A Comprehensive Review of Busbar Trunking Systems for Modern Electrical Power Distribution

Patel Vishvam Gaurangbhai[1], Parmar Jay Vasantkumar[2], Mrs. Rachana Patel[3]
[1,2]*Students, L.D. College of Engineering, Dept. of Electrical Engineering*
[3]*Faculty, L.D. College of Engineering, Dept. of Electrical Engineering*

***Abstract*—The Busbar Trunking System (BBT) is a modern electrical power distribution system widely used in industrial, commercial, and high-rise buildings. It has several advantages over conventional cable systems, including compact design, easy installation, improved safety, lower voltage drop, and better reliability. This review paper provides an overview of the history, construction, working principle, types, advantages, limitations, and recent developments of BBT. It also highlights future opportunities, such as smart monitoring and IoT-based maintenance, making BBT a reliable and efficient solution for modern power distribution**

***Index Terms*—Busbar Trunking System (BBT), Electrical Power Distribution, Busbar, Sandwich Busbar, Tap-off Unit, Energy Efficiency, Electrical Safety, Industrial Power Systems, Smart Monitoring, IoT.**

I. INTRODUCTION

The dynamic rise of industrialization, urbanization, and commercialization has tremendously increased the demand for reliable, safe, and efficient electric power distribution. It is a known fact that electricity was conventionally distributed by means of traditional cable systems. However, such systems usually have limitations in terms of large space occupancy, complex wiring, and poor adaptability, making them unsuitable for the modern industrialized world. Modern industries and high-rise buildings have an ever-increasing demand for electricity, and the equipment layout is constantly changing, thus conventional power distribution methods may not be appropriate for such settings. For this reason, the Busbar Trunking System (BBT) has become an increasingly popular choice as the preferred method of power distribution for low and medium voltage applications. [1] [3]

Although BBT systems are widely used in modern electrical distribution, their performance depends on many factors, including current rating, voltage drop, temperature rise, short-circuit withstand capability, installation environment, protection coordination, and maintenance requirements. A systematic review of these is therefore required to determine the effectiveness of BBT in relation to conventional cable distribution systems. [5]

II. HISTORICAL DEVELOPMENT OF BUSBAR TRUNKING SYSTEM

2.1 Evolution of Busbars

The notion of busbars traces back to the dawn of the electricity era, when they were made of bare copper buses for large currents in the substation and switchgear. Busbars were mounted on an open construction using porcelain insulators. Thus, the first busbars were designed for open use, but such a design required much space and was unsafe regarding dust, humidity, human touch, and other factors. All these factors prompted the development of an enclosed power distribution system that could provide safety and reliability. [6].

2.2 Development of Busway System

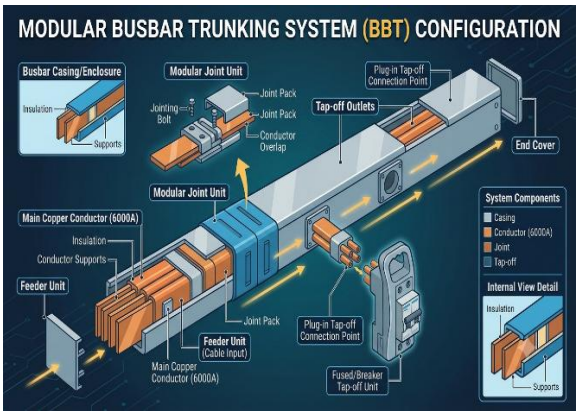
The first enclosed busway systems were created in the late 1920s and early 1930s in the United States within the automobile industry. Large-scale automotive producers needed reliable sources of electricity to supply big electricity-consuming machines while providing the ability to reconfigure production processes. The use of the conventional method of distributing electricity by means of cables proved to be

insufficient, while the busway systems could be assembled in the required configuration with greater ease. Enclosed busway systems have since become a standard feature in industrial, commercial, and electric utility facilities as the demand for electric power grew in these facilities. [6]

2.3 Evolution into Modern Busbar Trunking Systems
Over subsequent decades, Busbar Trunking Systems (BBTs) were significantly improved by the development of more advanced technologies. Air-insulated busbars replaced the open busbars and were later replaced by sandwich-type busbars, where the conductors are placed closer together, being fully insulated. Such improvements allowed to reduce voltage drops, improve heat dissipation and short-circuit withstanding capability and save space. The creation of plug-in tap-off units, reduced-joint systems, and flame-retardant insulation increased the safety, level of automation, and reduced the maintenance costs. At present, the BBTs are designed as standardised and prefabricated switchgear line-up, featuring a degree of system integration, which minimizes the required installation and maintenance efforts in industrial facilities, commercial complexes, hospitals, data centers, and high-rise buildings. [1] [3] [6]

2.4 Standardization and Technological Development
Today, busbar trunking system is produced by the leading manufacturers of electrical equipment, including Siemens, Schneider Electric, ABB, Eaton, Legrand, C&S Electric, Larsen & Toubro (L&T), and General Electric (GE). The producers constantly invest in research and development of products with reduced dimensions, increased IP protection, halogen-free insulation, and digital functions.

