Lifting Elevators into the Cloud – Permanent Detection of Wear Using Intelligent Sensors

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Abstract. Condition Monitoring Systems for elevators going beyond a mere display of stored faults or counter readings are hard to find on the lift market. Yet, only a few sensors already allow the monitoring of significant components of a lift system to ensure that wear is detected at an early stage and appropriate servicing recommendations are automatically generated. As such, a predictive maintenance of lifts is possible, which saves a lot of resources and time and nevertheless warrants a high availability of the lift system. Especially for retrofitting of existing lifts an intelligent device is needed, which doesn't need communication to the lift controller. Within the context of a field trial, several lift systems worldwide have been equipped with an IoT-device (Internet of Things) which evaluates every single elevator ride on the edge using intelligent algorithms permitting the wear of individual component groups to be detected. The collected data, resulting messages and alerts are transmitted automatically via the internet by a standard protocol into a cloud, where extended Big Data Analysis is done.

1 INTRODUCTION

The industrial Internet of Things (IoT) and its Digital Twin surrogate are fuelling exciting conversations about business process innovation on the factory floor and in industrial equipment manufacturing. One hot area in particular is the broad and often loosely-defined practice of Predictive Maintenance (PdM) of complex machinery as lifts are too.

As is frequently the case when technology innovation is trying to penetrate an established business practice, there's a good dose of hype and optimism on the side of technology pundits, countered by scepticism and resistance to change from maintenance organizations and experienced field service technicians.

Both sides must work together to create a functioning PdM solution. Neither Big Data Analysts, nor lift engineers or field technicians will be able to do this alone. Only when domain knowledge about lifts, metrologic know-how for lifts, and data analysts' knowledge of algorithms and statistics are brought together, can an efficient, economical, and, above all, functional solution succeed, which can then be the basis for a change in business models in the lift industry.

2 STRATEGIES TO ACHIEVE PREDICTIVE MAINTENANCE FOR LIFTS

2.1 Make the lift controller an IoT device does not provide PdM

Throughout the industry, but especially in the lift market, the controllers of the machines are connected to a cloud via the Internet under the slogan Predictive Maintenance. Technically, this is not far away from the remote data transmission for lift control systems, which was practised more than 20 years ago. And this method actually only allows a Preventive Maintenance. Preventive Maintenance of lift systems is carried out on the basis of intervals: within fixed intervals or after reaching a certain number of rides, door movements etc. Finally, the connection of the lift control to a cloud no longer provides information about the lift, as they would be available to the technician on site. Of course, access, management, linking to support documents and the like is much more comfortable than it used to be, *but this is not a Predictive Maintenance solution*.

2.2 Use of Sensors for Condition Monitoring

Today and in nearly all industrial areas Condition Monitoring is one of the mainstays needed to efficiently operate and service technical plants. This concept is based on a regular or permanent recording of the condition of the machine by measuring and analysing meaningful physical parameters. The technological developments achieved in sensor technology, tribology and microprocessor technology allow an unparalleled quantity and quality of information to be used for the maintenance of lifts too. An industrial environment cannot be pictured without Condition Monitoring any more. It must more or less be regarded as a compelling requirement for a condition-oriented predictive maintenance. The more comprehensive the maintenance strategy and the requirements it has to meet, the more distinctive will be the significance of Condition Monitoring.

The real challenge lies not in the selection of the sensors (this is where the domain knowledge of lift experts is necessary, but also available), but in the evaluation or processing of the sensor data.

2.2.1 Getting advantages from the collected data

Usually IoT vendor presentations suggest that further examination of misunderstandings and perhaps exaggerated expectations from PdM technology is in order.

One model to rule them all. The implied assumption that similar devices generate identical sensor data patterns and therefore a machine learning algorithm can handle multiple devices in the installed base is flawed. In reality, no two mechanical systems are alike even as they roll off the production line. And they begin changing as soon as they are put into duty. The baseline data generated by rotating and reciprocating equipment is highly configuration and application specific, and changes continually throughout the life of the asset due to wear and tear, different duty cycles, and operation and maintenance practices. Machine learning algorithms must adapt to these changes without compromising detection precision or suffering from an increasing rate of false positives.

