Modern Electrical Design and Installation of Equipment of High Rise Building Using Proposed Busbar Trunking and Fault Analysis System for the Perspective of Bangladesh

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***Abstract*— In this research work, for establishing a modern electrical design and installation of equipment of high rise building two new appliances have been proposed. The first one is usage of busbar trunking (BBT) system for main distribution line instead of conventional wiring system to provide much higher protection, easier installation process, reduce cost, time, space, and maintenance management. The second one is continuous fault analysis and monitoring using SICAM Q100 device which is the updated process to make sure more safety for monitoring power quality to acquire, visualize, analyze, and transmit measured electrical variables such as AC current, AC voltage, frequency, power, harmonics, etc. The measured variables can be output to a computer or control center via communication interfaces or shown on a display. Total electrical drawing has been drawn in AutoCAD. An entire substation for the high-rise building has been designed, according calculated load of the building. For protection of the building proper rated MCB and MCCB has been installed according to the load. To avoid fire hazard, fire detection and alarm system with immediate water supply has been installed in this building. Entire electrical connection has been designed based on Bangladesh National Building Code- 2014 (BNBC).**

***Keywords*— Busbar Trunking, SICAM Q100, Fault Analysis, Substation, Generator, Power Factor Improvement Panel, Wiring, Fire Protection and Circuit Breaker Protection**

I. INTRODUCTION

A safe electrical connection of a high-rise building depends on different important parameters. Such as, proper wiring with assortment of wires according the rated current, selection of circuit breakers to avoid short circuit and over current fault scenario, installment of a suitable step-down transformer for maintaining required voltage level, backup generator for emergency power supply, power factor improvement panel (PFI panel) for getting nearly unity power factor, sufficient fire security system to get rid of sudden fire hazard. All these concepts and installation of equipment are maintained properly according the standard code. Now a day's proper electric protection and installation is considered as one of the most important dealing issue for any residential and commercial buildings. So, for improvement in this section new electrical equipment and conductors are releasing and becoming available on a regular basis. High rise building is a building above four stories, and/or a building exceeding 15 meters or more in height above the average level of front road [27].

Usually high-rise buildings consist of a substation, HT panel, LT panel, transformer, generator, power factor improvement panel, different ratings of circuit breakers, different ratings of wires and fire detection with alarm system. Although many protective equipment are used in high rise buildings nowadays, the protection scheme can be more improved by using BBT system which will provide more protection and benefits with compared to the conventional wiring system. Fault analysis and regular monitoring of fault can also be imposed to improve protection and avoid fault in the system.

II. MATHEMATICAL EXPLANATION OF ELECTRICAL WIRING AND INSTALLATION

A) Electricity Supply Specifications

Electricity supply for domestic consumers, according to MS IEC 60038 standards, meets the following specifications [1]:

- Single phase supply with nominal voltage of 230V, range +10%, -6%;
- Three phase supply with nominal voltage of 400V, range +10%, -6%;
- Permitted frequency is 50Hz + 1%;
- Earthing system type (TT System)

B) Planning of Electrical Wiring Work

Prior to carrying out wiring work, planning and determination are completed for the tasks to be undertaken so that the work carried out is tidy, neat and safe to be used [1].

(i) Undertake a site Visit, (ii) Determine the consumer load requirements, (iii) Calculate the maximum load demand, and (iv) Submit the plans, drawings and specifications.

C) Fittings, Fixtures and Accessories

Switch Boards with back boxes and cover plates, Ceiling Roses, Socket Outlets with back boxes, Plugs, Light Fittings, Fans, pull boxes with cover plates have been put in this category, although there may be other items which may be included under electrical accessories related to electrical and electronic installations in buildings [2].

D) Switch boards

Tumbler Switches have been used for surface wiring and Piano Switches have been used for concealed or surface wiring. The Switches must conform to the relevant BS standard. The minimum ampere rating of switch shall not be below 5A. Depends on operation, switches may be: SPST (Single Pole Single Throw), SPDT (Single Pole Double Throw), DPST (Double Pole Single Throw), DPDT (Double Pole Double Throw). Usually the DPST switches are made for 10A, 15A and 20A rating [2].

E) General Requirements of Socket Outlets

Socket Outlets shall be 13 A switched shuttered 3pin flat pin type. All socket outlets must be switched (Combined) and shuttered and shall be for 3 pin Flat pin type (rectangular Cross section) 13A plugs fitted with tubular fuse. The corresponding plugs must be fitted with fuse. The maximum fuse rating shall be 13A for 13A Sockets or 15A for 15A sockets and so on. Wiring for sockets shall be radial type of wiring. However, ring type wiring may be used by strictly following the rules given in IEE Wiring regulations BS 7571:2008, 17th Edition and by using appropriate size of Cable [2]. All sockets should be matched with the rating of load according the standard.

F) Distribution wiring in a building

Every installation shall be divided into small circuits following the rules (given in this document) to avoid danger in case of a fault, and to facilitate safe operation, inspection, maintenance and testing. For the establishment of the circuits appropriate type of wiring is needed and appropriate terminations connections junctions of these circuits are needed. At the same time, appropriate types of protection against faults must be given at different levels. These are to be achieved through installation of appropriate distribution wiring in the building [2].

G) Distribution board

A Distribution Board is the junction point of the incoming line and the outgoing lines for the distribution of Electricity throughout the building. The incoming as well as the outgoing lines must have circuit breaker protection or Fuse protection. The junctions and terminations of the incoming and outgoing cables are made through copper bars containing bolts and nuts for Cable lugs known as bus-bars. A Distribution Board may be named MDB (Main Distribution Board) or FDB Floor Distribution Board or DB (Distribution Board) or SDB (Sub-Distribution Board) or BDB [4]. EDB, EFDF, ESDB, EBDB Sections of DB, FDB, SDB, BDB receiving feed from the Emergency Busbar which in turn is getting feed from Standby Generator through changeover switch. Each of these distribution boards must have bus bars for Line, Neutral and Earthing for a single-phase box. A 3-phase distribution board must have bus bars for Line1, Line2, Line3, Neutral and Earthing. These boxes shall be made with sheet steel of not less than 18 SWG thicknesses and must be appropriately paint finished to match the wall paint [2].

H) Circuit wiring

The number of final circuits (also termed as sub-circuits or circuits) required and the points supplied by any final circuits shall comply with

1) The requirement of over-current protection, 2) The requirement for isolation and switching, and 3) The selection of cables and conductors. All final circuits shall be wired using loop wiring system; no joint box shall be used.

- ✓ Size of cables to be used in a branch circuit shall be at least one size larger than that computed from the loading if the distance from the over-current protective device to the first outlet is over 15m [2].
- ✓ The minimum size of wiring cable used for a 15A socket outlet branch circuit shall be 4 mm (7/0.036). When the distance from the over-current protective device to the first socket outlet on a receptacle circuit is over 30 m the wire used for a 15A branch circuit shall be 6 mm2 (7/0.044) [2].
- ✓ For a single-phase circuit, red color insulation was used for the live wire and the black color insulation for the neutral and green + yellow bi-color insulation was used for the ECC. For a three-phase circuit, red color was used for the live (L_1), yellow color for the live (L_2), blue color for the live (L_3) cable and the black color for the neutral and green + yellow bi-color for the ECC. This color code of cables now can be replaced by the current IEC cable color code standards [2].

