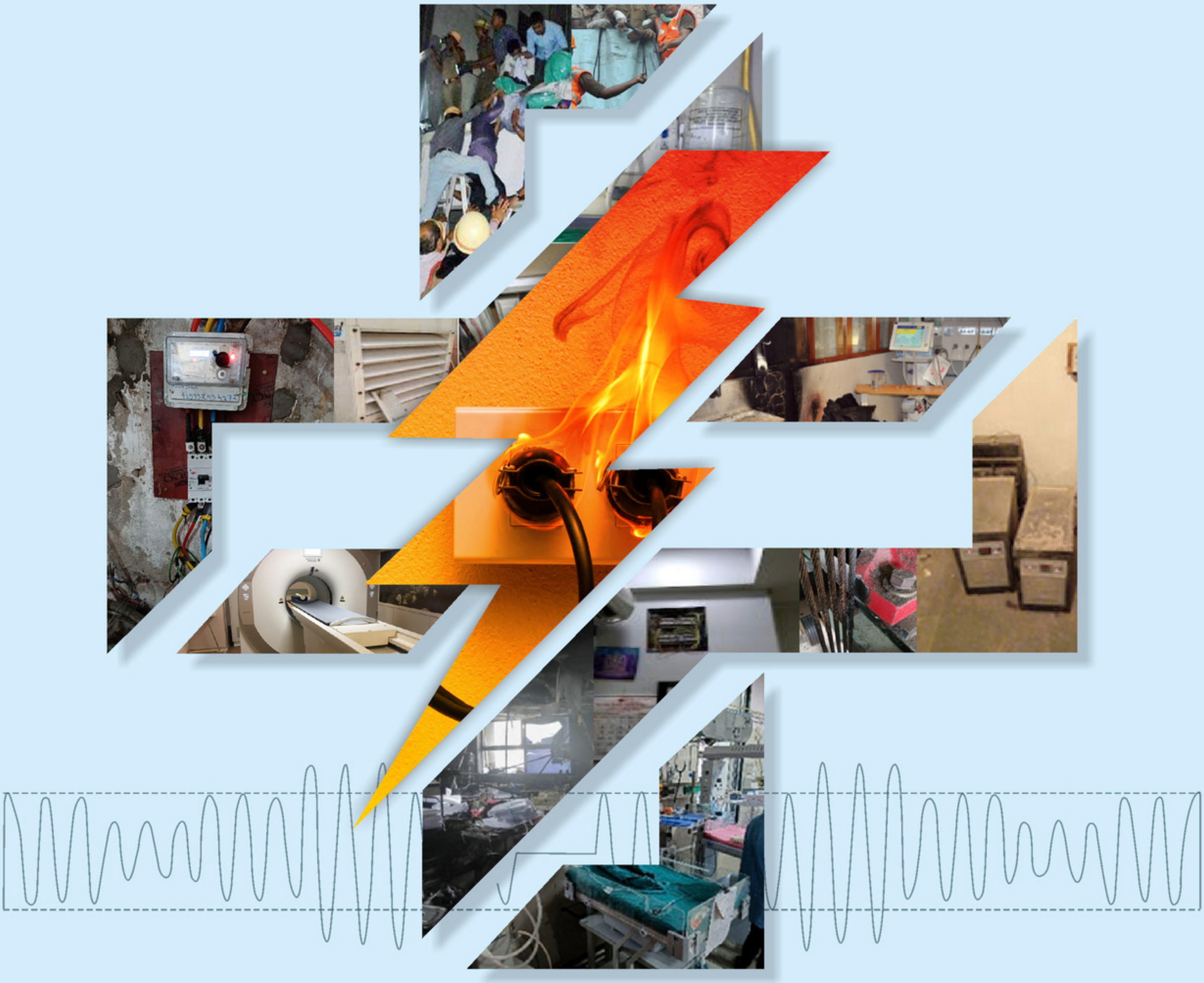
Application Note

Power Quality and Electrical Safety in HOSPITALS



Introduction

Power Quality (PQ) and Electrical Safety (ES) of Hospitals need an urgent check

To improve safety, hospitals must impart specific accountability while building 'collective responsibility'.

Hospital fires are on the rise. ICA India's analysis shows that over 90+ minor and major fire incidents in Hospitals across various parts of the country have led to over 120 deaths during the pandemic. The series of fire incidents raise several questions on the safety and reliability of Hospitals.

