New Edition of Code of Practice: Powering New Technology and Enhancing Electrical Safety

Paper for the 39th Annual Symposium of the Electrical Division of the HKIE,

Powering the New Normals, 21 October 2021

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ABSTRACT: The Electrical and Mechanical Services Department (EMSD) of the Government of the Hong Kong Special Administrative Region (HKSAR) published the 2020 edition of the Code of Practice for the Electricity (Wiring) Regulations (CoP) on 31 December 2020. Major revisions and new codes were introduced to facilitate safe adoption of relevant new technologies on electrical installations, support the Government's new policies and establish the benchmark against relevant international standards. This paper discussed the new codes for charging facilities of electric vehicles (Code 26S) and installations for modular integrated construction (MiC) (Code 26T), as well as the recommended use of arc fault detection devices (AFDDs) (Code 6B). The new edition of the CoP will be fully implemented on 31 December 2021 to replace the 2015 edition, after a one-year grace period.

I. INTRODUCTION

The Electrical and Mechanical Services Department (EMSD) is committed to enforcing the Electricity Ordinance and its subsidiary regulations with professionalism, reliability, commitment and integrity, as well as raising the trade's professionalism and enhancing the public's electrical safety awareness to ensure electrical safety in Hong Kong. To keep abreast of the latest technology development and safety requirements of electrical installations, the EMSD has published the fifth edition of the Code of Practice for the Electricity (Wiring) Regulations (CoP) in December 2020.

A work group consisting of representatives nominated by key stakeholders of the trade, including trade unions and associations, professional bodies, academic institutions, power companies and government works departments, were formed in 2019 for the review of the CoP. Major revisions include the recommended adoption of arc fault detection devices (AFDDs), requirements on USB outlets, renewable energy power systems, charging facilities for electric vehicles and installations for modular integrated construction (MiC), etc. With the introduction of these new codes and revisions, the EMSD facilitates the trade and the public with specific guidelines and requirements for safe adoption of relevant new technologies on electrical installations, supports the Government's new policies and establishes benchmark against relevant international standards, with the aim of fostering a smarter, greener and safer environment for all.

The paper particularly specifies three prominent up-to-date codes. In section II, the charging facilities for electric vehicles (Code 26S) are discussed. Section III focuses on installations for MiC (Code 26T). In Section IV, the operation mechanism and installation recommendations in respect of AFDDs (Code 6B) are deliberated.

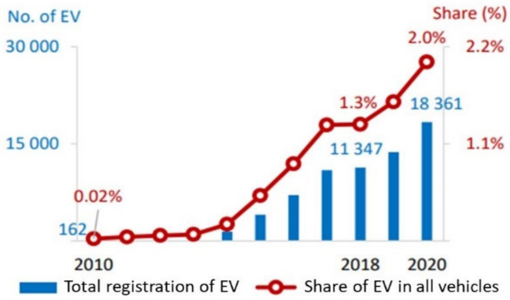
II. CHARGING FACILITIES FOR ELECTRIC VEHICLES (CODE 26S)

Extensive charging facilities are necessary to accommodate and encourage the use of electric vehicles (EVs). To assist the Government in attaining the long-term target of zero vehicular emission before 2050 and cope with the prospective increasing number of EVs, technical requirements on the installation of charging facilities for EVs have been included in the revision of the CoP (2020 edition).

A. Government Initiatives on EVs

Hong Kong strives to achieve carbon neutrality before 2050 as announced by the Chief Executive in the 2020 Policy Address. Promoting zero carbon emission from vehicles is one of the key approaches to endeavour for carbon neutrality. In Hong Kong, the number of EVs has raised significantly with an increase beyond 100 times, from 162 in 2010 to 18 361 in 2020 [1].

Figure 1. EV in Hong Kong [1]



Note: Government vehicles are excluded as registration are not required for them

To accommodate the wide adoption of EVs, sufficient charging facilities are vital in establishing a charging network to support the popularisation of EVs. According to the "Hong Kong Roadmap on Popularisation of Electric Vehicles", a target of at least 5000 public chargers will be provided by 2025 [2].

The new Code 26S is therefore devised with the aim of facilitating the quick and safe deployment of EV charging facilities by the trade, covering the introduction of charging modes, selection and erection of installations, protection requirements as well as provisions for diversity by adoption of load management systems to cope with capacity constraints in existing buildings.

