Cable selection and wiring system
By M. Sasikumar - 9840904848

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AND EHS SOLUTIONS
AN ISO 9001:2008 CERTIFIED CONSULTING ORGANISATION
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Mitsui Sumitomo Insurance Group, Japan is one of the largest insurance groups in the world & biggest in Asia, carrying out overseas business through
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Our expertise blends with clients’ technical requirements, resulting in a spectrum of services across the lifecycle of a project from the conceptualizing stage till decommissioning.

We Partner with clients to manage the Risk Profitably
Cable selection and wiring system

CHANGING ECONOMIC SCENARIO & RISING FATALITIES AND FIRE
Increase in Load?

The market for white goods* and televisions has been growing, but remains underpenetrated.

![Graph showing Indian market size (INR billion) with CAGR rates](chart)

*White goods refer to large household appliances such as washing machines, refrigerators, and air conditioners.

Source: JP Morgan, TechNavio, Spark Capital estimates, EY analysis

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Market Penetration - India vs. Global Average

![Bar chart comparing market penetration](chart)

Source: JP Morgan estimates, EY analysis
India looses about

- 7960 lives annually due to electrocution
- 2315 lives annually due to lightning
- 1290 fire incidents reported annually due to electrical
- 4563 animals lives annually due to electrocution
- Around 3031 non fatal electrical incidents reported annually

Importance of Cable selection and Wiring system
Trends in fires in the Major cities (2012-2016)

- **Number of fire incidents/Year**
- **Population**
- **Average fire deaths/year**

CTIF: International Technical Committee for the Prevention and Extinction of Fire
India loses about 25,000 lives annually to fire...

Deaths Caused by Fire (No. of Lives per 100,000 population)

Fire related deaths in Key Nations (2010)

India faces one of the highest rate of deaths due to fires in the world.

Russia sees significantly high deaths predominantly due to large wild fires.

India's topping the list in fire related deaths is owing to a combination of high population, and higher incidence. Countries like China and Brazil could be benchmarks for India to reduce the incidence.

European nations are "top of the range" benchmarks for reducing incidents.

Despite a population higher than India, China loses fewer lives to fire.

Loss of life due to Electrical and fire

Source data: NCRB reports (2001-2015)
HAZARDS OF ELECTRICITY
Electrical Hazards

Be safe with electricity

- Burns
- Electrocution
- Shock
- Fire
- Explosion
- Associated hazard (secondary)
KEY REASONS
Various causes for electrical fires

- Skilled manpower
- Overload & Short circuit
- Insulation failures
- Loosen conductors
- Inferior grade materials
- Poor designs & code violations
- Passive fire protection
- Electrical heat
- Maintenance
- Old installations
Electrical safety  Core issues

Old Installations
- Addition of loads - Modification
- Degradation of insulation & Components - Ageing
- Poor maintenance practices
- Technology upgradation
- Obsolescence of components

Workmanship
- High attrition due to globalization
- Training & Skill level
- Multi skill level – Non competence person
- Outsourcing
- Maintenance Man power Vs Cost reduction

Design Issues
- Code violations
- Competent designer
- Adequate sizing
- Selection of reputed make
- Cost reduction
- Coordination among various Departments
- Active & Passive fire systems
- Protective device coordination

Maintenance issues
- Work force Availability
- Outage based maintenance practices
- People skill level
- Predictive maintenance (Thermographic survey)
- Obsolescence of components

Based on CMSRS 600 building projects
You upgrade Your

- Gadgets
- Home appliances
- Office communication systems
- Security systems
- Office fitouts
- Lifts
- Fire systems

Around 40% Indians want to change mobile phones within a year: Study

Around 40% people want to change their mobile phones within a year of purchase and almost that many Indian consumers are open to buying refurbished smartphones, according to a study.

Average Indian customer will upgrade to bigger cars: Hyundai India MD Young Key Koo

Energy efficient equipments- LED’s & motion sensor’s
Have you changed your AC unit?
Have you reviewed your Cable and MCB rating?
Review on cable sizing?

Changed to LED lights?
SPECIAL WIRING REQUIREMENTS
Circuit Categories

1. Mains supply - Normal loads
2. Supply from safety sources - Telecommunication, access system, speaker
3. Critical systems - Emergency lighting, Fire network

IS 732 – 8.5.1.1
Circuit Categories?

Cat 3 - circuit shall not be mixed with any other category in conduits, ducts, multi core cables ...

Cat 1 and cat 2 circuits shall not be drawn in same conduits unless Cat 2 circuit insulated with highest voltage of cat 1 circuit

Shall not be mixed together

To prevent damage to critical systems – Fire alarm & emergency circuits

To avoid accidental charging of safe voltage to higher voltage level
How are your emergency lighting wires routed?