The Digital Twin provides the ability to track and analyze each asset individually, allowing the machine learning apply context beyond machine-generated sensor data, such as configuration and maintenance history. Although the digital twin is essential to implementing a PdM system, the focus on individual as-maintained unit configurations also highlights a potential concern: if, over time, assets drift to the degree they are no longer similar, the ability to conduct any type of broad installed base analysis is impeded. [1]

Machines learning algorithms do all the work. Machine learning enthusiasts seem to propose something little short of magic. Just feed the software with a wealth of machine-generated data, and AI-based algorithms do all the work on their own. They remove signal noise and data outliers, and smooth data just enough so no key features are lost; they identify the best-suited analytic algorithm; and provide highly accurate data trending and failure prediction. The reality can prove to be more complex, to say the least. Early adopters find that while building a proof-of-concept model is a manageable effort and the results can be very impressive indeed, these initial models can be difficult to scale, as the models must be validated for a much broader range of product configurations and applications, and be able to adopt to changes induced by cyclical changes and wear and tear. The effort to test and validate machine learning algorithms cannot be underestimated. Some types of artificial intelligence systems require regression testing every time a change is made. Ohers, black box type systems, such as neural networks, cannot be trusted blindly based on test results from limited training data. [1.2]

3 REQUIREMENTS FOR A PREDICTIVE MAINTENANCE SOLUTION FOR LIFTS

As is apparent from what is previously mentioned, it is not sufficient to equip a lift system with the highest possible number of sensors and send the measurement data via an Internet connection to a cloud, which would then send back the following maintenance recommendations, wear reports, and others to the appropriate locations. In addition, there are other boundary conditions, which will be briefly touched on here.

3.1 Independence from the lift control

A PdM lift solution must be completely independent of the controller. The diversity and also the small number of open protocols in lift construction would otherwise not permit the widespread application of the system, since the portfolio of every lift service company always includes systems from third-party manufacturers.

3.2 Cost efficiency

It is obvious that a PdM solution is only advantageous if it also saves costs and this not only during operation, but during the entire period of use including the installation of the PdM device. With very few installations, it can be assumed that a PdM solution was already provided for the construction of the system, so special value should be placed on efficient retrofitting.

3.2.1 Efficient installation

An efficient installation requires that the number of sensors used is manageable and easy to install. An installation time of a maximum of two hours should not be exceeded. This assumes that the device remains independent of existing components of the lift and no taps are made of the existing electrical and electronics, which would also require further documentation in schematics, etc. Also, the intended data transfer to the cloud must be chosen wisely, so as not to interfere during installation, e.g. the hanging cable must be extended by data lines to allow an antenna in the shaft head.

3.2.2 Selection of the sensors

Of course, the number of sensors should be as limited as possible, yet still monitor as many crucial components of the lift as possible. Of course, for each sensor, the costs and benefits must also weighed. A very interesting approach is the use of virtual sensors, which generate new measured values from the data of other physically existing sensors without the sensor actually having to exist.

3.2.3 Distributed intelligence

If the know-how for this is available, it makes sense to apply as much computing power as possible already in the PdM device on the lift system. This greatly reduces the effort of data transfer and can offer significant benefits depending on the choice of analysis concept. These preprocessed, on-the-edge generated data can then be transferred to the cloud, making it available for subsequent Big Data Analysis.

3.2.4 Data Transfer

Data transfer can only be cost-effective if no sensor raw data is transmitted. Instead, already aggregated data or only results should be transferred. Depending on the state of development of the PdM systems, today it is possible to find systems in the lift industry that transmit more than 20 gigabytes per month, but also smart systems that manage with only a few megabytes per month. In addition, the system should not rely on the assumption of a constantly available Internet connection - especially in lift systems this can only be achieved with great financial expense.