B. Classification of Charging Modes

Brief introduction is given in Code 26S to facilitate understanding on the four modes of charging specified in IEC 61851 for electric vehicle conductive charging systems.

- **Mode 1:** In Mode 1 charging, connection of the EV to the AC supply network utilises a standardised BS 1363 socket outlet and a charging cable without communication function to the on-board charger of the EV.

- **Mode 2:** In Mode 2 charging, an in-cable control box is incorporated into the charging cable assembly. The provision of fixed electrical installation for charging facility is similar to that for Mode 1 except that the final circuit, protective device and socket outlet shall be of a suitable rating to cater for the higher level of charging current not exceeding 32A.

- **Mode 3:** In Mode 3 charging, connection of the EV to the AC supply network utilises a dedicated EV supply equipment (EVSE) where the control pilot function extends to control equipment in the EVSE, permanently connected to the AC supply network. Subject to the power rating of the on-board charger of an EV, Mode 3 charging can deliver a higher charging current (e.g. 220V/32A, 380V/32A and 380V/63A).

- **Mode 4**: In Mode 4 charging, connection of the EV to the AC supply network utilises an off-board charger where the control pilot function extends to equipment permanently connected to the AC supply. In this charging mode, either single-phase or three-phase AC is converted to DC within the EV charging equipment. The resulting DC is supplied to the EV via a charging cable that is tethered to the EV charging equipment.

Control pilot functions provided by the EV supply equipment are mandatory in Modes 2, 3 and 4, which typically include the functions for continuous continuity checking of the protective conductor, verification that the EV is properly connected to the EV supply equipment, functional switching of the power supply to the EV, as well as control on maximum allowable current [3].

C. Selection and Erection of Installations

The EV charging installation should be selected and erected to ensure safe operation and ease of maintenance at all times. The EV charging installation should be designed and installed in accordance with IEC 61851 or equivalent. In addition, if the EV charging installation is designed for outdoor use, the equipment shall be selected with a degree of protection of at least IP44 in accordance with IEC 60529 to protect against water splashes (AD4) and the ingress of very small objects (AE3) respectively.

One socket outlet or connector shall supply only one EV. The socket outlets or connectors shall comply with the following standards or equivalent:

- in Mode 1 charging – BS 1363;
- in Mode 2 charging – IEC 60309, with the socket outlet or connector interlocked and classified to prevent the socket contacts being live when accessible;
- in Mode 3 charging – IEC 62196.

In Mode 3 and 4 charging, an electrical or mechanical system shall be provided to prevent from plugging/unplugging the plug unless the socket-outlet or the vehicle connector has been switched off from the supply.

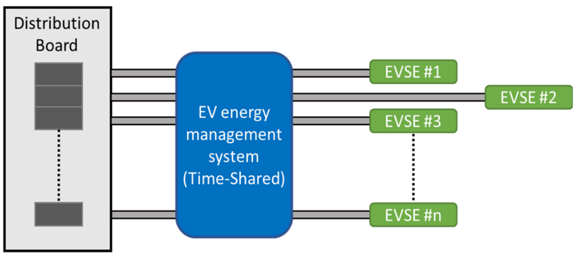
D. Load Management System

To cope with the practical constraint of limited power supply capacity for the addition of EV charging facilities in existing buildings, diversity may be allowed for a dedicated distribution circuit supplying multiple electric vehicle charging points if a load control system is available. Examples of load control systems for EVSEs are illustrated below.

- **Time-Shared Load Management**

Time-shared load management adopts the strategy to control the charging at various charging points based on time allocation [4]. It usually includes a system controller that preassigned the sequence and duration of charging. Charging is provided to an EV for a prescribed time period, and then charging is reallocated to the next EV according to the assigned schedule. In general, a system controller works independently with the EVSEs, and communication between the controller and EVSEs is not included.