TABLE I
NEW INTRODUCED COLOR CODES OF CABLES FOLLOWING IEC STANDARDS [2]

Wire	Current IEC Standards
Protective earth (PE) or ECC or Earth Lead Wire	Green + yellow bi-color
Neutral (N)	Blue
Single phase: Live (L)	
Three phase: L1	Brown
Three phase: L2	Black
Three phase: L3	Grey

I) Circuit wiring

For calculated load, cable size may be found with the help of different tables but it is needed to keep in mind and follow the rules about voltage drop. Also, the load factor is needed to be considered when finding the size of cable. When determining the cable size, the type of wiring system is needed to be considered i.e. in open wiring system, temperature would be low but in conduit wiring, temperature increases due to the absence of air [3].

J) Electrical Wiring in the Interior of Buildings

Surface Wiring or Exposed Wiring: Wiring run over the surface of walls and ceilings, whether contained in conduits or not, is termed as surface wiring or exposed wiring. Single core PWC insulated cupper through PVC Channels or through PVC conduits or through GI pipes of approved quality may be used for surface wiring. Surface wiring using twin core flat PVC insulated cupper on wooden battens used to be used long back. This is almost discontinued and discouraged now a day, PVC conduits or GI pipes, when used for surface wiring, shall be clamped with saddles at a spacing not exceeding 600mm, to the Wall or ceiling using plastic rowel plugs with countersunk galvanized screws [2].

Concealed Wiring: The wires in this type of wiring shall be placed inside GI conduits or PVC conduits that are buried in roofs and in brick/concrete walls. The conduits in the walls shall be run horizontally or vertically, and not at an angle. In a column structure building having no permanent walls, switch boards and socket boards, pull boxes shall be placed in columns and must be done during the casting of columns [2].

Wiring inside Suspended Ceilings (False Ceilings): Wiring inside suspended ceilings (False Ceilings) shall be surface wiring through conduits or through PVC channels mentioned under the heading of surface wiring methods [2].

Methods of Point Wiring: Wiring between a Light / fan point and its corresponding switch board is termed as point wiring. It is assumed that the load of such a point is not in excess of 100watts in general in special this may be up to 200 watts. Wiring for a light / fan point shall be made using one of the methods i.e., (i) Surface Wiring or (ii) Concealed Wiring [2].

Methods of Circuit Wiring: Wiring between a switchboard and a BDB/SDB/DB will be called circuit wiring. Circuit wiring shall be done with a live cable a neutral cable and an ECC cable for a single-phase circuit. Sometimes this circuit is also referred to as sub-circuit. An ECC must be provided with each circuit. The ECC at the switch board end shall be terminated in the earth terminal of the metal part of the Switch Board using a brass screw, bolt and a nut. The BDB/SDB / DB end of the ECC shall be terminated in the earthing busbar of the BDB / SDB / DB. The ECC in this case shall be PVC insulated copper cable of appropriate size but with yellow-green bi-color insulation. For each circuit, the live cable must be drawn using brown color insulated PVC cable and the neutral cable shall be drawn using blue color insulated PVC cable. Common neutral shall not be used under any circumstances [2].

✓ The minimum size of cable for a 5A circuit protected by a 5A circuit breaker or fuse shall not be below 1.5 mm

✓ The minimum size of cable for a 10A circuit protected by a 10A circuit breaker or fuse shall not be below 2.5 mm.

✓ The minimum size of cable for a 15A circuit protected by a 15A circuit breaker or fuse shall not be below 4 mm.

✓ The minimum size of cable for a 20A circuit protected by a 20A circuit breaker or fuse shall not be below 6 mm.

In general, the minimum size of cable for a particular circuit shall depend on the rating of the fuse or circuit breaker used for the protection of that circuit [2].

Feeder wiring between SDB and BDB, DB and SDB, FDB to DB, MDB to FDB etc: Wiring between a BDB and an SDB, an SDB and a DB, a DB and an FDB, an FDB and an MDB needs special attention and the rules are similar to circuit wiring. ECC must be present for each of the feed connections. The ECC in this case also shall be PVC insulated copper cable of appropriate size but with green+ yellow bi-color insulation. At both ends the ECC must be terminated at the earthing bus bar. Appropriate cable lugs / cable sockets must be used for terminating the L1, L2, L3, N and E connections on the bus bars of both the boards. The sizes of the cables must be chosen to match with the rating of the circuit breaker /fuse ratings as mentioned above. Circuit breakers / fuses must be provided at the outgoing and incoming sides of each of the bus bars of each BDB/SDB/DB/FDB boxes [2].

III. BUSBAR TRUNKING SYSTEM

Busbar trunking (BBT) system in compact design is the most efficient, safe and ideal system for electricity supply to industrial installations and high-rise structures, offering a wide current range from 125A to 2000A in type CBC (Copper conductor) and 160A to 1250A in type CBA (Aluminum conductor) with possibility of feeding loads up to 400A with standard plug-in boxes. The system has provision of 4 plug-in outlets per meter, which can be fitted quickly and provide total flexibility for any change in distribution layout at a later stage. The system has been designed especially for installations and projects where power supply has to be made available rapidly. These are most suitable for applications where exact location and power consumption is not sure and possible changes in physical distribution of loads are envisaged [4]. The proposed BBT system also has been chosen according to the calculated load of the building.

A) Typical power distribution by busbar from Panel

Benefits & comparison: Benefits of BBT system are numerous. The total cost of ownership (TCO) is very low compare to conventional cabling system for distribution up to load due to shorter & easier installation, reduced costs, time, and space and maintenance management [6].

Fig. 1. Busbar Trunking [5]

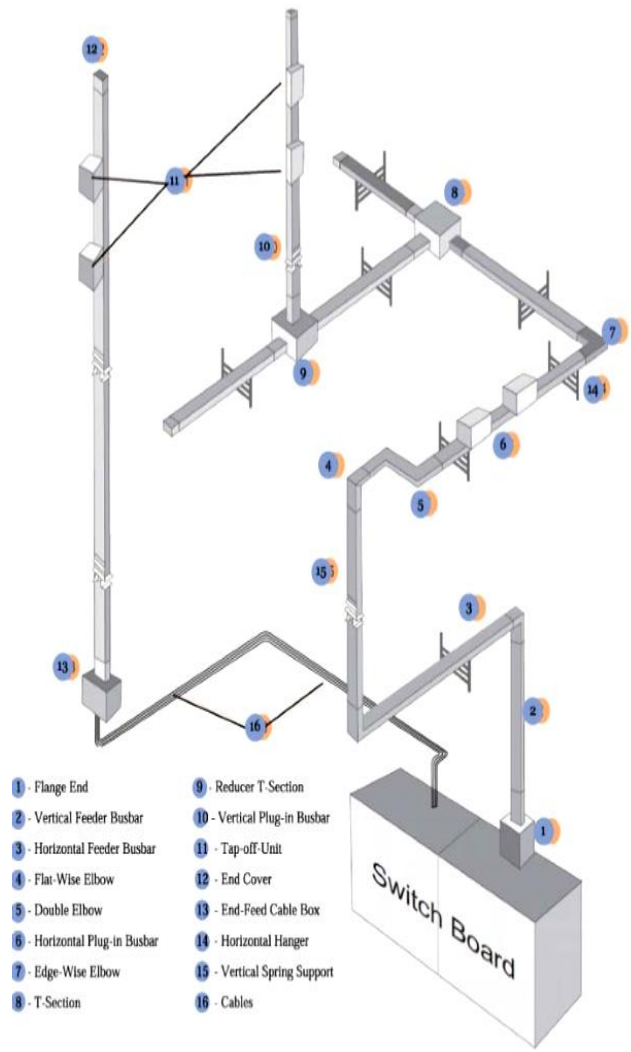

Fig. 2. Typical power distribution by busbar from Panel [6]

1) *Compactness:* Sandwich construction render to the BBT system more compact than air insulated busbar system, thus making them a preferred choice in plant room and building applications.