4 IMPLEMENTATION OF A PREDICTIVE MAINTENANCE SOLUTION FOR LIFTS

The above requirements have been implemented in a PdM system based on only two physical sensors: A 3-axis accelerometer mounted on the cab support frame and a load sensor that detects the current load in the car. A single-board computer continuously samples this raw data and recognizes in real-time (without any connection to the lift control system) the current driving condition of the lift system and the current position of the car in the shaft. From the two physical sensors, several hundreds of virtual sensors are calculated, which relate to specific components of the lift installation, such as e.g. traction sheave, frequency converter, door guides, door drives, etc. refer.

These data are generated at the unit itself and are statistically condensed. Actually, every lift trip is included in the calculations and thus generates a chronological progression over the virtual sensors over the individual days, weeks and months. The number of actual virtual sensors of several dimensions, and others, depending on the number of stops. For a system with 10 stops, there are a total of over 8,000 virtual sensors. Their progressions are monitored by the one-board computer for significant changes, so still on site at the lift system. If certain conditions are met, alerts are generated and sent to users via the cloud. In addition to the affected component, such warnings may also include the position in the shaft or the floor concerned and a corresponding action recommendation.

The algorithms for detecting wear and component problems are chosen so that user intervention is not necessary, since the monitoring and parameterisation of just under 800 limit values per stop by a user is hardly feasible and certainly not cost-effective to implement.

The compressed data from the virtual sensors is also transmitted to the cloud where it is further analysed in Big Data Scenarios to generate more in-depth inferences and recommendations based on the data of all monitored lifts and to find new relationships with the help of neural networks. This concept allows a lift system with, for example, 10 stops with less than 3 megabyte payload data per month to be operated on the cloud.

In addition to Predictive Maintenance, such a system can also be used for traffic analyses, as all stops, payloads and door movements approached are detected autonomously. Furthermore, derived functions such as person inclusion (no door movements after the end of the journey and payload greater than zero), emergency stops, etc. implemented and can be used as sources of information for emergency calls and error messages.

5 SUMMARY

Lift Predictive Maintenance requires sensor-based Condition Monitoring. Although numerous solutions already advertised on the market use the keyword PdM, they turn out to be the decades-old Preventive Maintenance approach, which now uses modern technologies such as IoT and Clouds, but ultimately only provides lift control data to the user.

Conclusive concepts, which were also implemented in real existing devices, are only occasionally found on the market and sometimes the look behind the scenes of these systems is very disappointing. Nevertheless, lift operators worldwide are beginning to demand service contracts based solely on availability and lift companies are beginning to offer them. Medium-sized service companies are only beginning to realize what changes will be made to the lift industry and make changes to their business model necessary.

In any case, this kind of cost-intensive preventive maintenance strategy for lift systems will soon be a part of the past. The only adequate countermeasure which will be able to compensate the partially massive cost reductions affecting lift components in the past few years can only be in form of an automatic wear and tear monitoring of safety-relevant and function-critical components.

LITERATURE REFERENCES

[1] J. Barkai, *Predictive Maintenance: Myths, Promises, and Reality*. LinkedIn (2018).

[2] S. Few, *Big Data, Big Dupe*, Analytics Press, El Dorado Hills (2018).

BIOGRAPHICAL DETAILS

Tim Ebeling has been employed since 2003 as head of development with Henning GmbH & Co. KG. In this capacity he has established the R&D centre in Braunschweig (Germany). A team of employees is now working there on the development and production of electronic and measurement components for lifts. Since 2012, the author is also managing director and since 2015 also a shareholder of the company. One of his particular focal points is the measurement technology. Especially in this area the author looks back on many years of experience in the development of acceleration and rope load measuring systems. The author's professional goal is to enrich the lift market with innovative lift components and opposing the increased cost pressure in the lift industry through the development of efficient sustainable and labour-saving components.