- Is this a temporary phenomenon or surfacing of a large-scale problem?
- Who is to be held accountable for fire safety? Hospital staff and management? Fire safety departments? Regulatory bodies? or patients?
- More importantly, what needs to be done now? Who needs to act? Where does one start?
- Above all, what is the solution to this emergency situation? What's a systemic solution and how does one approach the same with a short and long-term view?

This study answers these and many other such questions. Reducing fire risks and Electrical Network Hazards requires measures that attack the root cause of the problem. This study assesses the state of Power Quality and Electrical Safety (PQES) of Hospital facilities, independently, as well as for their interconnected impact. The insights have been built ground-up and based on detailed field-level data. The study provides a much needed comprehensive analysis of the electrical safety risks perceived in hospitals based on data from surveys of management and facility managers, power quality and electrical safety audits and extensive visual inspection. The methodology of the study and observations show the way to develop a long-standing framework to assess fire risks and preparedness of Hospital buildings to fight the incidents of fire.

Team ICA India

About Asia Power Quality Initiative

Transformation initiatives for better Power Quality!

Asia Power Quality Initiative (APQI) is an independent platform dedicated to capacities and knowledge building on issues related to Power Quality. Over the last 10 years, APQI's efforts and initiatives have been pivotal to bringing about several market transformations to improve Power Quality. Backed by strong research and expertise APQI has emerged as the go-to forum for Policy Makers, Professionals, Industry and Subject Matter Experts for issues concerning Power Quality at multiple levels.

The initiative is a joint effort of the International Copper Association (member of Copper Alliance), the Electrical and Electronics Institute (Thailand), the University of Bergamo (Italy) and other prominent organisations from Indonesia, Malaysia, Philippines and Vietnam. The initiative was established in 2008 with financial support from the European Union's Asia-Invest programme.

PQ Improvement resources for Safe, Reliable and Sustainable Buildings & Infrastructure with focus on the following areas:

- High-risk Buildings (Hospitals, High Rise Buildings)
- Data Centers
- Electric Vehicle Charging Infrastructure
- Smart City Infrastructure (Metro Railways, Smart Power Grids)
- Renewable Energy (Solar PV, Wind Energy)
- Emerging Technologies such as LVDC, Smart Power Grids, EVs

Visit http://apqi.org/ to explore an extensive library of resources on the subject of PQ improvement.

APQI's Resource Repository

Knowledge

A rich repository of 1,000+ Articles, Presentations, E-learning resources and E-books on Power Quality, available for free!

PQ Blogs | E-Learning Resources | E-Books

Awareness and Training

Uniquely curated knowledge capsules for electricity consumers to build awareness on losses incurred in a business due to poor power quality, conducted by APQI's Experts.

www.apqi.org

Smart Tools

APQI's tools for calculating distribution transformer losses and secqr® (lite)Harmonics and Power Factor Monitoring enable easy self-assessment of their electrical network in order to improve PQ.

International Copper Association India

Copper Alliance

About International Copper Association

International Copper Association India (ICA India) is a non-profit, non-commercial organization, which, as a part of its social activity, works to promote electrical safety, quality, sustainability, energy savings; capacity building by educating people working in the field at various levels like; electricians, engineers, contractors and spread awareness aimed to save human life and property from the hazards of electricity.

Our current initiatives aim to:

- Ensure safe and sustainable Buildings
- Drive awareness for good Power Quality
- Promote 5 mm Microgroove Copper Tube heat exchangers technology
- Promote greater adoption of Energy Efficient Motors and Pumps
- Improve reliability and reduce distribution losses in Transformers
- Encourage Renewable Energy Technologies
- Promote safety & reliability in Electric Vehicles and Charging stations

ICA India Partner Ecosystem

With a strong partner ecosystem, ICA India drives various advocacy initiatives to engage with Regulatory bodies, policy makers, and industry professionals across levels – decision makers to those working directly on the field.

ICA India is recognized as an expert knowledge partner and valuable collaborator by a variety of organizations including Regulatory bodies, Academic and Professional Institutions, Trade bodies, industries, and individuals as the end-users.

Foreword

Electrical power is at the heart of modern healthcare. The quality of electrical power and its safe delivery is closely coupled with the quality and delivery of healthcare services itself. While a lot of attention is given to the medical equipment, clinical services, exterior quality of infrastructure and human resources, the needs of the electrical power network continue to be underinvested.