2) *Energy efficiency:* Compactness of sandwich construction results in higher efficiency due to lower voltage drop and impedance. This ensures all connected equipment run cooler.

3) *Flexible:* Additions of floor to a building or any expansion to an existing system is extremely simple with sandwich BBT. They are scalable & elegant.

4) *Safe & sure:* Higher mechanical strength over long runs, better electrical conductivity lower mV drop which ensures high reliability. Ability to withstand high short circuit currents makes them doubly safe.

5) *Fire & retardant:* Sandwich constructions don't have air gape due to which natural progression of fire inhibited. Epoxy insulation, being flame retardant provides better resistance to spread of fire.

6) *Economical:* Inherently flexible design ensures easy installation and maintenance thus resulting in lower installation and maintenance costs.

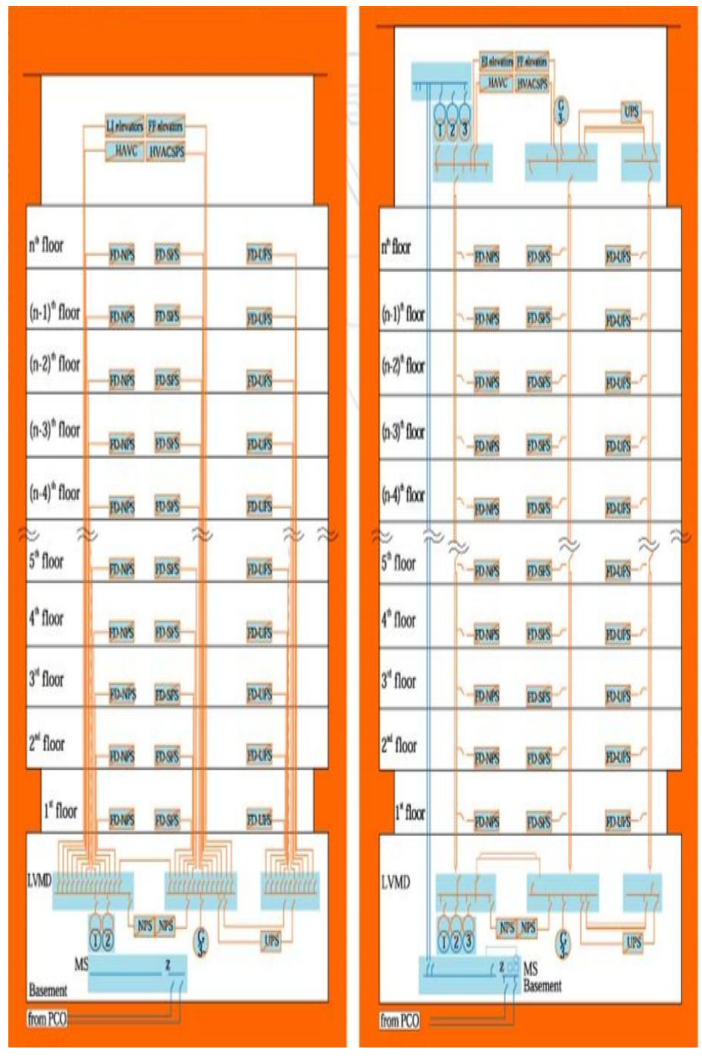

Fig. 3. The benefit of busbar over cabling system [6]

B)The benefits of Busbar over cabling system

The benefit of busbar over cabling system is given below [6] and is shown in the Fig. 3:

1) BBTs are functional and flexible; No additional ducting

or piping is necessary. Busbar projects are easy to prepare.

2) If additional extension is required in the existing BBT system, then it can be done reusing the existing one. But for the case of conventional cable, existing cable cannot be reused.

3) Load balancing is easy to achieve.

4) Unlike conventional cabling system, jointing can be done in BBT system. Expand, change, replacement and reusing feature.

5) Individual floor metering system can be easily incorporated.

6) Busbar installations can be changed or can be mounted to another establishment.

7) Minimizes cost of maintenance, operating, man power and mounting.

8) It can stand strokes with metal housing.

9) Voltage drop can be measured exactly as inductive reactance and electrical values are designed and calculated values.

10) Establishments can be operational in 50% shorter time to other systems, for its easy mounting and installation.

11) It gives a modern and esthetic appearance where it's used.

12) System does not cover a large area and helps space management. Considering its ampere range dimensions are small.

13) Reduces amounts and dimensions of panel boards, especially for compact types heat transfer is perfect. Short circuit withstands are high.

14) Energy can be collected from plug-in points without turning off the power.

15) Busbar can be applied to any kind of building by its modular structure. It covers much less space than cable systems according to its high ampere rate.

16) Cables enable fire to split out. It has no chimney effect because of its compact structure for that fire barrier in not needed.

IV. FAULT ANALYSIS

Universal unit for monitoring power quality and for energy management SICAM Q100 is a Class A multifunctional measuring device for monitoring power quality according to the according to the International Electro-Technical Commission (IEC) 62586-1 (PQI-A-FI) product standard. It is used to acquire, visualize, analyze, and transmit measured electrical variables such as ac current, ac voltage, frequency, power, harmonics, etc. The acquisition, processing and accuracy of measured variables and events are performed according to the IEC 61000-4-30 Class A power quality measurement standard. Long-term data and events are evaluated directly in the device and displayed as a report in accordance with power quality standards (such as EN 5016O). The measured variables can be output to a PC or control center via one of the communication interfaces or shown on a display. In addition to acquiring the power Supply quality according to Class A, SICAM Q100 also offers energy management functions such as the acquisition of load profiles and the relationship to different tariffs, as well as the Modbus Master function for connecting RS485 sub meters (for example, PAC) and LV circuit breakers (such as 3WL) [7].

Fig. 4. SICAM Q100, Power Monitoring Device and Power Quality Recorder, Class A [7]

A) Applications

SICAM Q100 is used in single-phase systems as well as three wire and four-wire systems (with neutral conductors). This universal device is most valuable for applications where the uninterrupted acquisition of supply quality data (e.g. EN 50160) must guarantee fault-free operation of the loads/ consumers connected to the power supply system. In addition to acquiring supply quality data, the unit can also be used for the comprehensive acquisition of other measured electrical variables that are required by the particular application: as part of an automation solution in industrial plants, for energy management and building automation, in commercial applications (assignment of cost centers), and for the comprehensive monitoring of important points in a power company's network. Early detection of supply quality problems thanks to uninterrupted acquisition of important power parameters. Manufacturer-independent, comparable measured values for evaluating supply quality are obtained using standardized measurement methods according to IEC 61000-4-30 Class A (0.1% accuracy). With its master function, SICAM Q100 makes it possible to integrate and further process data from peripheral devices (for example, a power meter or LV circuit breaker). Whether the need is for comprehensive supply quality monitoring and logging or for energy management functions (for example, to reduce operating costs): SICAM Q100 is a key component in any power monitoring system [9].