Besides, busbar trunking system should meet all international standards to ensure the proper functioning of electrical equipment. Previously, busbar trunking system was produced according to IEC 60439-2, which was canceled in 2012. The standard IEC 61439-6 became current and specifies requirements for low-voltage busbar trunking systems, construction, testing, verification, and assessment of performance. [5]



(AI-generated conceptual illustration of a BBT)

III. CONSTRUCTION AND COMPONENTS OF BUSBAR TRUNKING SYSTEM

The Busbar Trunking System (BBT) can be described as a prefabricated electrical power distribution system that allows the reliable transmission and distribution of electrical energy. The BBT uses copper or aluminium conductors that are isolated by insulation and protected by a metallic housing. The Busbar trunking system is different from traditional cable systems because it is manufactured in standard modules that can be assembled on site with relative ease. This feature allows for faster installation and facilitates future modification and expansion of the system. The Busbar trunking system is typically used in industrial plants, commercial buildings, data centers, hospitals, and high-rise buildings.
The Busbar Trunking System consists of various components that allow the distribution of electrical energy. These components include several busbar trunking system items that serve specific functions.

3.1 Busbar Conductor
Busbar conductors are the main current-carrying parts of the system. Typically, they are made of copper or aluminum. The choice of material depends on the required current carrying capacity and cost. Copper busbars have better electrical and mechanical properties than aluminum ones. They have a higher conductivity and, thus, lower voltage drops and power losses. On the other hand, aluminum busbars are cheaper and easier to process. Busbar conductors always have an adequate cross-section to carry a large amount of current. [1] [6]

3.2 Insulation System

Each conductor is separated by an insulating material, such as epoxy resin, polyester film or Mylar insulation. The insulation provides electrical isolation between two neighboring conductors, thereby ensuring the safe operation of the BBT. The modern sandwich-type BBTs utilize insulation layers, which are reduced for better heat transfer and offer improved dielectric strength. [1]

3.3 Metallic Enclosure

The insulated conductors are enclosed within galvanized steel or aluminum housing, providing mechanical protection and insulation against dust, moisture, accidental contact, and damage to the busbars. The enclosures also provide a protective earth (PE) and contribute to the safety and durability of the system. [3] [5]

3.4 Joint Pack

The joints provide connections between two busbar elements close to each other. The joints include the specifically designed connectors, the insulated covers, and the bolts that guarantee a solid electrical connection with reduced contact resistance. Tightening the joints is of particular importance since it ensures the normal current flow and eliminates any possibility of overheating. [3]

3.5 Tap-off Box

A Tap-Off Box is a removable device connected to the Busbar Trunking system (BBT) from which the electricity is tapped off, and it is distributed to the load, distribution boards, motors, and other electrical equipment.

The Tap-Off boxes are connected to the main busbar by plugging in to the busbar at the desired location. In some cases, circuit protection devices, for example, MCCB (Moulded Case Circuit Breaker) or MCB may be included in the Tap-off boxes providing protection of the circuits supplied from the box against overload and short circuit.

Main functions

- Tapping off the power from the main busbar without interrupting the electricity supply.
- Protection of the circuit by means of the MCCB/ MCB contained in the box.
- Isolating the connected load for maintenance purposes.
- Flexibility of distribution, as the Tap-off boxes can be located at any point along the busbar trunking system.
- Simplicity of modification – additional loads can be connected by providing additional Tap-off boxes at the required places. [4]

(AI-generated illustration of a Tap-Off Box in a Busbar Trunking System)

