An Overview on Traffic Signal System and its Maintenance in Hong Kong

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Abstract – Hong Kong is a highly urbanized cosmopolitan city with well-developed road network. A central control traffic signal system covering 1,800 signalized junctions is operating round the clock for the allocation of the right-of-ways properly at road junctions for safe movement of vehicles and pedestrians in the densely populated area, which concentrates in less than 30% of this small city of 1,100 square kilometre. The Electrical and Mechanical Services Department of the Hong Kong Special Administrative Region Government is responsible for maintaining this territory-wide traffic signal system, which is divided into smaller regions and centrally controlled by computer systems installed at Area Traffic Control (ATC) centres. All these ATC controlled traffic junctions are coordinated under a computerized adaptive control system that automatically optimizes traffic flow by adjusting the duration of green lights of individual junction or a group of junctions, through detecting and optimizing the average moving speed of vehicle queues passing from various directions through these junctions. To optimize life cycle management of traffic signal equipment, a comprehensive asset management system based on the Publicly Available Specification (PAS) 55 and Geographical Information System (GIS) with real time asset condition representations is being developed.

Keywords: Traffic Signal System, Area Traffic Control, Adaptive Control, PAS 55, GIS

1. Introduction

1.1 Background

Hong Kong is a highly urbanized cosmopolitan city with the populated area concentrated in less than 30% of this small city of 1,100 square kilometre. A central control traffic signal system covering 1,800 signalized junctions is operating round the clock for the allocation of the right-of-ways properly at road junctions for safe movement of vehicles and pedestrians.

1.2 Traffic Signal Basic

Traffic signals are commonly used in urban cities for controlling competing traffic flows in order to provide a safe and efficient movement of vehicles and pedestrians. Visible traffic signal, often called traffic signal lamp, traffic lamp or traffic light, gives out three colours of light (red, amber or green) in sequence to tell drivers and pedestrians when to stop and when they can go. Similarly, audible traffic signals provide indication to the visually impaired persons on the prevailing pedestrian signals states at road crossings.

A typical signalized junction consists of a controller, lamp poles, visible and audible traffic signals and other associated equipment such as pushbuttons for pedestrians, signal cable, detector loops, etc.

The different phases of traffic signals are controlled by the controller. Alternate sequence of traffic light is stored inside a non-volatile memory device such as an erasable programmable read only memory (EPROM). The signal time depends on traffic plans designed by the traffic engineer. There would often be several plans stored inside the EPROM for execution at different time of the day and different day of the week (e.g. plans for peak/off-peak hours and weekdays/weekends).

With the advance of intelligent transport system (ITS) technology, co-ordinated control of traffic lights are now common in major cities in the world. Traffic controllers are connected to a central computer, enabling real-time monitoring and control of traffic signals using pre-defined adaptive control algorithm.

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2. Traffic Signal Systems in Hong Kong

2.1 Overview

Stand-alone traffic light was first installed in Hong Kong in the 1960s. The first computerized Area Traffic Control (ATC) system started operation in 1977 when 84 ATC systems were installed as a pilot scheme in Western Kowloon of Hong Kong [1], enabling round-the-clock monitoring and controlling of the states of traffic signals at the junctions. Road efficiency was significantly improved as a result and ATC systems were subsequently widely deployed to other urbanised districts of Hong Kong.

Vehicle flow information is collected by the junction controller via detector loops installed beneath vehicle lanes. Vehicles are detected by means of electromagnetic induction. Real-time information such as the number of vehicles travelling through detector loops, time gap between cars and the average moving speed of vehicles can be measured and calculated. Such information is passed to the ATC central server for analysis. Making use of an adaptive control algorithm, the central server would automatically determine the optimized traffic plan over an individual or a group of junctions based on their traffic conditions. The optimized plan would then be sent back to the junctions for adjusting the duration of green lights of different directions in order to achieve area traffic optimization. This real-time optimization, namely traffic adaptive control, can minimize traffic delay and congestion.

In case of the failure of communication between the ATC centre and the controller, the latter can still operate by its own, sending out alternate signal phases with local traffic plans.