Healthcare facilities such as hospitals, diagnostic centers have unique needs, in comparison to the commercial buildings. A heightened awareness of these specific aspects will go a long way in reducing the risk of fires in hospitals.

I am happy that APQI - An initiative of Copper Alliance has attempted to bring on-the-ground facts through this Application Note. The gaps are evident on many fronts, where facilities do not meet even the basic requirement right from the design stage to the maintenance of the electrical power network.

India has developed some of the best standards in the world, historically, implementation has been slower than ideal, given the voluntary nature of adaptation.

Clearly, this demonstrates that there is no single solution to the problem at hand. A holistic approach that includes all stakeholders, focuses on closing the most urgent gaps to improve the power quality and safety of hospital buildings, while focusing on long-term initiatives to arrest issues in the future is the need of the hour.

By the rate at which the Indian healthcare industry is growing and modernizing, right intervention initiatives implemented in an integrated format is the way to ensure a stronger foundation for the future of safe and reliable healthcare delivery. This Application Note gives us the pulse of the present day conditions and emerges as a factual starting point to improve the situation in the future.

The Checklist cum Ready reckoner helps in consolidating the essence of this Application note.

Prof.(Dr.) R. Chandrashekhar

Chairman IGBC Green Healthcare Rating

Consultant, World Bank

Consultant, IUIH (Indo UK Institute of Health)

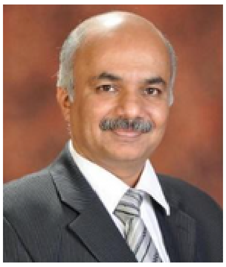
Peer review Consultant Govt. of Odisha, Tamil Nadu, Nagaland

Former Chief Architect with Ministry of Health & F W ,Govt. of India

Vice President RFHHA (Research foundation of Hospital & Healthcare Administration)

Vice President IBIMA (India BIM Association)

Foreword



It gives me immense pleasure that the International Copper Association of India (ICAI) has prepared a guiding book on Electrical Safety of Hospital Buildings.

Hospitals are critical infrastructures for saving precious human life. During Covid Pandemic across the Nation, a number of fire incidents occurred in Hospitals causing loss of precious lives and properties.

ICAI has taken a very good initiative for compiling all issues related to electrical safety in hospital buildings right from planning, implementation and monitoring of safe and reliable electrical infrastructure which plays a vital role for efficiency of hospital buildings. This compilation will definitely help all stakeholders who are involved in developing & maintaining the Electrical infrastructure in Government & Non-government Hospitals. For better Electrical Safety of any occupancy, the planning, implementation, execution and maintenance of electrical infrastructure is of prime importance, without that Hospital Buildings will not be safe place for treatment. We have various Codes and Standards issued by the Bureau of Indian Standard for providing electrical safety in various types of occupancies. If all these standards are implemented in the hospital project, then definitely we will be in the position to provide Safe Hospital Buildings which is very crucial considering the limitation of evacuation of patients in case of any emergency.

I wish this book shall be penetrated to all stakeholders to create an electrical safety culture in our society. By making good use of this compilation all responsible stakeholders for Hospital Buildings will implement these guidelines for providing safe hospitals for our citizens.

Mr. Santosh S. Warick
Director, Maharashtra Fire Services

Message

It is interesting to see all the valuable insights that have been brought by this application note, specifically for important sector as hospitals. Electrical Safety and Electrical Network Reliability must be the focus of Government and private hospital management, technical consultants and contractors. It addresses the safety issues right from design stage to execution, operation and maintenance. As evolved from this note, the power quality and electrical safety is a continuous activity and adherence to best industry practices is necessary in ensuring safety of installation. With the use of state of art medical equipment, it is essential to monitor power quality in ensuring flawless performance of equipment. This note has brought out issues related to power quality and its effects on functioning of equipment. Moreover it also suggests the ways of mitigating PQ issues. This note does a necessary job of providing practical recommendations for various sizes of hospitals and for various stakeholders, so that it is clear that the responsibility of hospital safety is to be shared together by everyone involved. Such in-depth and standard focused audits are required to mitigate safety risks before they turn into an incident.

I appreciate the efforts taken by International Copper Association of India in precisely bringing out the issues related to power quality and electrical safety of hospital Installations. I wish that all stakeholders take appropriate action as suggested in this note and ensure that the hospitals become accident free in near future.