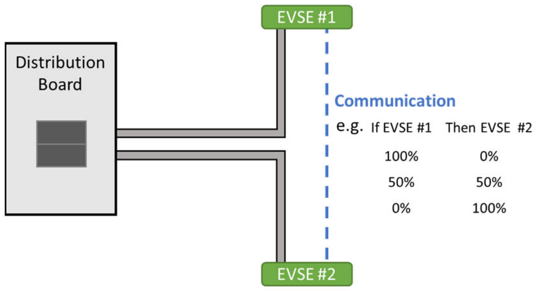
Figure 2. Time-shared Load Management [4]



- **Static Load Management**

In static load management, charging control is based on even power allocation to each EVSE, dividing the available charging capacity amongst the EVSEs connected [4]. For example, in a simple arrangement with two EVSEs, when only one EV is charging, it receives 100% of the available capacity, and when two EVs are charging, each of the EV receives 50% of the available capacity.

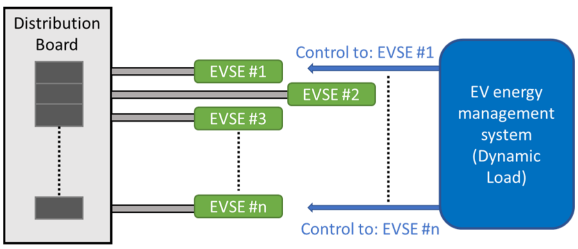
Figure 3. Static Load Management [4]



- **Dynamic Load Management**

The control of charging by dynamic load management is based on the capacity available and the requested demand from each EVSE [4] [5]. Dynamic load management delivers power based on the actual demand at each EVSE, which is considered more flexible in terms of sharing configuration. The load management system and the EVSE monitor the near real-time power consumption of an EVSE, then distribute a portion of the power supply available to each EVSE according to the actual usage.

Figure 4. Dynamic Load Management [4]



E. Selection of Residual Current Device (RCD)

Particular attention should also be paid to the type of RCD selected in EV charging facilities. As these types of equipment are often subject to DC current or AC current with DC components, the use of RCD Type AC is not suitable. Except for circuits using the protective measure of electrical separation, each charging point shall be protected by its own RCD of at least Type A.

For each charging point incorporating a socket outlet or connector complying with the IEC 62196 series, protective measures against DC fault current shall be taken, except where provided by the EV charging equipment. The appropriate measure, for each of these connection points, shall be of RCD Type B; or RCD Type A together with appropriate equipment that provides disconnection of the supply in case of DC fault current above 6mA. Figure 5 illustrates the requirement and its typical symbol of RCD to be provided for EV charging points of different modes / connectors [6].

Figure 5 – RCD Requirement for EVSE

Charging Mode – Connector Type	Symbol & Type of RCD Required
 Mode 1 – BS 1363  Mode 2 – IEC 60309	 Type A RCD
 (Examples for reference only) Mode 3 / 4 – IEC 62196	 Type B RCD

Other protection requirements are also incorporated in Code 26S, including protection against impact damage and devices for isolation and switching, etc., which will ensure electrical safety of the installation.

III. INSTALLATIONS FOR MODULAR INTEGRATED CONSTRUCTION (CODE 26T)

Hong Kong has long been recognised internationally for its formidable strength in infrastructure development. A huge portfolio of infrastructure comprising housing and land-supply programmes, hospital development plans and other livelihood projects are in the pipeline. However, there are some considerable concerns which must be addressed, particularly the shortage of labour and an ageing workforce, as well as the high construction cost faced by the entire construction industry.

To help relieve this situation, the Government has been promoting the adoption of MiC as an innovative construction method, which utilises the concept of "factory assembly followed by on-site installation" with a view to achieving lower project costs, better quality control, shorter construction time, faster capital return, better site safety, and better environmental sustainability with less wastage.

A. Guidance Note on Fixed Electrical Installations with Modular Integrated Construction Method

Given electrical installations are indispensable to modern buildings and infrastructure, the EMSD has issued the Guidance Note on Fixed Electrical Installations with Modular Integrated Construction Method in June 2019 [7], to provide specific guidance for project owners, developers, consultants, authorised persons, and registered electrical contractors/workers on how the adoption of MiC method on fixed electrical installations could be achieved under the current provisions of the Electricity Ordinance.

In view of the maturing technology and expanding application, the EMSD has reviewed the Guidance Note on Fixed Electrical Installations with Modular Integrated Construction Method with the trade during the revision of the CoP, and has adopted the latest trade practice to form the new Code 26T, providing specific requirements on fixed electrical installations designed and constructed using the MiC method.