In Hong Kong, traffic lamps using traditional incandescent lamps were replaced with light emitted diodes (LED) traffic lamps in 2008. Power consumption of LED traffic lamps is just one-third of traditional traffic lamps. Furthermore, the lifetime of LED traffic lamps is estimated to be about 10 years, much longer than the traditional ones which on average can last only one year, thereby greatly reducing the maintenance effort.

Apart from traffic lamps, electronics auditable traffic signal (eATS) system is also used in Hong Kong. Such system provides indication to the visually impaired persons on the prevailing pedestrian signals states at the crossings. The eATS comes with a tactile unit which gives out vibrating patterns to indicate the prevailing states of pedestrian signal [2].

2.2 Maintenance of Traffic Signal Systems

The Electrical and Mechanical Services Department (EMSD) of the Hong Kong Special Administrative Region Government (HKSARG) is responsible for the maintenance of all traffic light systems in Hong Kong. Like all electrical and mechanical systems, the maintenance activities can generally be classified as corrective and preventive.

Corrective maintenance is performed to rectify equipment failure. The most severe scenario of traffic signal failure is the blacking out of a signalized junction, in which all the signals of a junction do not light up. This is considered as a critical fault. Other types of failures which will not cause a junction black-out, such as failure in eATS, slanted lamp post, isolated failure of one lamp or even one set of lamps for a lane, is considered as non-critical.

Common causes of junction black-out include loss of power, damage of controller by traffic accident, lamp conflict (e.g. the green light of conflicting traffic directions light up at the same time). Junction black-out is automatically detected by the ATC server via the communication link. Alternatively, EMSD will also receive service call directly from the public via a telephone hotline.

Junction black-out must be handled with utmost urgency because both drivers and pedestrians are at risk as any car or any pedestrian may be crossing the junctions at the same time. Maintenance personnel are dispatched to the site immediately and most black-out situations are rectified within the same day.

Apart from corrective maintenance, scheduled preventive maintenance is also performed to minimize the risk of potential failure. Activities include visual inspection of equipment structure and integrity, checking of the controller log, the earthing condition and various cable connection and lens cleansing.

3. Asset Management System

3.1 Need for Better Management of Traffic Signal System Assets

The traffic signal equipment distributed throughout the roads of Hong Kong are exposed to all kind of weather phenomena – from the dry, cool winters to the wet and hot summers, from high winds during passage of typhoons to torrential rain and thunderstorms. Being on the road, they are also prone to damage caused by varying causes, e.g. damage of traffic controller and traffic light pole by vehicle collision, and damage of underground cable caused by other infrastructure works. As the proper functioning of traffic signal equipment is of paramount importance in ensuring road safety, EMSD decided to implement an asset management system based on the Publicly Available Specification (PAS) 55, with a view to improving the reliability and performance of the equipment in the long term.

The PAS 55 is a specification for the optimized management of physical assets published by the British Standards Institution (BSI). Developed by the Institute of Asset Management (IAM) in collaboration with the BSI, it provides clear definitions for the optimized management of physical assets.

The PAS 55 was first published in April 2004. Since then it attracted widespread adoption in utilities, transport, mining, process and manufacturing industries around the world. An updated edition of the PAS 55 was published in September 2008. The International Standards Organisation (ISO) also used PAS 55 as the basis for development of the new ISO 55000 series of international standards on asset management, which were published in January 2014.

While PAS 55 emphasizes on balancing performance, risk and cost (expenditure), the main objective in implementing PAS 55 for traffic signal equipment in EMSD is to improve maintenance performance, sustain the reliability and serviceability of traffic signal equipment, and to reduce the risk associated with traffic signal failure.

3.2 Asset Management of Traffic Signal Systems

The requirements of the PAS 55 follows the Plan-Do-Check-Act framework, similar to other management systems such as ISO 9001, ISO 14001, OHSAS 18001, all of which have already been implemented in EMSD. The establishment of the PAS 55 for traffic signal systems provides a systematic and holistic framework for optimization of lifecycle management of traffic signal equipment assets.

The asset management policy, strategy, objectives and plan were drawn up based on the requirements in the service level agreement under which EMSD provides maintenance service for the Transport Department, which is the ultimate asset owner.

All the key personnel in the maintenance team then participated in interactive sessions, drawing up the asset registers and asset management plan, developing risk management procedure, performing risk assessment and root cause analysis, and contingency procedure to mitigate those identified risks.