- Through same conduit?
- Through separate conduit?
SPECIAL WIRING REQUIREMENTS

• Emergency Lighting circuits
  - Inherently high resistance to attack of fire (FR rated wires)
  - Segregation from other circuits
  - Adequate mechanical strength

• Fire Alarm and Detection
  - Inherently high resistance to attack of fire (FR rated wires)
  - Segregation from other circuits
  - Adequate mechanical strength

• Normal lighting & Power circuits
  - FRLS preferred instead of PVC
  - Segregation of very low, communication and low voltage cables
SAFETY PROVISIONS OF ELECTRIC VEHICLE CHARGING STATIONS

Charging socket outlet shall be 800 mm above the ground level and charging cable shall be maximum of 5m

Normal Portable sockets are not permitted to be used for vehicle charging

Charging cable shall not be energized when cable is unplugged from the vehicle & cable shall be unlocked only below 60 V

Protection against overload, reverse power flow, RCCB with 30 mA and earth continuity monitoring system, should be provided for input and output of charging station
SAFETY PROVISIONS OF ELECTRIC VEHICLE CHARGING STATIONS

1. Enclosure shall be made of fire retardant material.
2. Fire detection and alarm system required.
3. Cable shall be fire retardant.
4. Fire retardant material shall be halogen free and it shall be self extinguishing.

CEA 2019
Generating units producing electricity from renewable sources will be required to be inspected by the electrical inspector before commissioning. Capacity which need to be inspected will be issued by appropriate government (500 KW) – CEA 2018
## General safety requirements

- **Proper Segregation** and clearance to be provided between positive and negative components including wiring, terminal boxes, etc. inside the combiner box and **shrouds shall be provided and terminals** to be identified by marking.

- **Transparent acrylic sheets** shall be provided between the positive and negative terminals and terminal points shall be covered with insulating materials as well to prevent any accidental contact after opening the box.

- Clear pathways of **minimum 75 cm in width for roof access** and emergency exit shall be provided for roof top system.

- Disconnection switches or circuit breakers provided to disconnect the PV system from all other conductors of the system shall be located at a readily accessible location and shall be manually operable.
Earthing for AC and DC system shall be interconnected at pit level so as to have equipotential system.

The frame of inverter cabinet shall be connected with the earthing bus bar through the earthing terminals using flexible braided copper wire.

Protective earthing shall be provided inside the inverter cabinet.

The inverter shall be provided with earthing on DC input side and Ground fault detector interruption.

IS 17293 – Solar DC cabling
# SOLAR POWER – PROTECTION REQUIREMENTS

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type-1 Surge Protective Device with arc extinguishing capability</td>
<td></td>
</tr>
<tr>
<td>The input circuits of combiner box shall be provided with over current protection as per IEC60269</td>
<td></td>
</tr>
<tr>
<td>The output circuits of combiner box shall be provided with isolation protection</td>
<td></td>
</tr>
<tr>
<td>All installations shall be IP 65 and above rated</td>
<td></td>
</tr>
<tr>
<td>Earth fault protection for PV array and inverter shall be provided.</td>
<td></td>
</tr>
<tr>
<td>The inverter shall be provided with at least fuse with disconnecting switch at DC input side and circuit breaker with emergency stop switch at the AC output</td>
<td></td>
</tr>
</tbody>
</table>
Cables & Wiring
Choose the right size wire for the amount of current expected in a circuit.

The wire must be able to handle the current safely.

The wire’s insulation must be appropriate for the voltage and tough enough for the environment.

Connections need to be reliable and protected.

Sizing of cables & wires

- Voltage drop over the length of the cable
- Permissible maximum temperature it shall withstand
- Current to be carried
- Method of laying cable
- The prospective short-circuit current to which the cable may be subjected
- The characteristics of the overload
- Load cycle, load cycle
- Thermal resistivity of soil
- The operating voltage

NBC Part-8 Clause-5.3.3.1

Choose the right size wire for the amount of current expected in a circuit.

The wire must be able to handle the current safely.

The wire’s insulation must be appropriate for the voltage and tough enough for the environment.

Connections need to be reliable and protected.
A variety of materials can be used in wiring applications.

The choice of wiring material depends on the wiring environment and the need to support and protect wires.

Loose or oxidized connections can create heat or arcing. Special clamps and terminals are necessary to make proper connections using aluminum wire. Antioxidant paste can be applied to connections to prevent oxidation.

Aluminum Cable and connections should be handled with special care. Connections made with aluminum wire can loosen due to heat expansion and oxidize if they are not made properly.
Aluminium conductor cables - sizes less than 16 mm² cause termination problems leading to heating at the terminals and enhance the possibility of a fire.