B. Certification of Electrical Work by Registered Electrical Workers

Given that electrical installations are prefabricated and pre-installed on modules in MiC factories probably outside Hong Kong, they would form parts of the fixed electrical installations upon permanent installation on site as part of a premises or building. As such, the design and construction of these electrical installations should conform to the requirements of the Electricity Ordinance. Specific guidance is provided on the certification of electrical work by registered electrical workers and contractors.

When a registered electrical contractor is employed to carry out the design of a fixed electrical installation, including the wiring installation with MiC method, a registered electrical worker employed by this registered electrical contractor shall certify the design of the fixed electrical installation and this registered electrical contractor shall endorse the certificate (i.e. Part 1 of Work Completion Certificate) to confirm that the fixed electrical installation has been designed in accordance with the Electricity Ordinance.

When the same or another registered electrical contractor is employed for carrying out electrical installation work at the premises, the fixed electrical installation shall, after completion (including any work completed after repair, alteration or addition) and before it is energised for use, be inspected, tested and certified by a registered electrical worker of this registered electrical contractor and this registered electrical contractor shall endorse the certificate (i.e. Part 2 of Work Completion Certificate) to confirm that the fixed electrical installation complies with the requirements of the Electricity Ordinance and is in safe working order.

C. Factory Acceptance Test Before Delivery

If part of the electrical installations is constructed and installed in modules at the off-site workshops (e.g. factories outside Hong Kong), these parts of the electrical installations could be regarded as a MiC electrical assembly and should be inspected and tested to the satisfaction of the registered electrical contractor before delivery to site for permanent module fixing. In addition, this registered electrical contractor shall also ensure the MiC electrical assembly being constructed and installed at the off-site workshop with suitable materials and good workmanship.

D. Quality Control and Supervision System by Registered Electrical Contractor and MiC Factory

This registered electrical contractor is also recommended to establish or agree with the factory to implement a quality control and supervision system (including the factory test requirements) to ensure the MiC electrical assembly being constructed and installed at the off-site workshop with good workmanship and quality. Such arrangement is similar to the typical factory acceptance test for major electrical plant equipment (e.g. main switchboards and power transformers) and the tests have long been adopted in the trade and proven to be effective in ensuring built quality off-site, as well as compliance with relevant technical and safety standards before acceptance of equipment for delivery to site. The existing Code 21B on testing of low voltage installations, which has stipulated the necessary test items and requirements for low voltage fixed electrical installations, further serves as a practical reference for test items to be included in the factory test for MiC electrical assemblies.

While the epidemic has normalised remote work with ample technological solutions already in place, we encourage the trade, particularly the registered electrical contractors for MiC projects, to adopt innovations and IoT technologies which allow effective off-site monitoring of manufacturing processes at MiC factories, as well as managing and witnessing factory tests without the hassles of sending registered electrical workers often across borders to MiC factories for supervision.

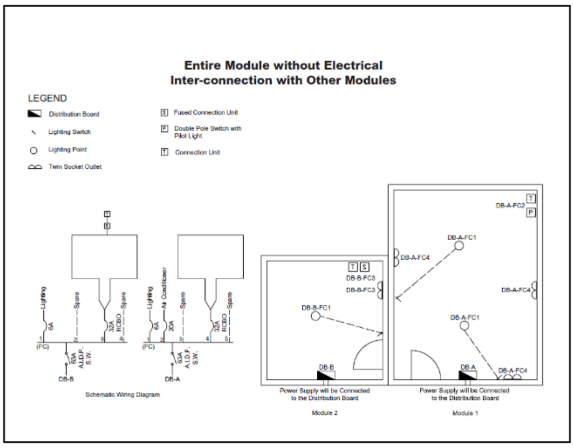
E. Selection and Erection of Wiring Installations

To facilitate the adoption of MiC for wiring installations, Code 26T also provides examples of wiring installations in buildings/developments with the MiC method for general reference. Wiring installations by MiC can be generally, but not exhaustively, classified into or a mix of the following types:

1. Entire module without electrical inter-connection with other modules

   The wiring installation and associated electrical installations such as distribution board, switches, socket outlets, fuse spurs, lighting connection units, etc. of a module are installed at a factory. There is no electrical inter-connection with other modules. After the entire module is installed on-site, the power supply will be connected to the distribution board of that module.