3.3 Asset Management Plan

The asset management plan sets out the approach on lifecycle management of traffic signal systems. Substantial focus was given for the continuous improvement on preventive and corrective improvement procedure that optimized the risk associated with failure of traffic signal systems.

3.4 Asset Inventory Register

Traffic signal equipment is categorized in a two-level structure, as shown in figure 1.

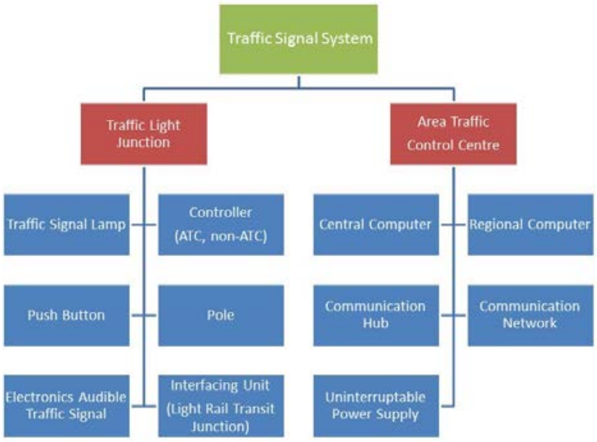

Fig. 1 Asset Categorization of Traffic Signal System

The first level consists of the main asset category of traffic light junction equipment (i.e. the "out-station" equipment), and Area Traffic Control system (i.e. the "in-station" equipment). The second level consists of each functional unit of the out-station or in-station equipment. Because of the already large number of assets at the second level, further break-down into board or component level was not undertaken in order to better focus the management of individual assets.

The assets are classified as either critical or non-critical. As the most critical failure of traffic signal systems is junction black-out, i.e. all traffic lights of a junction going black, those assets whose failure would lead to junction black-out are classified as critical asset.

The maintenance team then went through a detailed assessment of the conditions of individual assets, giving them a rating between 1 and 5. This, together with other important asset information such as the expected service life and estimated remaining years of service, are recorded in the asset inventory register, as shown in figure 2.

Types	Name of Asset	Critical / Non-critical	Asset Condition	Expected service life	Remaining Service Life (yrs)
Controller type: PSC MK3 (Non-ATC) 5 + (ATC) 1259					
	Controller	C	1	10	3 to 8
	Aspects Housing	N	3	10	2 to 8
	e-ATS (electronic audible traffic signal)	N	3	10	2 to 8

Fig. 2 Asset Inventory Register

3.5 Risk Management

A thorough risk assessment process was then embarked upon. The process was based upon past failure records as well as enquiries and complaints related to traffic signal equipment received in recent years. Various risk event and the consequences were examined in detailed. A 5 x 5 matrix is used to assign the risk level of each individual risk event. The team then examined individual whether the risk level is acceptable based on the principle of "As Low As Reasonably Practicable", and if not, worked out the risk mitigation measured. All these are recorded in the Asset Risk Register, as shown in figure 3.

For risk events of critical equipment with risk rating moderate or above, root cause analysis was also performed to facilitate future data collection for asset performance monitoring.

Risk Identification				Risk Analysis				Risk treatment	
Asset/ Asset Group	What can happen/ Risk Event	Possible Effect	Existing control	L	C	Risk Rating	Is risk acceptable?	Treatment options	Risk Treatment Plan
Controller type: QTC									
Controller	Power failure	Black out at junction	Inform CLP, HK Electric, police	1	4	M	No	Contingency Procedure	Contingency Procedure
	Hardware failure	Black out at junction	PM & CM	1	4	M	No	Replace controller with repeated faults	Asset Management Plan
	Damaged by traffic accident	Black out at junction	CM, inform police, replace by spare unit.	1	4	M	No	Review location of controller for repeated accidents	Review in Quarterly Maintenance Meeting

Fig. 3 Asset Risk Register

A specific contingency plan was also drawn up to highlight the specific response, communication and co-ordination requirements in the event of junction black-out and traffic accidents.

4. Benefits Brought About by Implementation of Asset Management System

4.1 Increased Staff Alertness on Traffic Signal System Risk Characteristics and Urgency of Failure

Through the participation of the whole traffic signal maintenance team in the development of the PAS 55 system and all the brainstorming sessions for asset condition assessment and risk assessment, their awareness of the risk and consequence, and the alertness on urgency of various failures of traffic signal systems were significantly enhanced.

