Building and Construction Authority

Code of practice for Design and Performance of Remote Monitoring & Diagnostics Solution for Lifts

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Preface

1. With Singapore becoming an increasingly built-up nation, there will be a greater reliance on lifts. As the number of lifts increases, the industry faces challenges in raising its workforce capacity and capabilities to meet the increased demand for maintenance services as well as evolving public expectations. Advancements in technology have presented opportunities for the lift industry to achieve better productivity and move towards a leaner workforce. This can be achieved through the adoption of technology such as Remote Monitoring & Diagnostics that would enable existing work processes to be re-designed and streamlined, thereby enhancing manpower efficiency and achieving better lift performance.

2. The aim of this code is to set the fundamental requirements and guidelines for the use of Remote Monitoring & Diagnostics for lifts in Singapore.

3. The Building and Construction Authority would like to extend its sincere appreciation to the lift industry and other partners for contributing invaluable effort, time and inputs towards the development of this code of practice.

1. Introduction

1.1 Scope

1.1.1 This code shall apply to the design and performance of Remote Monitoring & Diagnostics Solution for lifts in Singapore.

1.2 Purpose

1.2.1 The purpose of this code is to establish minimum standards for lifts connected to Remote Monitoring & Diagnostics Solution in the Republic of Singapore. The code is written with the intent to inform lift owners and contractors about the baseline requirements for an acceptable Remote Monitoring & Diagnostics Solution in Singapore.

2. Definitions and terminology

For the purpose of this code, the following definitions apply:

2.1 Big Data

Big Data refers to extremely large data sets collected from the lifts - both structured or unstructured that can be analysed to provide insights on the performance of the lifts.

2.2 Big Data analytics

Big Data analytics, an advanced data analysis tool that applies data mining, predictive analytics and machine learning to sets of Big Data.

2.3 Data Mining

Data Mining, a form of data analytics that involves sorting through large data sets to identify trends, patterns and relationships.

2.4 Data Visualisation

Data Visualisation, refers to the use of statistical graphics, plots, information graphics and other form of tools to communicate information in a clear and efficient manner

2.5 Discrete Signals

Discrete Signals are signals that can report on two states, such as either on or off, open/closed.

2.6 Edge Analytics

Edge Analytics is an approach to data collection and analysis in which an automated analytical computation is performed on-site on data from a sensor, network device or other component instead of waiting for the mostly unprocessed data to be sent back to a centralised data storage for analysis.

2.7 First Time Fix Rate

First Time Fix Rate, indicates the percentage of technical faults which do not re-occur for the next 30 days after the maintenance personnel last resolved ~~the~~ a technical fault.

2.8 Hoistway

The fixed structure consisting of a shaft way for the travel of one or more lifts.

2.9 Internet of Things (IoT)

Internet of Things, refers to a huge network formed by the combination of a variety of sensors, hardware and etc connected to the internet. The aim is to have all the items connected with the network, and the system can identify the items, locate, track, monitor, and trigger the corresponding event automatically and in real time.

2.10 Intrusive Data Acquisition System

Intrusive Data Acquisition System refers to any means of acquiring data from the lift controller for the purpose of data analysis

2.11 Machine Learning

Machine Learning, is an artificial intelligence technique that uses automated algorithms to analyse through various data sets.

2.12 Non-Intrusive Data Acquisition System

Non-Intrusive Data Acquisition System refers to any means of acquiring data, other than from the lift controller, for the purpose of data analysis. Example could be the use of sensors on lift car or inside the hoistway.

2.13 Non-Technical Faults

Non-Technical faults refers to issues in the lifts which have no direct bearing on the safety and reliability of the lifts. Examples are faulty buttons or damaged display indicators.

2.14 Performance

The behaviour of the lift which is determined by one or more measured or calculated parameters such as temperature, vibration, speed or acceleration.

2.15 Read-only function

Read-only function refers to the capability of being accessed but not being changed or deleted.

2.16 Remote Monitoring & Diagnostics (RM&D) Solution

Remote Monitoring & Diagnostics refers to the use of technology to automatically track and log the usage, operations, and response of lifts, to detect lift anomalies, predict future anomalies/breakdowns, and provide information for diagnosis and reduction of such anomalies and breakdowns.

2.17 Rectification Works

It refers to any activities such as inspection, functional checks, servicing, repairing, or replacing of components with the intent to keep the equipment functioning as originally designed for.

2.18 Sensors

A sensor is a device, module, or subsystem used to detect events or changes in its environment and send the information to a network.

2.19 Shall

Indicates that the requirement is strictly to be followed in order to conform to the standard.

2.20 Should

Indicates that among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.