Figure 6 – Typical Diagram of the Entire Module without Electrical Inter-connection with Other Modules



2. Cable connection between the modules at the termination box or through "looping-in" wiring system

   The wiring installation and associated electrical installation such as distribution board, switches, socket outlets, fuse spurs, lighting connection units, etc. of a module are installed at a factory. After the entire module is installed on-site, the power supply will be connected to the distribution board of a module that has already been installed at the factory, whilst cable connections between the modules will be carried out on-site at the termination boxes or through "looping-in" wiring system to the equipment terminals of a module so as to complete the circuits.

Figure 7 – Typical Diagram of Cable Connections between the Modules at the Termination Box

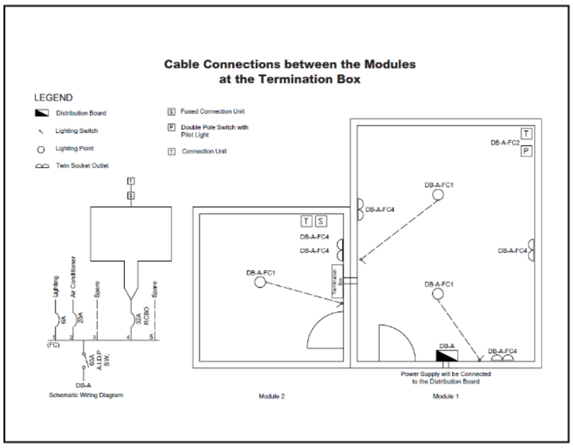
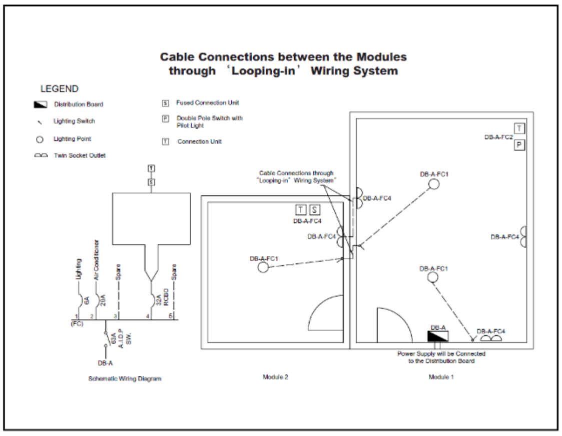


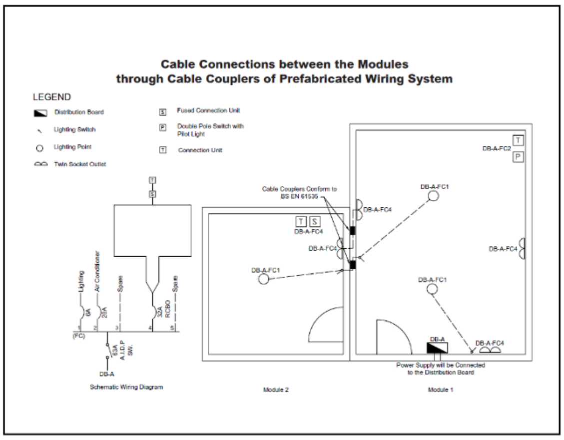
Figure 8 – Typical Diagram of Cable Connections between the Modules through "Looping-in" Wiring System



3. Cable connections between the modules through cable couplers of prefabricated wiring system

   The prefabricated wiring system and associated electrical installations such as distribution board, switches, socket outlets, fuse spurs, lighting connection units, etc. of a module are installed at a factory. After the entire module is installed on-site, the power supply will be connected to the distribution board of a module that has already been installed at the factory, whilst cable connections between the modules will be carried out on-site via cable couplers so as to complete the circuits.