List of the total applications performed by SICAM Q100 are following [9]:

i. Voltage quality - application overview
   Voltage events - interruption, voltage dip,
   Over voltage, and transients
   Main voltage unbalance
   Main voltage harmonics

ii. Communication
iii. Time synchronization
iv. Continuous measured value acquisition
v. Event-specific measured value acquisition
vi. Power management
vii. Measured value acquisition via recorders
viii. Evaluations
ix. Automation functions
x. Transient recording
xi. Fault recorder
xii. Load profile recording
xiii. Device parameterization
xiv. Visualization of values
xv. Configuration of power quality reports
xvi. Data transmission and download

Voltage quality (also known as power quality) refers to various characteristics in a power supply system. Voltage quality criteria are defined by a number of technical regulations, such as the EN 50160 power quality standard. These criteria describe the main characteristics of voltage at customers' power supply terminals in public low-, medium-, and high-voltage systems. Voltage measurements and evaluations can be used to determine voltage quality. As consumers' awareness of energy efficiency grows, quality of supply becomes a major focus. So, it is also in the interest of power utilities to monitor power quality, thus ensuring proper and efficient operation and improving the system. A high-quality, reliable power supply also means high customer satisfaction [7].

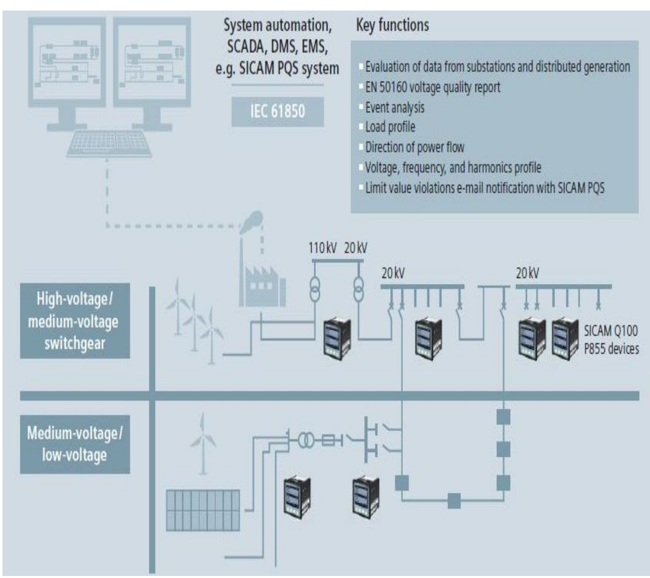

Fig. 5. Application- Voltage quality on all voltage levels of the power supply system [7]

B) Function Overview

Continuous measured value acquisition: Alternating voltage V, alternating current I, Power frequency f (fundamental component), Active power P, Reactive power Q, Apparent power S, Power measurements W, Active power factor cosθ, Measurements up to the 63rd harmonics order, Inter harmonics of voltage and Current, Flicker according to IEC 61000-4-15 [7].

Event-specific measured value acquisitions: Min. /max./mean values, recording of events such as voltage dips, over voltages, interruptions, Limit value violations, Acquisition of load profiles, Transient recording [7].

Transient recording: SICAM Q100 records temporary overvoltage's as transients if the instantaneous value of the primary rated voltage exceeds the parameterized reference value at multiple sampling times [7].

Fault recorder: The fault recorder records 2560 sampled values per 10/12 period in programmable time units. The fault recorder functionality can be activated for the voltage and current measured variables. For event analysis, a pre-trigger time (pre-trigger ratio in %) can be set, which allows the history of the measured value to be analyzed prior to the fault's inception [7]. The event recorder records PQ events only (voltage, frequency, voltage unbalances).

Load profile recording: The load profile reflects system behavior and documents the distribution of power fluctuations and peaks. The appropriate recording and visualization of power flows in the system permits a transparent analysis of the energy flow, making it possible to optimally configure the process in terms of energy [7].

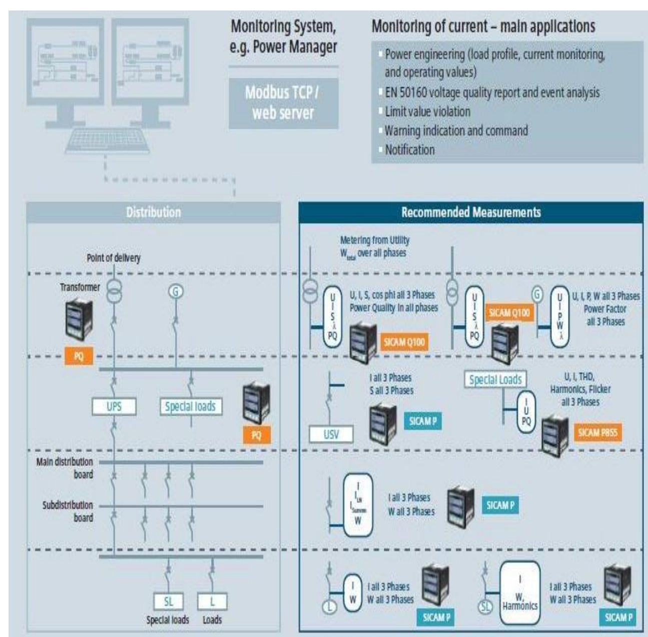

Fig. 6. Application- Voltage quality and power monitoring for industry, building and data center [7]

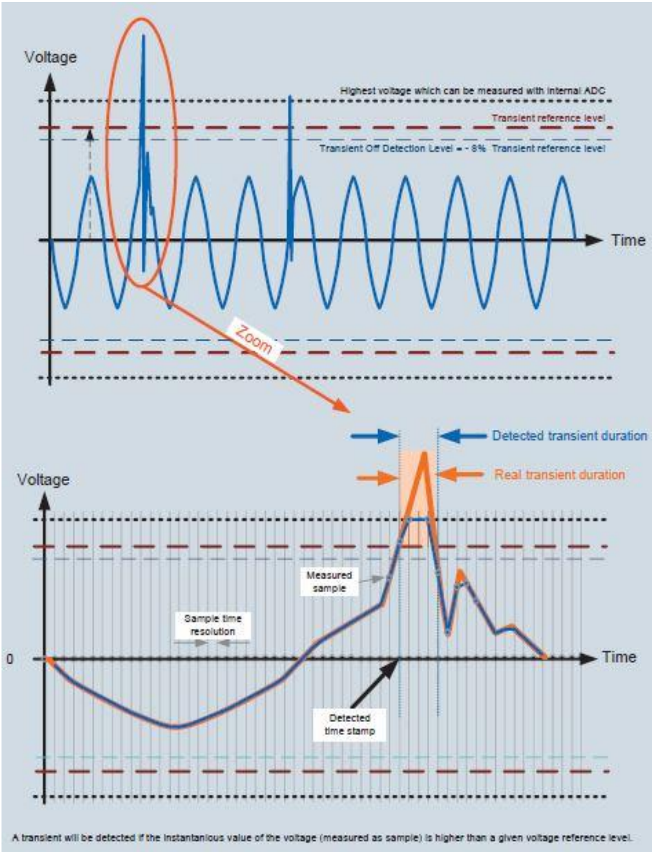

Fig. 7. Representation of measurement system concept when a transient is detected [7]

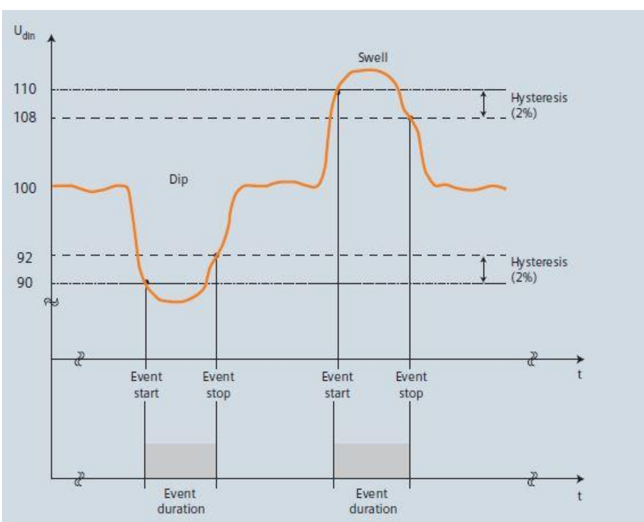

Fig. 8. Recording by the event recorder over voltages and under voltages [7]

SICAM Q100 supports two load profile recording methods: fixed block and rolling block **[7]:** The load profile data is stored in a ring buffer with up to 4000 data records. Each new data record overwrites the oldest record. Each data record contains the power demand values, min/max values, a timestamp, and the status information for a completed sub period [7].