2.21 Technical Faults

Technical faults refer to the malfunction or breakdown of the lifts due to failure of components. External factors such as water ingress, user behaviour-related or natural disasters are not considered as technical failures.

3. Remote Monitoring & Diagnostics

3.1 General requirements

3.1.1 Lifts equipped with Remote Monitoring & Diagnostics (RM&D) shall meet the provisions in the Code.

3.1.2 The performance of the RM&D should as much as possible, ensure that the maintenance outcomes of the lifts in the prevailing requirements of the Building Maintenance & Strata Management Regulations (Lift, Escalator and Building Maintenance) are tracked and monitored at all times.

3.1.3 Any electronic devices installed for the purpose of the RM&D Solution shall not compromise the safe operations of the lift.

3.1.4 The RM&D Solution should support an open standard interface for its performance data, such as Open Platform Communications United Architecture.

3.2 System architecture

3.2.1 The RM&D Solution system architecture shall consist of the following combinations:

a) Data Acquisition
b) Data Pre-processing
c) Data Analytics

3.3 Data Acquisition

3.3.1 General Requirements

3.3.1.1 A data acquisition system shall be used to continuously monitor and track the performance data of the lift.

3.3.1.2 The data acquisition system should be collecting performance data from the lifts when normal power supply to the system is interrupted. In such scenario, it is not necessary to collect any data after the lifts completed their emergency operations and parked at the designated floor.

3.3.1.3 The data sampling frequency will depend on the performance parameters and the amount of storage available. It should be sufficient such that it does not affect the accuracy and precision of the data analytics.

3.3.1.4 The data acquisition system shall be of either the intrusive type or non-intrusive type.

3.3.2 Intrusive or Non-intrusive Data Acquisition System

3.3.2.1 The intrusive or non-intrusive data acquisition system shall be of the read-only function.

3.4 Data Pre-Processing

3.4.1 To minimise the latency of data analytics and reduce the strain on the central data diagnostic resources, a data pre-processing unit incorporating edge analytics should be provided.

3.4.2 The data pre-processing unit should also be capable of separating performance data collected from the data acquisition system into different categories. Critical data [NOTE] should be sent immediately for data diagnostics purposes while less critical data can be uploaded when the network bandwidth is less congested.

NOTE Critical data are any information collected from the lift operations that are pertinent in the prediction of imminent breakdowns or safety related issues.

3.5 Transmission and Storage of Data

3.5.1 The transmission of data shall be through a secure network.

3.5.2 Data transmitted shall be stored in physical data centre or IoT server.

3.5.3 Data transmission and storage should meet security requirements specified in section 6.

3.6 Data Analytics

3.6.1 The analytics tool should be capable of analysing trends, patterns and relationship of data sets in order to identify anomalies in the performance data of the lifts.

3.6.2 Data analytics tools such as regression, decision trees, clustering, or machine learning should be employed to predict potential failures of lift components and future breakdowns of the lift.

3.7 Use of the Data Analytics

3.7.1 General Requirements

3.7.1.1 The data analytics shall have predictive maintenance capability. It shall be able to issue a recommendation to carry out part replacement, repair or maintenance on the lift before a breakdown occurs. For urgent cases, such as breakdowns or faults which could lead to breakdowns imminently, the system should be able to provide information including the level of urgency for maintenance personnel to rectify the problem immediately. For the less urgent ones, the system should provide information and schedule the maintenance or repair to take place in the coming days or weeks or on the next scheduled maintenance.

3.7.1.2 The data analytics shall also provide recommendations to improve the maintenance programme, including recommendations and guidance for maintenance personnel to carry out their required maintenance tasks, with the aim of improving the first time fix rate.

3.7.2 Monitoring Outcomes

3.7.2.1 The following information corresponding to Table 1 shall be monitored and piped to the data analytics system to generate recommendations on possible rectification works and the suggested timeline to complete them.

