energy consumption when the best available technology is used. Thus, all efforts concentrated on promoting any incentives that might lead to change and improvement of the current state should be considered.

Energy performance of a lift system in Europe can be currently calculated and classified using the document developed by Association of German Engineers (VDI 4707). The new international standard ISO 25745-2 is expected to be released in the near future and will become a new, widely accepted benchmark and a reference for all new installations. Both methods are similar in the approach to energy calculation and classification. The problem in all cases is that calculations are based on estimations of lift usage for a specific building. This might be sufficient for an initial evaluation, however the next step in evaluation of energy consumption in a lift system would be continuous monitoring, recording all values of lift travel, load in the car and electrical current drawn from the mains supply. An energy usage model which is informed by data from the continuous monitoring system would then allow for a much greater control of the system improving overall efficiency by suitable control strategy.

2.2 Lift System

New technology solutions that are implemented in the project include the following:

- Lift car design and optimization of modular lift car design.
- Adjustable counterweight technology.
- New, software based control system.
- Open protocol remote monitoring system (the i-COM) with modular capability, accessible from internet-enabled devices
- The latest technology drive and suspension system.
- Improvements in the installation technique.

2.3 Lift Car Design

A virtual model of a lift car was developed with the use of Computer Aided Design (CAD) software, which allowed for an accurate and detailed model before any manufacturing will take place. The lift car design is based on a lightweight aluminium framework. This solution benefits from versatile structural options, allowing for implementation of the lift car design in a broader range of sizes, depending on the requirements. Additionally this also allows for limiting the number of traditional fasteners used. Another factor that was taken into account in the design process was an improved installation methodology, where the components are pre-manufactured in the factory, being delivered to the site and installed with minimum work required, due to the secret fixings and modern adhesive bonding used in the process.

The design implements new, cost-efficient composite panels developed for the aerospace industry applications. The panels are of a special construction allowing for better noise and vibration characteristics and a shorter lead time. Another benefit of this solution is the number of parts required. As the panels are cut to size before assembly, it effectively limits the number of panels required per side and further limits the number of fasteners and fixings necessary. Most importantly, the characteristics of panels are such that these panels are of improved fire-resistance as well as of smoke and toxicity properties, allowing them to be used in the modern built environment. Additionally, bespoke design of the car allows for quicker and flexible response to the customer needs.

Benefits of this solution include: limiting the mass of car leads to limiting mass of other components (counterweight); limiting the number of components (panels) lead to reducing the time to manufacture, limiting the number of fasteners reduce mass of car, special fixing solution allow for shorter installation time, limiting the mass of components and simplification of assembly process would allow for reduced installation time. All this improvements will reduce carbon footprint of a lift car. This in effect is a reduction of energy used in manufacture and installation. Additionally reduction of masses will require less energy for acceleration.

2.4 Adjustable counterweight design

Advancement of technology, particularly drive inverters and regenerative systems allowed for improvement of energy efficiency of an MRL lift system, reclaiming energy used in the regenerative phases of a four quadrant operation. These systems provide the required functionality; however there are implications for the actual savings that might be achieved. The main problem of these systems is that regeneration will never be the perfect solution, as the mechanical energy is converted into electrical energy and back into mechanical energy. This is related to losses due to component efficiency which multiply themselves in the cycle. Additionally, from a mechanical point of view, the system is also less efficient when the car load is significantly different from the counterweight balance. So if it is balanced to 0.4-0.5 of the rated load, this leads to a situation that the energy is consumed even when the lift car is moving without load. Statistically this situation occurs in 50% cases of lift travel [6]. One more fact is that people transfer in the building is balanced – traffic in is equal to the traffic out. It is clear that there are exceptions to this, particularly when people use the stairs to go down more often that to go up.

All this has facilitated an improvement in the determination of an adjustable mechanical system that might feasibly be implemented in a low to mid rise lift system. Possible energy gains have been quantified based on the results of lift traffic surveys and correspondingly generated traffic patterns. A virtual model of the adjustable counterweight system has been developed, showing the operational principle and the mechanical components. This work can lead to a more efficient mechanical design of a lift system in certain circumstances. One limitation of this solution is that it can only be incorporated in low and mid-rise systems when the peak traffic is within its rated capability. The advantage of the proposed system is that it can potentially be used as an add-on without redesigning the existing MRL arrangement.

2.5 Control System

The energy performance of a lift system depends on the following two main operational components: running and standby energy consumption. Thus, it is important that the new lift design addresses the issue of energy consumption in both areas. Recent research suggested that the standby energy efficiency of a lift system can account for 5% to 95% of its energy consumption [4], depending on a particular system and its usage patterns and energy consumption during running condition and standby.