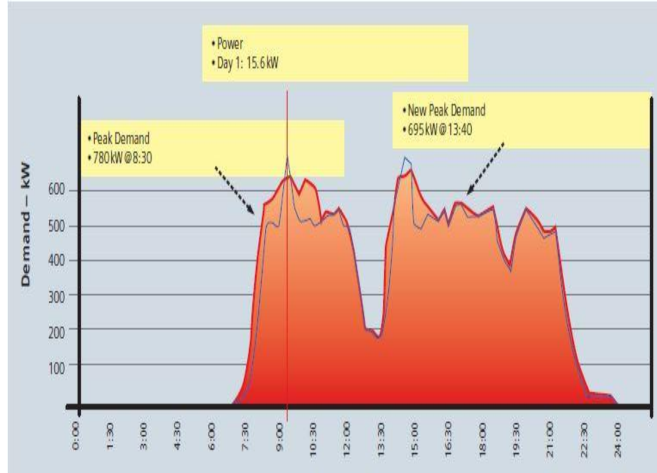

Fig. 9. Load profile [7]

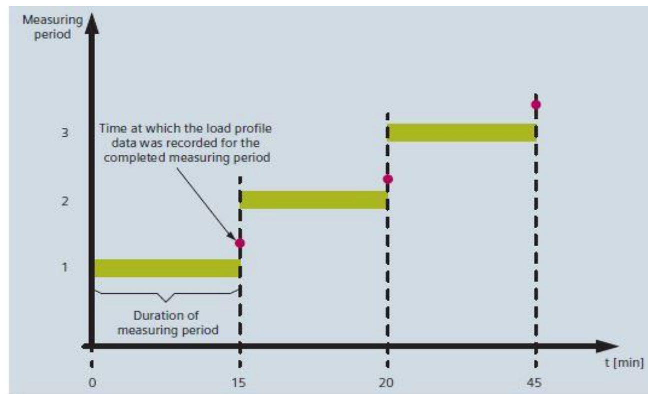

Fig. 10. Load profile recording using fixed block method [7]

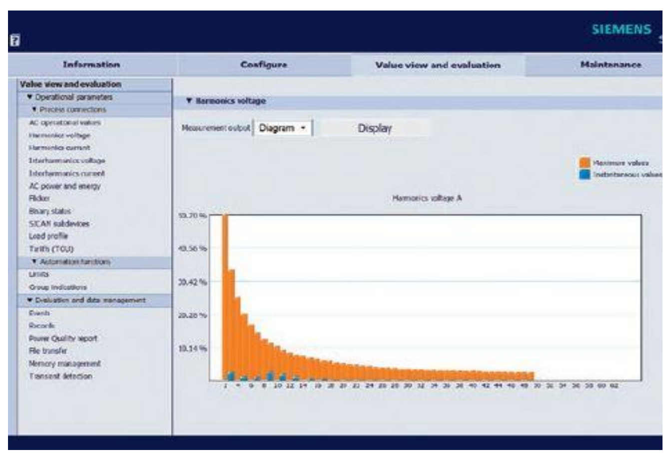

Fig. 11. HTML display of harmonics [7]

Visualization of values: Depending on which operating parameters are selected, the input/output window displays either the measured values in the corresponding unit of measure or a tabular list that is updated every 5 seconds [7].

1) Operational measured values, 2) Voltage harmonics, 3) Current harmonics, 4) Inter-harmonics, 5) Power and energy, 6) Binary outputs, 7) Limit values, 8) Group indications, 9) Flicker.

Data transmission and download: Via IEC 61850, stored data from SICAM Q100 can be transmitted from the 2-GB memory, exported, or downloaded manually via HTTP. The following data formats are supported [7]:

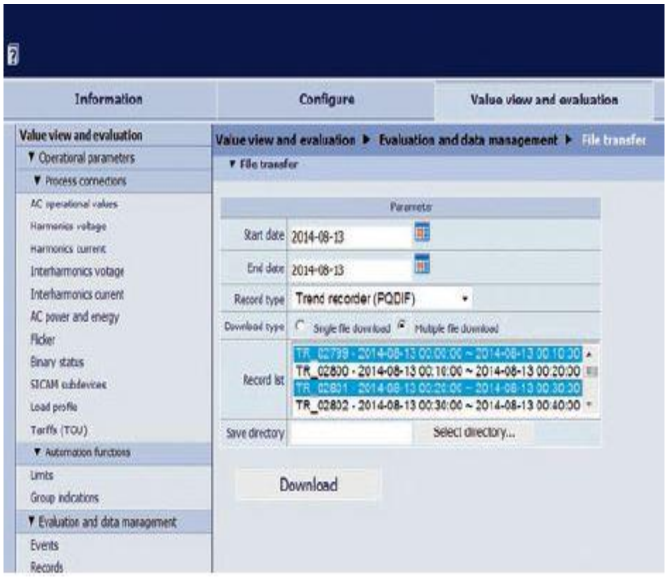

Fig. 12. Data transmission and download [7]

V. SUBSTATION DESIGN

The consumers do not use high voltage and so the same must be stepped down to low voltage. The stepping up and stepping down of voltage is one in the sub-stations. The importance of substations further increased with the development of transformers and converting plants and now a day the substations are of via importance to the operation of the above-mentioned systems [8].

Necessity of using substation:

1) To switch on and off the power lines i.e. switching operation.

2) To transform voltage from higher to lower or vice-versa i.e. voltage transformation operation.

3) To convert ac into dc or vice-versa i.e. Power converting operation.

4) To convert frequency from higher to lower or vice-versa i.e., frequency correcting operation.

5) To improve the power factor by installing synchronous condenser at receiving end of the line, i.e. power factor correction operation.

A) Indoor Substations

In these substations, the electrical equipment is installed within the building of substation [2].

11kV/0.4kV Electrical Substation of a Building: According to the rule of the distribution companies of Bangladesh, 11KV/0.4KV Electrical indoor substations shall be required for a building if the load requirement of the building exceeds 50kW. In most cases, substations are required for Multi-storied residential, Multi-storied Commercial buildings, Multi-storied Office building and Industries. To determine the rating of the substation required, a load factor of at least 80% shall be applied to the estimated load of the building. The future expansion requirements should definitely be taken into consideration.