Table 1: List of Monitoring Outcomes

Lift system and their sub-system	Monitoring Outcomes
1. Traction Machine	To be able to monitor and analyse the performance of the lift and identify potential issues with the traction machine; and provide recommendation on possible rectification works and indicate when they are required.
2. Brakes	To be able to monitor and analyse the performance of the lift and identify potential issues with the brakes; and provide recommendation on possible rectification works and indicate when they are required.
3. Suspension Means	To be able to monitor and analyse the performance of the lift and identify potential issues with the suspension means; and provide recommendations on possible rectification works and indicate when they are required.
4. Guide system (i.e. guide rail and guide shoes or rollers)	To be able to monitor and analyse the performance of the lift and identify potential issues with the guide system; and provide recommendations on the possible rectifications for the guide system and indicate when they are required.
5. Car and Landing Doors (including door protective devices)	To be able to monitor and analyse the performance of lift and identify potential issues with the car and/or landing doors system; and provide recommendations on possible rectification works and indicate when they are required.
6. Levelling Devices	To be able to monitor and analyse the performance of the lift and identify potential occurrences and instances of mis-leveling; and provide recommendations on possible rectification works and indicate when they are required.
7. Fault Diagnosis including the following components: a) Overspeed Governor b) Safety Gear c) Controller and Inverter Drive d) Buffer e) Compensation System	To be able to monitor and analyse the performance of the lift and indicate if one or more of the following fault(s) is/are possible cause(s) for the stoppage of the lift: • Overspeed Governor Activation • Safety Gear Activation • Controller and Inverter Drive Failure • Buffer Activation • Compensation System Activation • Ascending Car Overspeed Protection Activation • Unintended Car Movement Protection Activation • Fire Emergency • Power Failure

3.7.3 Feedback System

3.7.3.1 There should be a feedback system to improve the accuracies of the data analytics and allow adaption to change in usage patterns and lift aging.

3.7.3.2 In addition, there should be a process in place to ensure minimal room for poor or erroneous feedback to the data analytics system. For example, this can be carried out using user-driven confirmation.

4. Data Visualisation

4.1 A data visualisation platform shall be provided to the lift owner or his representative by the service provider of the Remote Monitoring & Diagnostics Solution to provide real-time insights on the lift status and performance.

NOTE Real-time does not imply that data should be displayed without any delay after it is being processed. It is acceptable that the processed data be available after a suitable predetermined period of time.

4.2 Where a data visualisation platform is provided, it should be a web-based interface and/or a mobile application.

4.3 Notifications via mobile applications, text message, emails or other means shall be used to keep the lift owners, or their representatives updated about any abnormal status of the lift at all times.

4.4 The data visualisation platform should include the following specification of the lift in Table 2 for easy reference:

Table 2: List of Recommended Specifications to be shown on the data visualisation platform

S/N	Items	Definition	Denomination
1	Manufacturer of the Lift	The name of the original equipment manufacturer.	-
2	Lift Number	Alphanumeric characters for identification of the lift.	-
3	Lift Model	Alphanumeric characters for identification of the lift model.	-
4	Lift Type	The primary use of the lift.	-
5	Address of the Lift	The location of the lift in Singapore.	-
6	Lift service contractor	The name of the maintenance contractor.	-
7	Year of Installation	The year when the lift was first installed.	YYYY
8	Number of landings served /stops	The number of stops.	-
9	Rated Speed	The contract speed of the lift.	m/s
10	Rated Capacity	The maximum load the lift can carry.	kg
11	Current Floor Served	An indication on the location of the lift.	-
12	Current Lift Status	An indication on whether lift is moving.	-
13	Current Door Status	An indication on whether lift door is opening or closing.	-

4.5 It should be also possible for users to extract any of the indicator data for analysis (Refer to Annex A for more information):

a) Indicator data for a particular lift for a specific time period;
b) Indicator data for a group of lifts in a particular location for a specific time period;
c) Indicator data for a group of lifts maintained by a particular lift service contractor for a specific time period;
d) Indicator data for a group of lifts supplied by an Original Equipment Manufacturer for a specific time period.

5. Remote Testing, Intervention and Control

5.1 For Remote Monitoring & Diagnostics Solution that comes with remote testing, control and intervention function, they shall neither interfere with the safety of the lift nor compromise the safety of the users who are using the lifts.

NOTE: Remote testing, control and intervention function can be used for troubleshooting, minimising mantrap occurrences and reducing rescue duration.

6. Cybersecurity Requirements

6.1 Scope

6.1.1 This section specifies the cybersecurity requirements for the control system of the Remote Monitoring & Diagnostics Solution. This includes computers, operating systems, applications, and other programmable configurable components that form part of the security function of the system. Remote systems and services are excluded.

6.1.2 It is intended to cover Remote Monitoring & Diagnostics Solution installed in both new and existing lifts.

6.2 General Requirements

6.2.1 The fundamental requirement is to address cybersecurity threats in the Remote Monitoring & Diagnostics Solution lifecycle which includes product development, verification, operation, and maintenance. It focuses on the operational security function of the system that prioritizes protection of people, assets and information as well as the prevention of unauthorized use of monitor and/or control devices, processes.

6.2.2 IEC 62443-3-3:2013 and IEC 62443-4-2:2019 should be referenced when addressing cybersecurity threats for Remote Monitoring & Diagnostics Solution.