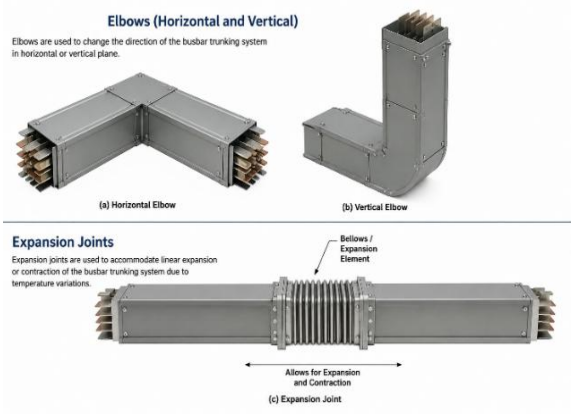
3.6 End Feed Unit

The end feed unit is mounted in the busbar trunking system (BBT) at the point of entry of the electrical power from the main switchboard or transformer. It guarantees the isolation and connection of the power supply to busbar conductors. The BBT was connected to the electrical panel with the flange connection. The connection method ensures a reliable mechanical connection between the BBT and the electrical panel and sets up an electrical connection of the busbars in the BBT with the busbars in the panel.

After mounting the flange connection, the busbars in the BBT and the busbars in the panel were fixed by tightening all the screws to the required torque value. The advantages of flange connection include Reliable mechanical connection of the BBT and the electrical panel; Alignment of busbars in the BBT and the panel; Elimination of stresses in the busbars of the BBT; Simplicity of installation and subsequent maintenance and service; Reliable electrical connection of busbars with high current capacity. [1] [6]

3.7 Elbows and Expansion Joints

Elbows are utilized to change the direction of the bus bar route. The busbar is provided with expansion joints to relieve the stresses due to expansion and contraction of the busbar due to temperature rise or fall. [6]



(AI-generated illustration of horizontal and vertical elbows and an expansion joint in a Busbar Trunking System.)

3.8 Supporting Structure

The complete Busbar Trunking System is mounted on specially designed support brackets or hangers that maintain proper alignment and provide mechanical support throughout the installation. These supports ensure safe operation by minimizing vibration and mechanical movement. [1]

3.9 Major Components of Busbar Trunking System

Component	Function
Busbar Conductors	Carry electrical current
Insulation	Prevents short circuits and electrical leakage
Metallic Enclosure	Provides mechanical protection and earthing
Joint Pack	Connects adjacent busbar sections
Tap-off Unit	Supplies power to individual loads
End Feed Unit	Connects BBT to the main power source
Elbows	Change the direction of the busbar route
Expansion Joint	Compensates for thermal expansion
Support Brackets	Secure the busbar during installation

IV. WORKING PRINCIPLE OF BUSBAR TRUNKING SYSTEM

The Busbar Trunking System (BBT) is divided into sections and provides a path for distributing electrical power from the main power supply to the load.

The current from the transformer or main distribution board (MDB) is delivered to the BBT end feed unit. From there, the current flows to the busbars surrounded by an insulated copper or aluminium conductor. The power is tapped off at the desired location using special units to supply the load, motor control centres (MCCs), distribution boards, and other equipment. The Busbar trunking system provides a simple and effective way of supplying power to the load without using a large number of cables. It allows easy expansion to meet the growing demand for electricity.

The conductors carrying the current from the BBT have small resistance enabling the voltage drop along the busbars to be minimal. This characteristic of BBT makes it highly efficient compared to other traditional methods of power distribution. The busbar trunking system has fewer power losses due to the use of closely spaced insulated conductors as in the case of the modern sandwich type busbars. The current flowing through the busbars experiences less impedance hence greater efficiency.

The Busbar trunking system has joint packs that provide low impedance connections between the busbar sections. The joints must be properly tightened to the manufacturer's recommended torque value to avoid local heating. Moreover, the metal cover provides safety to the conductors and grounds the busbar trunking system. Another advantage of the Busbar trunking system is that it offers plug-in tap-off units that allow connecting additional loads without having to modify the main busbar trunking system. In most cases, the tap-off boxes contain protective circuit breakers such as MCBs or MCCBs providing short circuit and overload protection to the connected equipment. This feature enables the system to be easily expanded, retrofitted, and reconfigured with minimum effort and downtime.