Conductor sizes less than or equal to 16 mm², only copper conductor cables should be used.
## Cables Insulation Types

<table>
<thead>
<tr>
<th>For the mains cable</th>
<th>Tough plastic sheathed (TPS) cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>For installation wiring</td>
<td>Tough plastic sheathed (TPS) cables</td>
</tr>
<tr>
<td>For main earth or main equipotential wire</td>
<td>Poly vinyl chloride (PVC) insulated conduit wire</td>
</tr>
<tr>
<td>Underground installation and installation in cable trench,</td>
<td>PVC insulated, PVC sheathed armored cables or XLPE insulated, PVC sheathed cables armoured cables</td>
</tr>
<tr>
<td>feeders between buildings, etc</td>
<td>PVC insulated, PVC sheathed or XLPE insulated, PVC sheathed</td>
</tr>
<tr>
<td>Installation in plant rooms, switch rooms etc, on cable tray</td>
<td>PVC sheathed unarmoured cables</td>
</tr>
<tr>
<td>or ladder or protected trench, where risk of mechanical damage to cable does not exist.</td>
<td></td>
</tr>
</tbody>
</table>
Cables Insulation Types

Only the given types of wires should be used as per applicability and requirement.

- Fire Retardant (FR)
- Heat Resistant Fire Retardant (HRFR), HR-PVC
- Halogen Free Flame Retardant (HFFR)
- Cross linked polyethylene (XLPE)
Separate dedicated and fire compartmented shaft should be provided for carrying such high voltage cables to upper floors in a building.

Suitable fire detection and suppression measures shall be provided throughout the length of the cable on each floor.
- It is desirable to use flame retardant cables and wires in electrical distribution systems.
- It is recommended to use 4 core cable in place of 3.5 core to minimize heating of neutral core due to harmonic content and to avoid overload failure.
- In final circuits where cable size of 16 mm$^2$ and below are used, these shall be 4 core cables.
Conductors

- The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area not less than 1.50 mm$^2$ copper.

- The cross-sectional area of conductor for power wiring shall be not less than 2.5 mm$^2$ copper.

- The minimum cross-sectional area of conductor of flexible cord shall be 1.50 mm$^2$ copper.
### 5.8 Installation Circuits

5.8.1 The nominal cross-sectional area of copper phase conductors in a.c. circuits and of live conductors in d.c. circuits shall be not less than the values specified below:

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Circuit</th>
<th>Minimum Copper Wire size</th>
<th>Number of Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>i)</td>
<td>Lighting</td>
<td>1.5 mm²</td>
<td>2 or more</td>
</tr>
<tr>
<td>ii)</td>
<td>Socket-outlets, 6 A</td>
<td>2.5 mm²</td>
<td>Any number</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Areas such as</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>kitchens and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>laundries 3 x</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>double socket-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>outlets per circuit.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other areas up to 12 double socket-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>outlets</td>
</tr>
<tr>
<td>iii)</td>
<td>Signaling and control circuits</td>
<td>0.5 mm²</td>
<td>(see Note 1)</td>
</tr>
<tr>
<td>iv)</td>
<td>Socket-outlets, 16 A</td>
<td>2.5 mm²</td>
<td>1</td>
</tr>
<tr>
<td>v)</td>
<td>Water heater &lt; 3 kW</td>
<td>2.5 mm²</td>
<td>1</td>
</tr>
<tr>
<td>vi)</td>
<td>Heaters or electric equipment more than or equal to 3 kW</td>
<td>4.0 mm²</td>
<td>1</td>
</tr>
<tr>
<td>vii)</td>
<td>Free standing electric range Separate oven and/or cook top</td>
<td>4.0 mm²</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTES** — In multi-core flexible cables containing 7 or more cores and in signalling control circuits intended for electronic equipment, a minimum nominal cross-sectional area of 0.1 mm² is permitted.
## Circuit wire sizes