Location of an electrical substation: In a multi-storied building, the substation shall preferably be installed on the lowest floor level, but direct access from the street for installation or removal of the equipment shall be provided. The floor level of the substation or switch room shall be above the highest flood level of the locality. Suitable arrangements should exist to prevent the entrance of storm or flood water into the substation area. The location of a substation will depend on the feed point of the 11 KV supply authority line and the location of the LT vertical riser cables.

For small to moderate power rating up to 2MW, two types of indoor transformers have been widely used recent years. These are (i) Oil Type Natural Cooled transformer and (ii) Cast Resin Dry Type Natural Cooled transformers. In most cases Oil Type Natural Cooled transformer may be used for substations if adequate space is available to accommodate the transformer. Cast Resin Dry Type Natural Cooled transformers should be used (i) in places where stringent protection against spread of fire is needed and (ii) in places where space saving is of utmost importance [2].

TABLE II
AREA REQUIRED FOR TRANSFORMER AND RECOMMENDED MINIMUM AREA FOR SUBSTATION OF DIFFERENT CAPACITIES [2]

Capacity of a Transformer (KVA)	Transformer Area (m2)	Total substation area (with HT, LT panels & Transformer Room but without Generators) (m2)
1x150	12	45
1x250	13	48
2x250	26	100
1x400	13	48
2x400	30	100
3x400	40	135
2x630	26	100
3x630	40	190
2x1000	40	180
3x1000	45	220

Choice of Oil type or Dry type transformers:

1) Dry type transformer should be installed where risk of spreading of fire is high and where flammable materials are to be kept around the substation.

2) For Hospital buildings, Multistoried Shopping Centers Dry type transformers should be used to for minimizing fire risks.

3) An industrial building, containing inflammable materials, Chemical and having the substation in the same building Dry type transformers should be used for minimizing fire risks [2].

Type of connection between a Substation Transformer and its LT panel: Connection between a Substation

Transformer and its LT panel can be established a) by using NYY underground LT Cables or b) by using ceiling suspended busbar trunking. For small size transformers, the first method should be used although there is no restriction in using the second method. However, for big substations the second method is safer and at the same time gives a neat solution [2].

B) Standby Power Supply

Provision for Standby Power Supply: Provision should be made for standby power supply, in buildings. The Standby Power Supply may be a Petrol Engine or Diesel Engine or Gas Engine Generator or an IPS or a UPS [2].

Capacity of a Standby Generating Set: The capacity of standby generating set shall be chosen on the basis of essential light load, essential air conditioning load, essential equipment loads and essential services load, essential lift (s), one or all water pumps and other loads required as essential load. Table 3 shows minimum generator room area requirements for different sizes of generators. In the case of a gas engine driven generator, the generator must be located outside the building with adequate ventilation and windows. In general, the generator room must have adequate ventilation and fans for continuous cooling. The generator shall not be placed in a basement. The generator must not be placed on any other floor other than ground floor [2]. A standby generator, if needed, is to be connected at the supply input point after the energy meter and after the main incoming switch or the main incoming circuit breaker, but through a changeover switch of appropriate rating. The rating of such a switch shall be at least 1.25 times the rating of the main incoming circuit breaker. The wiring for this purpose shall be made following the standard practices mentioned under the heading of wiring using cables of appropriate size [2]. A generator room needs some required minimum space. Table III shows the area requirements for standby generator room.

TABLE III
AREA REQUIREMENTS FOR STANDBY GENERATOR ROOM [2]

Capacity (KW)	Area (m^2)	Capacity (KW)	Area (m^2)
1x25	20	1x150	36
1x48	24	1x300	48
1x100	30	1x500	56

VI. FIRE DETECTION AND ALARM SYSTEM

This statement is noticed by the Accord on Fire and Building Safety to support factories in the implementation of fire protection measures. Fire protection is a fundamental accord goal. The accord is primarily concerned with the life safety aspects of fire protection. The keys to fire life safety are:

* Fire prevention. * Early warning of the fire. * Containment of the fire. * Safe exits.

1) Early warning of fire is achieved through automatic fire alarm systems. Fire alarms can be initiated automatically by smoke detectors or heat detectors, or manually by pull stations. The alarm then sounds by means of bells or horns in order to notify the occupants to evacuate the building.

2) Containing the fire is achieved by creating fire compartments using fire resistant walls and floors. Fire barriers are required from floor to floor in multi-stored buildings, around certain rooms within the building, and to enclose exit stairwells. Sprinkler systems serve two functions: detecting the fire for immediate evacuation; and containing the fire at its source.

3) Safe and efficient exiting is accomplished by providing necessary exits (at least two) and ensuring that the exits remain free of smoke and fire by requiring fire barriers around the exit stairs. Locks are not permitted on exits [9].

A) Fire Detection and Alarm System inside a Building

The major parts of a Fire Detection and Alarm System inside a Building may be listed as [2]:

A number of different types of Fire Detectors/ detection devices wired in a number of radial circuits.

Manual Call points: A central control panel for Fire Detection A number of alarm sounders/alarm devices wired in a number of radial circuits Cables for wiring the Fire Detectors/ detection devices Cables for wiring the alarm sounders/alarm devices.

Control Panel: The control panel will indicate in which detection circuit (zone) an alarm or fault condition has been generated and will operate common or zonal sounders and auxiliary commands (for example door release or Fire Brigade signaling) [2].

Detectors: A number of types of Detectors (smoke detectors, heat detectors, ionization smoke detectors, Optical beam smoke detectors, Opto-heat detectors) For the installation [2].

Alarm Devices: Alarm devices fall into two types, audible and visual. The audible types are most common, with a variety of types being available from bells to all kinds of different electronic sounders including those containing pre-recorded spoken messages. Finally, visual alarms are to be used where the hard of hearing may be occupying a building or where the ambient noise is such (above 90dBA) that audible warning may not be heard, where hearing protectors are in use or where the sounder levels would need to be so high that they might impair the hearing of the building occupant [2].

Double Input/ Output Module: With a microprocessor, AI-511 Addressable Dual I/O Module can communicate with FACP, monitor power supply, and judge the logic state of input signal, control output and state indicators [12].

Pull Station: Connecting to the loop of SHIELD fire alarm system, BG-I450F Digital Manual Call Point (the MCP) is suitable for public places. When there is fire, pressing the action plate on the MCP can send the alarm signal to fire alarm control panel. After receiving the signal, the control panel will show address information of the MCP and generate alarm sound. Electronically addressed: the address can be modified in field. Alarming by pressing: can be reset by a special key, plug-in structure, designed to comply with EN 54-11 [13].

Water Sprinkler: It is used to spray the water according the response of the sensor.

Fire Extinguishers: There are three types of fire extinguishers available in Bangladesh are:

Water and Foam: Water and Foam fire extinguishers extinguish the fire by taking away the heat element of the fire triangle [21].

Carbon Dioxide: Carbon Dioxide fire extinguishers extinguish fire by taking away the oxygen element of the fire triangle and also are removing the heat with a very cold discharge [21].

Fig. 13. Intelligent Eight Loop Control Panel [10]

Fig. 14. Combined Heat & Smoke Detector [11]

Fig. 15. Water Sprinkler [20]

Fig. 16. Double Inputs/ Output Module [12]

Fig. 17. Fire Extinguishers [21]

Fig. 18. Pull Station [13]

VII. ELECTRICAL DESIGN AND INSTALLATION OF EQUIPMENT WITH PROPOSED MODERN APPLIANCES

High rise building is a building above four stories, and/or a building exceeding 15 meters or more in height above the average level of front road [18]. This work has been done taking a 10-storied building with ground floor as a sample model of high rise building. The substation of this building is an indoor type substation 11kV/0.4kV. There is also an individual generator room. In this building, lots of modern electrical equipment has been installed. This research work offers BBT system from ground floor to top floor instead of wire and for wiring inside each floors and flats traditional wiring system according to the Bangladesh National Building Code 2014 has been used. This research work has also offered fault analysis for observing any fault in the installed connection.