The Busbar trunking system is highly reliable especially when dealing with huge short circuit currents because of its excellent mechanical properties. BBT has been developed to provide mechanical strength, short circuit withstanding

capability, and fire resistance. It employs the use of standard accessories, compact design, and flame retardant materials for enhanced performance and reliability. This makes it appropriate for use in industrial facilities, commercial complexes, hospitals, airports, data centres, high-rises, and other critical infrastructures with high power consumption needs. [1] [5]

Working Process of BBT

- The electrical power is fed from the transformer or Main Distribution Board (MDB).
- The power is fed to the Busbar Trunking System through the End Feed Unit.
- The current flows through the insulated copper or aluminium busbars enclosed in the metallic housing.
- At various points, the Tap-off Units take off the power from the busbar without interrupting the supply.
- The circuit protective devices such as MCBs or MCCBs in the Tap-off Units provide the distribution of power to machines, distribution boards, or other electrical equipment.
- The current flows through the busbar to feed other loads downstream up to the end of the distribution.

V. TYPES OF BUSBAR TRUNKING SYSTEM

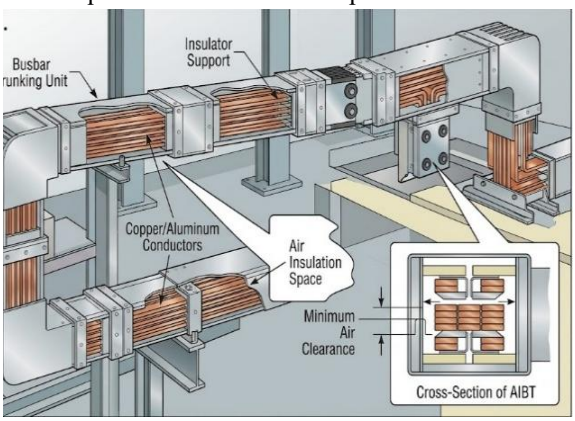
Busbar trunking system can be offered in different types that serve various purposes. Therefore, the choice of this equipment depends on the voltage, installation conditions, expandability, and other factors. Contemporary busbar trunking systems allow realizing the high reliability of power supply, safe operation, and convenient expansion and maintenance.

5.1 Air Insulated Busbar Trunking System

In an air-insulated busbar system, the conductors are separated by air within a metallic enclosure, which provides insulation between the conductors. It is usually applied for medium and high current ratings due to a requirement of sufficient space for their mounting. This busbar type is rather simple in its construction, easy to maintain, but takes more space than the sandwich-type busbars, and has a relatively high impedance.[6]

Feature:

- Air is used as the insulation medium.
- Suitable for medium and high current ratings.
- Easy inspection and maintenance.
- Requires more installation space.



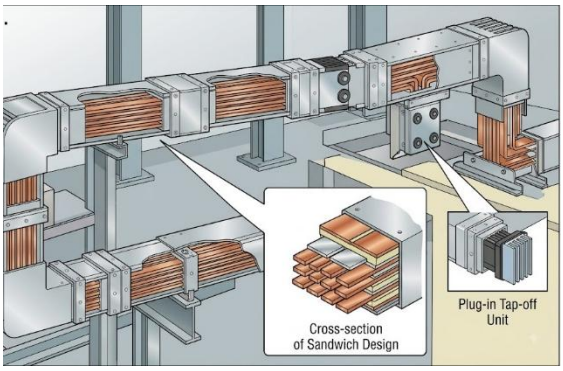
(AI-generated illustration of Air-Insulated Busbar Trunking System (AIBT)

5.2 Sandwich Busbar Trunking System

The sandwich busbar system is the most common Busbar Trunking System in modern distribution networks. In this design the insulated conductors are placed closely together without gaps and enclosed in a compact metallic housing. The reduced spacing between the busbars allows to lower the impedance and improve the current carrying capability of Busbar Trunking System, by minimizing the voltage drop and increasing the short circuit withstand capability. Due to the increased power density and reduced footprint the sandwich BBT is used in industrial facilities, commercial complexes, hospitals and data centers. Insulation materials such as Polyester film (PET), Polyimide film and Epoxy/polyester based insulation are widely used in Sandwich Busbar Trunking System . [8]

Feature:

- Compact and space-saving design.
- Lower voltage drop.
- Better heat dissipation.
- High short-circuit strength.
- Suitable for indoor installations



(AI-generated illustration of Sandwich Busbar Trunking System)

5.3 Feeder Busbar Trunking System

A feeder busbar system is a system that is used for distributing power from the main distribution board (MDB) to the sub-distribution boards (SDBs) or large loads. It does not provide for the derivation of power from an intermediate point, in contrast with plug-in systems, and is designed for continuous power distribution with high reliability and minimal losses over long distances. [6]

Application:

- Main power distribution.
- Transformer to MDB connections.
- Generator connections.
- Large industrial facilities.