4.2 Prioritization of Asset Replacement

The comprehensive and regular review of asset condition implemented in the PAS 55 system enabled the prioritization of asset replacement. This will reduce the risk of unexpected breakdown of traffic signal equipment which would jeopardize road safety.

4.3 Enhancement in Maintenance Procedure

Following the detailed risk assessment, a number of new risk treatments which would help reduce future failures were identified and implemented. One example was the checking of surge arrestors before the rainy season.

A large part of northern Hong Kong is flat and exposed. Controllers in this area are particularly prone to be affected. Surge arrestors are installed in controllers to protect them from voltage spikes induced by lightning during the passage of thunderstorms or typhoons. Following the identification of lightning strike as one of the significant risk events, maintenance staff were dispatched to check the conditions of surge arrestors before the typhoon season in 2013. According to the fault statistics, the number of controller failures was substantially reduced during the typhoon season in 2013 as compared to 2012.

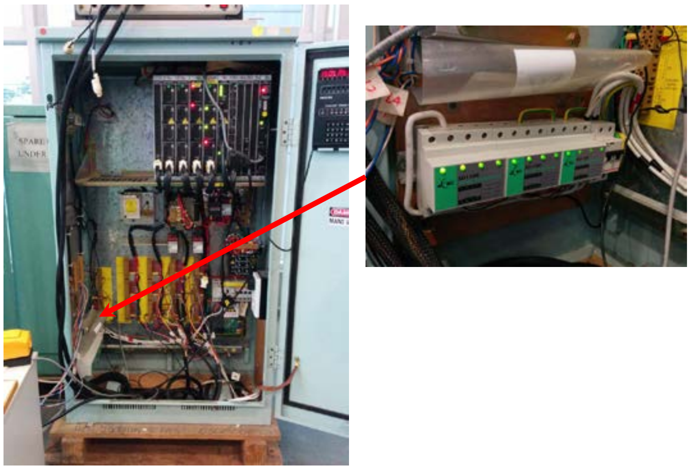

Fig. 4 Surge Arrester inside a Traffic Controller

4.4 Enhancement of Monitoring and Response to Failure

With the critical analysis of past failures and complaint incidents, the maintenance team identified and implemented a number of improvement measures, including the implementation of a two-tier monitoring system to ensure timely feedback of repair status to complainants, enhancement of fault data collection and analysis, taking immediate action to investigate in repeated faults at the same junctions.

5. Further Development

5.1 Integration of Traffic Signal Assets with Geographic Information System

As there are a huge number of traffic signal assets distributed over the whole of Hong Kong, in order to improve the user-friendliness of the asset management system and to enhance maintenance planning, a project is under way for the integration of the various databases with a geographic information system (GIS).

As the engineering assets for which EMSD provide operation and maintenance services are distributed throughout the territory of Hong Kong, representation of asset inventory and condition on a GIS will greatly enhance the effectiveness in management of these assets.

In the long term, different categories of assets will be added to form different layers in the GIS.

5.2 Conversion to ISO 55001

The International Organization for Standardization (ISO) has just released an international standard on asset management, ISO 55001:2014, in January 2014. EMSD is working towards the conversion of the PAS 55 asset management system for traffic signal systems to ISO 55001:2014 within 2014.

6. Conclusion

An area-wide network of traffic signal systems at road junctions of the Hong Kong enables safe and efficient movement of vehicles and pedestrians. The implementation of Area Traffic Control further enables computerized adaptive control of traffic flow.

Proper maintenance of traffic signal systems is of paramount importance to ensure the safety of the public. With the implementation of PAS 55 asset management system to the maintenance of traffic signal systems, major steps were taken to assess and mitigate the risk of various failure scenarios commonly encountered. The critical internal assessment by all the maintenance team members and the external assessment by certification bodies has proven to be a key success factor to sustain the effectiveness of the asset management system as well as the maintenance management system built upon the ISO 9001 management system including IMS and PAS55.

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References

[1] Transport Department, Hong Kong, *Hong Kong Transport 40 Years*, November 2008.

[2] Transport Department, Hong Kong, *Electronic Audible Traffic Signals*.

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