Figure 9 – Typical Diagram of Cable Connections between the Modules through Cable Couplers of Prefabricated Wiring System



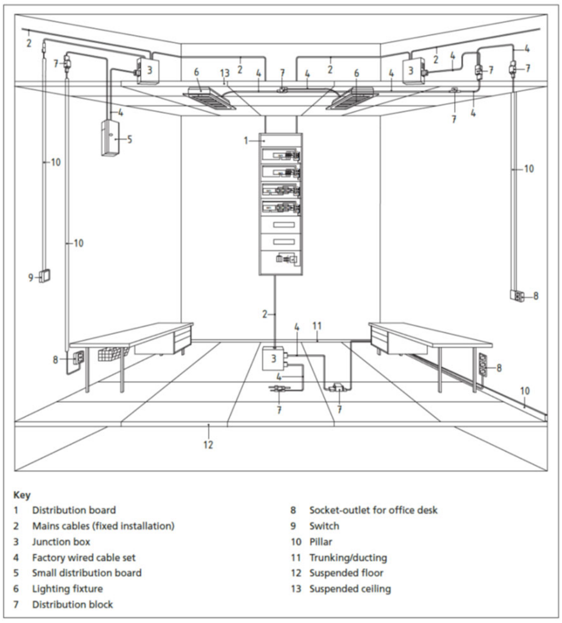
Simplified diagrams are also provided in Code 26T and are shown in Figure 6-9, to illustrate the configuration and connection methods of the above examples.

F. Prefabricated Wiring Systems for MiC

Modular and prefabricated electrical equipment have been readily available for major equipment typically used in low voltage distribution systems in buildings (e.g. switchboards and busbar trunking). Until recently, panelised electrical modules and prefabricated cable containments, etc., are also seen to be adopted at sub-main level in some projects, and these require on-site cable laying and installations. Nevertheless, to achieve the full benefit of MiC for electrical installations, prefabricated wiring systems are an established alternative to conventional fixed wiring methods, as adopting such systems can minimise wiring work on sub-main and final circuits that are often labour intensive on-site and allow permanent connection of cables in a quick "plug-and-play" approach.

To facilitate the trade in adopting prefabricated wiring systems, Code 26T specifies BS 8488 as the accepted standard for prefabricated wiring [8]. BS 8488 covers the key aspects of prefabricated wiring systems rated up to 500V and 100A a.c., including specifications and safety requirements on construction, earthing, protection and associated tests, as well as a guide to use with typical examples at its annex as shown in Figure 10.

Figure 10 - Diagrammatic Presentation of a Typical Prefabricated Wiring System [10]



Lighting systems, typical features of most buildings and infrastructures, can easily adopt prefabricated wiring systems, which allow rapid connection on-site with minimal effort, and can be used in suspended floors and ceilings often found in commercial buildings, schools, hospitals and infrastructures.

Cable couplers conforming to IEC 61535 or equivalent, should be used in prefabricated wiring system. IEC 61535 specifies cable couplers of two-wire and up to five-wire including earth if provided, having a typical current rating from 10A to 100A and connecting capacity from 1.5mm^2 to 10 mm^2 [9]. These cable couplers shall be distinctively labelled to facilitate electrical circuit checking.

As prefabricated wiring systems are intended for permanent connection in fixed electrical installations of the buildings/developments, their installation including the connection and disconnection of cable couplers, shall be carried out by registered electrical workers or skilled persons under the instruction of registered electrical workers.

IV. ARC FAULT DETECTION DEVICES (CODE 6B)

Arc fault detection devices (AFDDs) are intended to reduce the risk of fire caused by electric arcing faults. Protective devices like circuit breakers, residual current devices (RCDs) and fuses are not designed with early detection feature for arc fault. To further enhance electricity safety in Hong Kong while keeping abreast of the technological development, the use of AFDDs has been introduced in the CoP (2020 edition) to provide additional protection for arc faults.

A. History of AFDDs

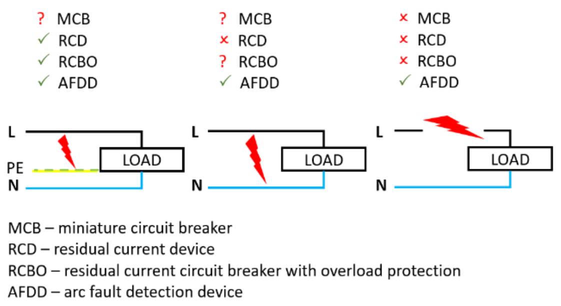
The United States (US) is one of the first countries applying AFDDs [10], which are known as Arc Fault Circuit Interrupters (AFCIs). In the US, AFDDs have been deployed successfully since 2002, with the 1999 National Electrical Code (NEC) requiring AFDDs installation on bedroom branch circuits [11]. In 2008, the International Electrotechnical Commission (IEC) initiated the standardisation work for AFDDs. Since 2013, AFDDs have been covered by IEC 62606 - "General requirements for arc fault detection devices" [12]. In 2014, IEC 60364 - "Electrical installations for buildings" Part 4-42 gives recommendations on the application of AFDDs in residential and commercial buildings [13]. Recently, the IET Wiring Regulations, BS 7671:2018 includes the recommendation and installation arrangement of AFDDs, with a view to providing extra measures for protection against fire with an arc fault origin.