5.4 Plug-in Busbar Trunking System

The plug-in busbar system is designed to offer flexibility in terms of power distribution. The busbar has regularly spaced plug-in stations at which tapping units can be connected without having to permanently alter the busbar itself. This feature enables circuits to be added or disconnected with ease, which is particularly useful for machine tool applications where the layout often changes. [8]

Features:

- Easy expansion.
- Flexible power distribution.
- Quick installation of tap-off units.
- Reduced downtime during modifications.

5.5 Lighting Busbar Trunking System

Lighting busbar systems are specially designed for distributing electrical energy to lighting equipment and other secondary consumers with a current rating of up to several amperes. Such schemes are used in areas with a large amount of electrical equipment that requires individual connection to the power supply, for example, in shopping malls, warehouses, airports, industrial buildings, and commercial structures.

Features:

- Designed for low current ratings.
- Lightweight construction.
- Easy relocation of lighting fixtures.
- Simple installation and maintenance.

BBT Type / Configuration	Construction / Insulation	Typical Application	Main Characteristics
Sandwich BBT	Closely packed conductors with insulation between conductors	High-rise buildings, industries	Compact, efficient, low voltage drop, high short-circuit withstand capability
Feeder BBT	Depends on the manufacturer's construction	Main power distribution	Reliable transmission of high current over longer distribution paths
Plug-in BBT	Insulated busbars with plug-in points	Manufacturing plants, commercial buildings	Flexible, expandable, convenient connection of loads
Lighting BBT	Compact insulated conductors	Lighting distribution in commercial/industrial buildings	Lightweight, compact, easy installation

VI. ADVANTAGES, LIMITATIONS AND COMPARISON OF BUSBAR TRUNKING SYSTEMS

6.1 Advantages

- Busbar trunking system (BBT) can carry greater current which makes it appropriate for big commercial building, industry and plants.
- It is more compact comparing with traditional ways of electricity distribution.
- The installation of busbar trunking system is quite simple and takes less time due to simple mounting of busbar sections and tap-off units.
- Due to the particular design, BBT has a smaller voltage drop.
- It is easier to cool down the busbar trunking system with metal housing.
- The busbar system can be used for distributing electricity to the majority of electrical equipment. It is possible due to the possibility of connecting the tap-off units to the busbar trunking system on different sides and using various schemes.
- It is easier to add new electric equipment using BBT. For this purpose it is necessary to install additional tap-off units and there is no need to redesign the whole power distribution system for its expansion. This is a significant advantage for the systems with possible growth.
- Higher safety level is ensured by the busbar trunking system as conductors are placed in an insulated case. BBT prevents people from touching live parts, mechanisms and elements from damaging electric circuits, as well as environmental influences.
- The busbar trunking system needs less maintenance comparing with traditional ways of electricity distribution.
- The busbar trunking system provides a nice and well-organized electric distribution in an industrial or commercial building.

[1][6][8]

6.2 Disadvantages

- High Initial Cost – the cost of busbar trunking components, including busbar sections, tap-off units, joints, and accessories, may be higher than traditional cable wiring methods.
- Specialized Installation – installation requires trained and qualified electricians to ensure that connections, joints, torque, and electrical parameters are correctly set.
- Limited Flexibility – although busbar trunking allows for easy tapping, changes to the busbar route and layout may necessitate the addition or removal of entire sections.
- Environmental Factors – consideration must be given to the surrounding environment when selecting busbar trunking enclosures and insulation to deal with issues such as moisture, dust, corrosion, and temperature.
- Mechanical Damage – improper handling and installation can damage the busbar enclosure, insulation, or connections, resulting in reduced performance.
- Joint Maintenance – joints and connections need to be inspected and tightened regularly to avoid overheating and poor conductivity.
- High Replacement Cost – if busbar trunking is damaged, large sections may need to be replaced, which can be more costly than replacing damaged cables.
- Design Considerations – the busbar trunking system needs to be appropriately sized and protected based on current ratings, short circuit capabilities, voltage drops, installation conditions, and protection requirements.