**NBC Part-8 Clause-5.8.5.2**

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Circuits</th>
<th>Minimum Wire Size</th>
<th>Wire Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>vii)</td>
<td>Cooking hobs</td>
<td>2 + E cable</td>
<td>Red-Black-Green or Green/Yellow</td>
</tr>
<tr>
<td>viii)</td>
<td>Separate ovens</td>
<td>1.5 mm²</td>
<td>Green/Yellow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 + E cable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 mm² (stranded conductors)</td>
<td></td>
</tr>
<tr>
<td>ix)</td>
<td>Electric range</td>
<td>2 + E cable</td>
<td>Red-Black-Green or Green/Yellow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 mm² (stranded conductors)</td>
<td>Green/Yellow</td>
</tr>
<tr>
<td>x)</td>
<td>Mains</td>
<td>2 wire cable</td>
<td>Red-Black</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 mm² (stranded conductors)</td>
<td></td>
</tr>
<tr>
<td>xi)</td>
<td>Main equipotential bonding wire</td>
<td>Conduit wire</td>
<td>Green or Green/Yellow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 mm² (stranded conductors)</td>
<td></td>
</tr>
<tr>
<td>x.ii)</td>
<td>Main earth wire</td>
<td>Conduit wire</td>
<td>Green or Green/Yellow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 mm² (stranded conductors)</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
1. 2 + E is also known as twin and earth.
2. Earth wire can be as per the following:
   - a) Green/Yellow throughout their length with, in addition, light blue markings at the terminations; or
   - b) Light blue throughout their length with, in addition, green/yellow markings at the terminations.
3. The above sizes are recommendatory and shall be modified as per voltage drop, starting current, distance from DB, etc.
NEUTRAL CONDUCTORS

IR IMAGE SHOWS HIGHER TEMPERATURE IN NEUTRAL CONDUCTOR

Neutral conductor size = Phase conductor for lighting circuits
Balancing of three phase loads before hand NEC-part 9-5.2.3.6
Harmonic filters twice the conductor size for high harmonic loads like data centres
Power factor improvement

Higher temperature in neutral conductor
Most probable reason for fire in buildings

In adequate conductor size
In equal loading
 Significant harmonic currents

Power Factor

NEC 2011 Part 1 - Section 9 – 4.10
IS 732 – 8.2.3
Over Load and short circuit protection

- Over current and short circuit protection devices shall be placed at a point where there is a reduction of current carrying capacity of the conductors of installation.
- Provided until there is no branch circuits or outlets.
- Short circuit protective device may be placed at a point where there is reduction in current carrying capacity and the protective device shall not exceed three meter in length.

IS 732 – 5.3.3.2-a

Where is your Protective device for you AC unit is placed?
When HV cable is hanging/running below the basement ceiling slab, the cable shall be laid in a fire rated enclosure/ cable tray.

**NBC Part-8 Clause-5.3.3.2**
Distribution of Supply
Use of busbar trunking system is ideal for high load density in modern large buildings and high rise buildings demands compact and safe.

Busbar trunking can be installed in vertical risers shafts or horizontally in passages for transmission and distribution of power.
Compact and sandwich type Bus system
FIRE SPREAD
Wiring and Cabling shall have flame retardant property.

MV and LV wiring running in shafts and false ceiling shall run in metal conduits.

230V wiring for lighting and other services in false ceiling shall have 660V grade insulation.

HV, MV & LV wire running in shafts and in false ceiling shall run in separate shafts.
Electrical distribution cables/wiring shall be laid in separate shaft.

Shaft shall be sealed at every floor by fire stop materials.

Water mains, gas pipes, telecom lines, intercom lines or any other service line shall not be laid in duct for electrical cable.

All metallic items shall be bonded to the earthing system.

NBC Part-4 Clause-3.4.6
RISK OF SPREAD OF FIRE

• Wiring system passes through walls, roofs, the openings remaining after the passage shall be sealed with fire resistant material.

• Cable terminations shall be coated up to length of 1m and up to a length of 1m in cross over points.

NEC 2011 Part 1 - Section 9 – 4.12.1
SAFETY BY DESIGN
SHOCK PROTECTION
MITIGATION MEASURES - SHOCK
SAFE GUARD AGAINST DIRECT CONTACT WITH LIVE ELECTRICAL PARTS

Restrict access or contact by Enclosure/ Guarding/ Barrier/Out of reach condition

Provide interlock. On opening the door the circuit should trip
Mitigation Measures for Shock and Electrocution

Shock Protective Devices – RCCB/RCD/RCBO

RCCB (Residual Current Circuit Breaker)
RCD (Residual-current device)
RCBO (Residual Current Circuit Breaker with Over Current Protection)
Mitigation Measures for Shock and Electrocution

**Shock Protective Devices – RCCB/RCD/RCBO**

1. RCCB with 30 mA sensitivity to be provided for all sockets, portable tool & Welding machines
2. RCCB with 100 mA sensitivity for all lighting circuits
3. RCCB with 300 mA sensitivity for all outdoor circuits which are prone to moisture ingress
4. Manual testing once in a month and electrical testing once in three months recommended
5. 30 mA RCCB should trip within 40 m Sec when 150 mA current injected for testing
Electric fire protection - Thermography
MAKE SHIFT ARRANGEMENTS