B. Basics of Arc Fault

An arc fault is defined as a dangerous unintentional arc [12]. It creates high intensity of heat which may ignite the surrounding materials. Instantaneous outbreak of arc fault is rare as it usually takes time to develop, and it may originate from a number of causes, such as damaged wires, crushed cables, loose terminations and deterioration of insulation.

In general, there are two types of arcing fault, i.e. series arc fault and parallel arc fault. A series arc fault occurs between two parts of the same conductor. When a conductor is damaged or with loose connections, it leads to localised heating. As the temperature of insulation increases, it may carbonise the insulating materials. As carbon is a conductive material, the current passing though it generates arcs [13]. Then each arc amplifies the carbonisation of insulation, and may eventually ignite the insulation if this is not detected in time [13, 14]. In case of series arc fault, its fault current is typically too low to initiate the operation of protective devices such as circuit breakers or fuses, and only AFDDs are able to isolate the series arc fault.

Figure 11. Characteristics of Different Protective Devices under Arc Faults



A parallel arc fault occurs between two different conductors. Right after the insulation between two conductors are damaged, a significant current is able to flow between the two conductors. While flowing through the insulation materials, these leakage currents optimise their paths through generating arcs. Gradually, the cycle on carbonisation of insulation materials takes place and may cause ignition [13]. In case of parallel arc fault, the impedance of the fault can be large due to damaged insulation, then the parallel arc fault current may trigger the operation of protection devices.

C. Operation Theory of AFDDs

An AFDD is an electromagnetic switching device with electronic components to constantly monitor and analyse patterns in electrical current and voltage. It utilises electronic technology in analysing the waveforms of an arc to distinguish what is known as dangerous arcing fault and normal arcing in normal circumstance. Although different AFDDs manufacturers may make use of different detection algorithms for arc analytics, their efficacy should be the same [15]. AFDDs should be able to detect parallel arcs and series arc. Once an arcing fault is sensed by an AFDD, it disconnects automatically to protect the installation from damage, such as arcing and thermal impacts.

D. Recommended Application of AFDDs

Given the established standards and improved reliability, AFDDs complying with IEC 62606 or equivalent are recommended as a means of providing additional protection against fire caused by arc faults in final circuits. AFDDs shall be placed at the origin of the circuit, if used.

Examples where AFDDs can be used:

i. premises with sleeping accommodation (e.g. dwellings, hotels and guest houses);
ii. premises for manufacturing or storing readily combustible substances or substances liable to spontaneous combustion;
iii. premises where combustible materials are used as the main construction materials (e.g. wooden buildings); and
iv. premises with endangering or irreplaceable goods.

In light of the introduction of AFDDs installation in the CoP, the EMSD is liaising with the

Architectural Services Department and the Housing Authority to support trial projects on the adoption of AFDDs. The EMSD is also exploring to introduce the use of AFDDs in venues (e.g. museums) during alteration or addition works on existing installations. With the Government's leadership in the application of AFDDs, it is foreseen that with a wider adoption of AFDDs, electricity safety will be further enhanced in Hong Kong.

V. CONCLUSION

The new codes and revisions discussed in this paper, alongside with other major revisions of the 2020 edition of the CoP, demonstrate our on-going commitment and partnership with the trade in respect of electrical safety, as well as our proactive role in not only providing practical guidance to facilitate the adoption of new technologies and applications, but also fostering the transition of our community towards a smarter and more sustainable future. The new edition of the CoP will be fully implemented on 31 December 2021 to replace the 2015 edition, after a one-year grace period.

VI. ACKNOWLEDGEMENTS

Sincere thanks are extended to members of the working group for the review of the CoP (member organisations include the Electrical Division of the HKIE) in offering their expertise advice and support in the revision and development of the CoP.

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