[3] [6] [7]

6.3 Comparison between BBT and Conventional Cable Systems

Parameter	BBT System	Conventional Cable System
Construction	Enclosed copper or aluminium busbars	Individual insulated cables
Current Capacity	Suitable for low to very high current ratings	Suitable for a wide range of current ratings
Installation Space	Requires relatively less space	Generally requires more space, especially for multiple cables

Installation	Modular and comparatively faster	Cable laying, routing and termination can be time-consuming
Power Distribution	Easy distribution through tap-off units	Requires separate cable connections to loads
Voltage Drop	Generally low due to low impedance design	Depends strongly on cable size, length and installation method
Heat Dissipation	Generally better due to enclosure and conductor arrangement	Depends on cable spacing, insulation and installation conditions
Future Expansion	Relatively easy by adding tap-off units where provision exists	Additional cables and modifications may be required
Maintenance	Mainly inspection of joints and tap-off connections	Inspection of cables, terminations and supporting arrangements
Flexibility	Good for fixed and structured distribution routes	More flexible for irregular or frequently changing routes
Safety	Enclosed conductors provide good protection from accidental contact	Insulation provides protection, but exposed cable routes may require additional mechanical protection
Initial Cost	Generally higher	Generally lower for smaller installations
Large Power Distribution	Highly suitable	Can become bulky when many high-current cables are required

6.4 Future Technical Improvements in BBT

- Smart Monitoring: The technology can be equipped with sensors to monitor currents, voltages, temperatures, power consumption, and other parameters associated with irregularities.
- IoT: BBT can be integrated with IoT-based management systems for remote monitoring and predictive maintenance.
- Predictive Maintenance: By continuously tracking the temperature and electrical parameters, BBT can predict possible malfunctions before they occur.
- Reducing Losses and Improving Performance: More advanced BBT can potentially be designed to reduce line losses and enhance thermal performance.
- Integration with Renewable Energy Systems: BBT can be utilized in systems using solar photovoltaics, battery storage, and other renewable energy technologies.
- Digital Protection and Diagnostics: Upgraded systems utilizing BBT would benefit from modern diagnostics and protection systems, resulting in increased reliability.
- Modular Design: Future BBTs will potentially adopt a modular design making it easier to upgrade or modify an electrical distribution system.

[6]

VII. CONCLUSION

Busbar trunking systems (BBT) have emerged as one of the most promising alternatives to traditional power distribution using cables. This technology enables achieving high current ratings in a relatively small volume, ensures low voltage drops, provides a modular configuration of taps, enhances overall safety, and facilitates cost-effective and convenient expansion and reconfiguration of the electrical power distribution network.

The present work discussed the history of the development of busbar trunking, analyzed its principles of operation, structural features, and highlighted its advantages and disadvantages, comparing it to traditional power distribution methods. Although the initial investment in BBT configuration is usually higher, and it requires trained professionals for its reliable and safe installation and maintenance, the overall benefits of their application in terms of compactness, organized layout, and high power rating make them highly relevant for a wide range of applications.

Furthermore, future prospects for the development and application of busbar trunking systems are highly promising, including the introduction of solutions for monitoring and controlling technical condition with the tools of the IoT (Internet of Things), the creation of smart tap-through units and busbar joints with the capabilities of artificial intelligence, new approaches to insulation technology, thermal performance, and much more. All this will allow taking the technology of bus distribution to a new level and ensuring its reliability, safety, and efficient operation. Thus, busbar trunking systems have a great future ahead, which will be competitive and complementary to traditional ways of power distribution, offering a wide range of benefits and solving many problems associated with the use of electric power in modern civilization.

REFERENCES

[1] Electrical Standard Products Larsen & Toubro Limited Busbar Trunking System Catalog SP 50463.

[2] L&TElectrical&AutomationIEC60431&2:2005B SE N60439 1&2:2000 NZ34392:2002AS34392:1994 JISC8364.

[3] SIVACON 8PL Busbar Trunking System Catalog LV 79 · 2005, © Siemens AG 2005.

[4] Controls & Switchgear Co. Ltd. Bus Trunking System Catalog Division C - 59, Equipment is designed for low Voltage power distribution as per IEC 439(part 2), IS part 2).

[5] IEC 61439-6:2012 Low-voltage switchgear and controlgear assemblies - Part 6: Busbar trunking systems (busways)

[6] Y. N. Burali and M. B. Patil, “Busbar Trunking System for Electrical Supply to Industrial & Commercial Installation,” IOSR Journal of Engineering (IOSRJEN)

[7] M. Ashiquzzaman, K. F. Nasrin, T. Ahmed, and M. N. B. Masum, “Modern Electrical Design and Installation of Equipment of High Rise Building Using Proposed Busbar Trunking and Fault Analysis System for the Perspective of Bangladesh,” International Journal of Multidisciplinary Sciences and Engineering, vol. 9, no. 6, June 2018.

[8] Busbar trunking system Catalog Siemens LV 71.T 2004BD2A/BD2C