New, software based control system programmed in C using Microsoft technology would allow for substantial improvements in panel size as compared to a traditional panel with logic gates, reduction of control system components, time required for manufacture and improved efficiency of the system therefore reducing energy consumption. System software allows to operate the panel in "Eco mode", reducing the energy used for lights and fans during operation and to set the system to the 'Standby' mode. Two additional features that allows for improvement in energy efficiency of the control system is drive standby and micro-controller standby function which could be used during periods of inactivity. Size of all main components used in the panel design allows implementing the main panel in the landing door frame. This offers a significant advantage in the MRL lift arrangement as in this type of lift most problematic is the access to the control cabinet.

2.6 Monitoring System

The newly developed remote monitoring system (i-COM), allows for a continuous monitoring of a number of parameters in the lift. This in turn determines an efficient service schedule thus reducing the costs to the maintenance company and the customer. Parameters, which are directly related to the ride quality, are currently implemented in the monitoring system, including velocity, acceleration and jerk. Additionally it is possible to monitor other properties of the system such as drive parameters, fault log, waiting time statistics, floor levelling statistics, floor usage statistics, maintenance log and remote control of the lift.

A system based on CAN-bus technology would allow ultimately for a number of modules to be connected, namely:

1) Voice transmission module (autodialer)
2) Continuous load monitoring module
3) Condition monitoring module (state of machine, bearings, guide rail performance and lubrication). This solution would allow for a determination of component degradation and predictive maintenance ensuring energy efficiency and a minimum out of service time.

Remote monitoring system has also allowed for further improvements in standby energy consumption of a lift. Periods of inactivity can be logged in the control system, allowing to visualize and decide on particular control strategy, effectively allowing to switch off most of the components on a periodic basis. In case of seasonal operation, monitoring software can allow for further savings, such as reduction of lift speed.

2.7 Drive system

The system benefits from an underslung, 2:1 drive, using polyurethane multi-belts with steel sheaves and pulleys. Implementation of a belt system instead of traditional steel wire ropes has a number of advantages, such as reduced size of traction sheave which allows for a smaller machine running at higher speed, reduction of rope and sheave wear and improvements in ride quality. Other benefits include reduction in overhead clearance required for machine, reduction in space required for car pulleys, reduction in cost of replacement as the belts benefit from greater longevity. Problems in this type of project include design and selection of components, belt monitoring system and certification. A similar solution was used for years by major companies in the lift market, however because of patents on particular designs and solutions, this did not become an industry standard.

The lift is driven by brushless Permanent Magnet Synchroneous Motor (PMSM), a type of rare earth magnet induction motor which benefits from a higher power density for their size as compared to AC Induction motors (ACIM). Use of PMSM in the lift industry is increasing as it allows for more compact design and provides highest efficiency in comparison to ACIM [6].

2.8 Installation technique

The study conducted within this research project has led to consideration of improvements in the installation techniques for low- to mid- rise lift systems. Two particular areas are under investigation, which are using laser sensors to provide accurate alignment of drive and guiding and evaluation of solutions available to reduce installation costs. Laser solutions that were introduced to the lift industry in the past are increasingly used in a number of industries such as automotive, wind power, manufacturing, nuclear, aerospace, and marine [7]. Although the range of applications was investigated in the past it is considered that the area is not sufficiently exploited in practice.

3 CONCLUSION

Main restrains to the energy efficient development that were determined by De Almeida et al. [4] include lack of monitoring of energy consumption, awareness and knowledge about energy efficient technology. In this project it was considered to tackle all three main barriers, which would change the common perception of a lift system as optimally designed.

Other barriers that can be identified based on recent work are particular manufacturer restrictions on the technology (patents), lack of availability of components and UK market demands in the low- to mid- rise lift sector. In order to progress further and to satisfy the modern ecological demands towards a more sustainable environment further research and development effort is needed to be implemented, particularly within the small and medium size enterprise in the lift engineering sector.

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BIOGRAPHICAL DETAILS

Rafal Kwiatkowski graduated in 2013, achieving Masters degree in Mechanical Engineering and Energy Engineering at Heriot Watt University in Edinburgh. Since then he has been working on a development of a Green Lift at ACE Lifts Ltd.

Stefan Kaczmarczyk is Professor of Applied Mechanics at the University of Northampton. His expertise is in the area of applied dynamics and vibration with particular applications to vertical transportation and material handling systems. He has been involved in collaborative research with a number of national and international partners and has an extensive national and international track record in consulting and research in vertical transportation and lift engineering. He has published over 90 journals and international conference papers in this field.

Charles Salter is the owner and Managing Director of ACE Lifts. He has over 35 years of lift industry experience, 25 of those establishing and running ACE Lifts (formerly Artisan Control Equipment). His area of expertise is in the electronic aspect of lifts; specifically control systems and remote monitoring and has contributed to a number of industry texts regarding these. Charles is currently studying for an MSc in Lift Engineering at Northampton University.

Laurel Mulhern is the Sales and Marketing Manager at ACE Lifts Ltd.