6.3 Architecture and Design

6.3.1 The architecture and design of the control system should meet IEC 62443 or equivalent.

6.4 Product Development Lifecycle

6.4.1 The product development lifecycle should be certified to IEC 62443-4-1 or equivalent.

6.5 Component and System Security

6.4.2 The components, specifically embedded devices, network components, host components and software applications, should be certified to IEC 62443-4-2 or equivalent.

6.4.3 The system security should be certified to IEC 62443-3-3 or equivalent.

Annex A
(informative)

List of RM&D Indicators

This section includes the following RM&D indicators, which should be used to evaluate whether the RM&D Solution is effective or not.

S/N	Type of Indicators	Abbreviation	Formula	Units
1	Technical Faults per Equipment	TFPE	$TFPE = \frac{\text{Total Number of Technical Faults}^{NOTE(1)}}{\text{Total Number of Equipment}}$	Technical Faults per lift per month
2	Faults per Equipment	FPE	$FPE = \frac{\text{Total Number of Faults}^{NOTE(2)}}{\text{Total Number of Equipment}}$	Faults per lift per month
3	First Time Fix Rate	FTTR	$FTTR^{NOTE(3)} = 1 - \frac{\text{Total Number of the Repeated Technical Faults}}{\text{Total Number of Technical Faults}}$	% (per lift per month)
4	Mean Time To Repair	MTTR	$MTTR^{NOTE(4)} = \frac{\text{Total Downtime of Technical Faults}^{NOTE(5)}}{\text{Total Number of Technical Faults}}$	Hours/failure (per lift per month)
5	Average Monthly Uptime	UT	$\frac{\text{Maximum Possible Running Hours}^{NOTE(6)} - \text{Total Downtime of Technical Faults}}{\text{Maximum Possible Running Hours}}$	% (per lift per month)
6	Diagnostics Accuracy	DiA	$\frac{\text{Total Number of Intervention Cases marked as True (T)}^{NOTE(7)}}{\text{Total Number of Intervention Cases}^{NOTE(8)}}$	% (per month)
7	RM&D Device Availability	DA	$\frac{\text{Total number of RM\&D units that are online}}{\text{Total number of RM\&D units}}$	% (per lift per month)

NOTE(1) A list of technical faults is given in Annex B.

NOTE(2) Faults is sum of technical faults and non-technical faults. A list of non-technical faults is given in Annex B.

NOTE(3) Technical faults that happen within the next 30 days after they have been rectified are to be considered for the calculations.

NOTE (4) MTTR exclude the following: (1) major repair/overhaul that takes more than 1 day (refer to the list of exclusion cases below for more details); (2) waiting time for spare parts arrival; and (3) additional time needed to do hot-testing.

NOTE (5) Total downtime of technical faults is the sum of all time spent to rectify all technical faults in hours.

NOTE (6) Maximum possible running hours is the number of days in the month multiplied by 24 hours for each lift.

NOTE (7) A True (T) Intervention Case is when the RM&D prediction matches diagnosis/faulty component on site.

NOTE (8) Intervention cases are defined as cases prompted by RM&D Solution whereby a visit to lift by maintenance personnel is required.

List of Exclusion Cases

S/N	Examples of MTTR Exclusion Cases (non-exhaustive)
1	Hoisting motor replacement/repair
2	Ropes replacement
3	Main/Diverting sheave replacement/repair
4	Major lift components, e.g. governor, safety gear
5	Total failure of Frequency Inverter
6	Water ingress situation
7	Building power failure

Annex B
(informative)

This section includes examples of technical faults and non-technical faults.

S/N	Technical Faults	Non-Technical Faults
1	Motor	Noise
2	Machine brake [including Brake Monitoring Switch]	Display Indicators/LCD
3	Electrical Components [Switches/Contactors/Relays/PCBs]	Faulty buttons [Car/Landing]
4	Main Drive Unit/Frequency Inverter	Card reader
5	Landing Doors	External Element Blocking Doors [Object/Human]
6	Car Doors	Car Interior [False Ceiling/Cladding]
7	Buffers	Fire Homing/Power Failure Mode
8	Speed Control System [Shaft/Motor Encoder]	Natural Disaster/Incident leading to component failure [Water ingress]
9	Overspeed Governor & Governor Rope	CCTV Cameras
10	Levelling Accuracy	Oil Pots Leakage
11	ACOP/UCMP/Rope gripper	
12	Battery Failures [ARD/EBOPS]	
13	Suspension Ropes	
14	Worn out Bearings	
15	Load Measuring Devices	
16	Compensation Devices [Chain/Rope]	

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