To start an electrical design and installation of a high rise building it's required to get its architectural design. After getting the architectural design it's easy to draw electrical design and necessary electrical equipment. By electrical design it is easy to show the entire electrical condition like load of the building, transformer and generator ratings, ratings of busbar trunking system, MCB and MCCB, ratings of different wires, several MDB, SDB and SB.

A) Block diagram of this project

In this block diagram have to shows every part and electrical system.

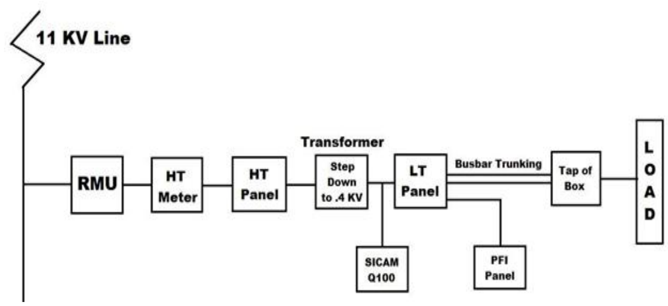

Fig. 19. Block diagram of electrical system

Load calculation: To calculate the load of any section (no. of flats, no. of floors for flat and ground floor, stairway & corridor, lift or elevator and water pump) of the building it is necessary to review the electrical drawing. Total load and load for each section can be calculated by the following relation [14]:

* Total power rating (watt) of individual load = quantity x per load in watt

(i.e. 5 pieces 56" ceiling fans' total power rating = 5 x 80W = 400W)

* Total power rating of each section = ∑ of total power rating (watt) of individual loads

* Total current rating of each section = Total power rating of each section / supplied voltage (single phase or three phase voltage rating)

* Total current/power rating of each floor = ∑ of total current/power rating of each section

* Total current/power rating of the building = ∑ of total current/power rating of each floor

Protection by following MCB or MCCB: All the MCB and

MCCB are chosen according to proper calculation of circuit and following standard ratings. All electrical section (each room, each ac, each flat, ground floor, lift or elevator, water pump, transformer, generator) are protected by MCB. Total building has the MCCB for establishing a master protection. MCB and MCCB can be set according the connection and phase of load. There are three types of MCB and MCCB can be found available: single phase (SP), double phase (DP), and three phase (TP). The total number of circuit can be identified from the AutoCAD design of electrical plan.

* 40A/32A MCB (TP) is used for each flat
* 10A/16A/20A MCB (SP/DP) is used inside flat according the load current capacity.

All these arrangements of MCB and MCCB are fixed inside a sub distribution board of flats and floors [19].

B) Substation

***Selection of Transformer*:** For the purpose of transformer selection, at first it is required to calculate the total current (Amp) from the total load (kW). The formula of calculating total current in A.C. 3-phase is:

$$A = \frac{1000xkW}{\sqrt{3}xVxp.f.} \qquad (1)$$

i.e., Total load of a high-rise building = 334004 Watt with the power factor 0.8 then total current rating is,

$$A = \frac{1000x334.004kW}{\sqrt{3}x415Vx0.8} = 581.52 \text{ Amp}$$

Then from this calculated ampere the KVA rating of the Transformer of the substation is calculated. The formula of calculating in KVA is

$$KVA = \frac{\sqrt{3}xVxA}{1000} \qquad (2)$$

$$KVA = \frac{\sqrt{3}x415Vx581.52A}{1000} = 418$$

So according to this calculation it is ideal to choose a 3-Phase 450 KVA Transformer.

C) Selection of Generator

***Load Calculation for Generator*:** A backup generator can be used for supporting full load or few of them (some ceiling fan and light of each flat, lift or elevator, ground floor, Stairway and Corridor, water pump) in emergency situation.

i.e., Total load (Generator) required for full building = 20444W = 20.444kW

and total current required for Generator =35.55A

Generator capacity required for this building:

$$KVA = \frac{\sqrt{3}X\,415V\,X\,35.55\,A}{1000} = 25.55 \text{ KVA}$$

So, a 3 phase, 30KVA diesel stand by Generator can be used for this building.

D) Power factor improvement panel

Calculation reactive power of the capacitor bank and improve power factor

***Dimensioning of the capacitor bank*:** For the dimensioning of the capacitor bank to be installed in order to improve the power factor of a plant, it is necessary to calculate correctly the power factor according to the consumption or to the load cycle of the plant. This in order to avoid the intake of excess reactive energy, which is a condition normally forbidden by power supply authorities. To carry out distributed or group power factor correction, it is necessary to calculate the cosϕ of the single load or of the group of loads (factory areas) [15].

This can be carried out as follows:

1) Directly-through direct measuring by means of a power factor meter, 2) Indirectly-through the reading of the active and reactive energy meters.

The power factor meter is a measuring instrument able to display the power factor cosϕ according to which the load is absorbing energy. The reading of the instrument shall be carried out in different moments of the load cycle, so that an average power factor value can be obtained, if the readings of the active and reactive energy absorbed by the load or by the whole of the loads constituting the factory areas during a work cycle are available, the average power factor can be calculated as follows:

$$\cos\varphi = \cos(tg^{-1}\,(E_{Qf}\text{- } E_{Qi}/\ E_{Pf} \text{ - } E_{Pi}\ )) \qquad (3)$$

Where, E_{Pi}, and E_{Qi} are the values of active and reactive energy read at the beginning of the work cycle.

E_{Pf} and E_{Qf} are the values of active and reactive energy read at the end of the work cycle.

Calculation of the necessary reactive power: Once the power factor (cosφ1) of the installation and the power factor to be obtained (cosφ 2) are known, it is possible to calculate the reactive power of the capacitor bank necessary to improve the power factor. Indicating by:

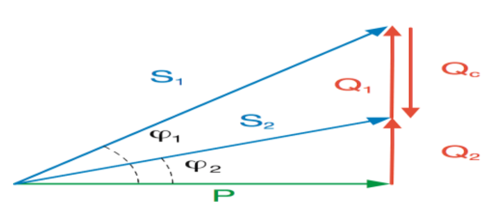

Fig. 20. Relation among three powers

P-the installed active power

Φ1- the phase displacement angle before power factor correction

Φ 2 - the phase displacement angle to be obtained with the power factor correction the power of the capacitor bank Q_c is:

$$Q_c = (tg\varphi_1 - tg\varphi_2) \cdot P = K \cdot P \qquad (4)$$

Once the initial COSΦ is known, power factor correction table allows to calculate (in kvar per kW installed) the power of the capacitor bank necessary to obtain a defined power factor. In a three-phase system the capacitor bank constituted by three capacitors having the same capacitance, can be delta connected or star connected. When selecting the connection modality, it is necessary to keep into account that with delta-connection, each capacitance is subject to the Supply line-to-line Voltage, but, at the same level of generated reactive power, it has a value equal to 1/3 of the value it will have in case of star-connection:

$$Q_{cY} = Q_{c\Delta} \longrightarrow C_Y = 3 \cdot C_\Delta \qquad (5)$$

$$Q_{CY} = 3 \cdot \omega \cdot C_Y \cdot (U_n / \sqrt{3})^2 = \omega \cdot C_Y \cdot U_n^2 = Q_{C\Delta} = 3 \cdot \omega\, C_\Delta \cdot U_n^2 \longrightarrow C_Y = 3 \cdot C_\Delta \qquad (6)$$

In the low voltage field, where insulation problems are less important, the delta connection is usually preferred for the capacitor bank, since it allows a smaller sizing of the capacitances of each phase [15].

Factor K (kvar/kW)

	final cosφ												
initial cosφ	0.80	0.85	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1
0.60	0.583	0.714	0.849	0.878	0.907	0.938	0.970	1.005	1.042	1.083	1.130	1.191	1.333
0.61	0.549	0.679	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.157	1.299
0.62	0.515	0.646	0.781	0.810	0.839	0.870	0.903	0.937	0.974	1.01 5	1.062	1.123	1.265
0.63	0.483	0.613	0.748	0.777	0.807	0.837	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.451	0.581	0.716	0.745	0.775	0.805	0.838	0.872	0.909	0.950	0.998	1.058	1.201
0.65	0.419	0.549	0.685	0.714	0.743	0.774	0.806	0.840	0.877	0.919	0.966	1.027	1.169
0.66	0.388	0.519	0.654	0.683	0.712	0.743	0.775	0.810	0.847	0.888	0.935	0.996	1.138
0.67	0.358	0.488	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.966	1.108
0.68	0.328	0.459	0.594	0.623	0.652	0.683	0.715	0.750	0.787	0.828	0.875	0.936	1.078
0.69	0.299	0.429	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.907	1.049
0.70	0.270	0.400	0.536	0.565	0.594	0.625	0.657	0.692	0.729	0.770	0.817	0.878	1.020
0.71	0.242	0.372	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.214	0.344	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.186	0.316	0.452	0.481	0.510	0.541	0.573	0.608	0.645	0.686	0.733	0.794	0.936
0.74	0.159	0.289	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.132	0.262	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.105	0.235	0.371	0.400	0.429	0.460	0.492	0.526	0.563	0.605	0.652	0.713	0.855
0.77	0.079	0.209	0.344	0.373	0.403	0.433	0.466	0.500	0.537	0.578	0.626	0.686	0.829
0.78	0.052	0.183	0.318	0.347	0.376	0.407	0.439	0.474	0.511	0.552	0.599	0.660	0.802
0.79	0.026	0.156	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.634	0.776
0.80		0.130	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.608	0.750
0.81		0.104	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82		0.078	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.556	0.698
0.83		0.052	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.530	0.672
0.84		0.026	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85			0.135	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86			0.109	0.138	0.167	0.198	0.230	0.265	0.302	0.343	0.390	0.451	0.593
0.87			0.082	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88			0.055	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89			0.028	0.057	0.086	0.117	0.149	0.184	0.221	0.262	0.309	0.370	0.512
0.90				0.029	0.058	0.089	0.121	0.156	0.193	0.234	0.281	0.342	0.484

Fig. 21. Data table of factor K (kvar/kW) [15]

***Calculation of capacitor bank*:** In a plant with active power equal to 334.004 kW at 415 V and cosφ= 0.80, and we want to increase the power factor up to 1**.** In the table 1 above, at the intersection between the row "initial cosφ" 0.80 with the column "final cosφ" 1, a value of 0.750 for the coefficient K is obtained

Therefore, a capacitor bank is necessary with power Q_c equal to:

$Q_c = K \cdot P = 0.750 \text{ x } 334.004 = 250.5$Kvar.

E) Selection of wires

Supply line entering substation: For connecting the DPDC supply line 11kV to the building's substation 2xSEYFGY, 6/10(12) kV, IEC 60502-2 cable is used. This cable is suitable for indoors, outdoors, underground and in water for continuous permissible service voltage of 6.35/11kV. 90^0C [16], [17].

From Tap Off box to SDB: From tap off box to SDB the BYA cable is used (Fig. 24). This wire is suitable for surface mounted or concealed steel conducts or trunking.

From SDB to SB and loads: Here we have used BYA 450/750V single core cable (Fig. 24). This cable suitable for use in surface mounted or embedded conduits or trunking. Also, suitable for field protected installation in lighting fittings and inside appliances up to 1000 V (ac) or up to 750 V to earth (dc).

From CT to voltage sensing DB and other part: From CT to voltage sensing DB the NYY cable is used (Fig. 25). This wire is suitable for surface mounted or concealed steel conducts or trunking.

Fig. 22. 2xSEYFGY, 6/10(12) kV, IEC 60502-2 cable

Fig. 23. BYA 450/750V single core cable

Fig. 24. NYY 600/1000V, VDE-0271/3.69m, single core cable

Selection of Busbar Trunking System: From L.T panel of transformer secondary side to FDB for each floor. We have used bus bar trunking from the secondary side of the transformer to the bus bar tap off box situated in each floor. For this purpose, Al 630A, 415V, 50 Hz, 3p+N+PE, BBT System has been used.

E) Equipment list at a glance for the experimented designed high-rise building

TABLE IV
A SAMPLE LIST OF EQUIPMENT OF HIGH RISE BUILDING ACCORDING SAMPLE CALCULATIVE RATING

1	Wire	BYA 450/750Vsingle core cable, NYY 600/1000V single core cable, 2xSEYFGY 6/10(12) kV cable
2	Busbar	Al 630A,415V, 50Hz, 3p+M+PE
3	Fault Analysis Device	SICAM Q100
4	Transformer	3Phase 450KVA Transformer
5	Generator	30KVA Diesel Generator 3Phase 415V
6	Fire Alarm System	Intelligent Eight Loop Control Panel Combined Heat & Smoke Detector, Standard Detector Base, Intelligent Sounder Strobe, Double Inputs/ Output Module, Pull Station, Water Sprinkler, Fire Extinguishers.
7	MCB	MCB-SP 10A,16A, 20A,32A, MCB-TP 20A, 40A, 6A
8	MCCB	MCCB-TP 650A, 350A, 600A, 63A

VIII. CONCLUSION

Without a professional AutoCAD drawing it is not possible to proceed with the construction of the building and installation of electrical equipment. A professional AutoCAD drawing gives proper ideas about proper location, size and structure of both electrical and architectural site of a high-rise Building or any constructional work. For using BBT system it is required to know ratings, installation procedure, conductor types and all about its sites. The installation cost of BBT system is a little higher than wiring system but in the long run BBT system is more cost effective. A new device (SICAM Q100) has been introduced for fault analysis and continuous monitoring of fault which will help to reduce and avoid faults in the system. This device is the most updated and latest technology that can be used for this purpose. Circuit breakers of proper ratings are installed to ensure safety issue of the building. The substation has been designed by using proper calculated rating and by following standard codes. Fire detectors and alarm systems are installed to ensure avoiding fire hazard.

This entire research has been completed by following and maintaining Bangladesh National Building Code.

The manual system of controlling the building load (light, fan) is still available. But in future the automation process can be used widely controlling the building load in a high-rise building. Then the calculation and installment of P.L.C will be considered in the electrical design of high rise building. This research contains selection, connection and fittings of different ratings of wires for different purposes. This research proposes best equipment (wire, circuit breaker, transformer, generator, BBT, fault analysis device, fire detection and alarm system) for highest efficiency and safety of any high-rise building.

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