Mr. S. A. Patil
Chief Engineer (Electrical)
Public Works Department,
Maharashtra State

Chief Electrical Inspector
Government of Maharashtra

Message

Healthcare Establishments employ all sorts of electrical equipment like Motors (for Chillers, lifts etc), UPS systems, Computers, isolation transformers besides critical and sensitive equipment like MRI, CT scan, X ray, Linac etc. Besides this, all hospitals use highly inflammable gasses in many critical care areas and patient movement areas. Reliability and continuity of power is of utmost importance besides safety. It is also a difficult exercise to evacuate a hospital in case of emergency since many patients need assistance. Imagine a fire in an operation theater or ICU where patients are under sedation or immobile.

Series of Fire accidents in hospitals in India and abroad during COVID exposed the lack of proper safety systems and highlighted the necessity of a proper audit of Electrical safety. NFPA indicates that oxygen levels beyond 23%, may give rise to fire accidents with a simple spark. It is practically observed that many critical areas have got more than 23% oxygen content. Also the systems like UPS gives rise to harmonics and increased neutral currents, if not filtered affecting power quality besides overheating of equipment.
There is not much awareness about the Electrical safety, Power quality issues and Fire safety among the Hospital operators and maintenance teams.

So far there is no consolidated report or book addressing the safety and power quality issues on Hospitals and information is available in bits and pieces. APQI has done a commendable job by collating various safety aspects, audit reports and evolved checklists for a smooth operation and functioning of hospitals. This Application note is very much useful for all stakeholders involved in hospital planning and operations and they all will be immensely benefited with this.

Thanking you.

Mr. Srinivas Valluri
M.Tech, FIE, M.I.Fire.E(UK)
Master trainer- ECBC, IGBC-AP
Chartered Engineer
CEO-Director- Synergy infra

Acknowledgement

“When the problem feels too big, focus on the little things you love”.

It is said and believed that a nation’s progress depends on its citizen’s education, good health, and empowerment. Hospitals are places where one goes for healing during sickness. Imagine if the same hospital becomes life threatening by it’s infrastructure alone, what would be the patient’s mental condition added to her/his already poor health condition.

A healthy healthcare infrastructure therefore is essential for India’s 1.30 bn population to continue to be its biggest asset. Today with advancements in technology and power of IT at hand, our healthcare systems are increasingly dependent on pathological diagnosis instead of clinical ones. Besides medical intervention is increasingly getting driven by robotics, AI and many such innovation to extract best out of collective knowledge. Unlike other facilities, healthcare facilities are far more sensitive to power quality issues as even the slightest downtime can pose a big risk to the patient’s health.

As India started it’s journey on the path of digital economy, we at Asia Power Quality Initiative (APQI), supported by Copper Alliance, recognized early the imperative of both good power quality and also the impact of poor power quality.The power electronic driven ecosystem is dependent on clean power at the same time they themselves are polluter. So, we created in mission mode many applications note and good practice guide in areas of IT, ITes, Data Centres, Textile, Steel etc those proved to be powerhouse for capacity building of stakeholders engaged in those sectors.

Then came Covid and we became acutely aware how vulnerable we are if our healthcare system itself remain in poor health due to widespread use of electricity in every operational area. Risks to electrical safety were noticed within the hospital facility, across various hospital types and throughout the country. We also discovered to our dismay that the level of information and understanding about electrical safety and power quality amongst the hospital management is seriously lagging and more so when all of them are in fire fighting mode to save precious life. Sometimes in our urgency ignoring basics comes at a greater cost to of our life and reputation itself. So, we at APQI, already in mission mode, decided to do something about it to lend our knowledge and hands in building awareness and capacity amongst health care sector stakeholders.

Acknowledgement

As electrical safety and power quality are intertwined, we thought to address them collectively since under most fire incidents the common denominator appears to be electrical short circuit that is quite avoidable by being proactive in addressing the root cause right at conception stage or after required audit during operational stage. Exactly in the way we deal with human health either adopting and maintaining healthy lifestyle or taking corrective action after pathological findings towards predictive maintenance need.

We are deeply indebted to the following eminent industry moderators and thought leaders for their association with the purpose of this application note. Their valuable direction and contribution towards its review, finalization, and promotion can not be measured in any physical terms.

- Prof (Dr) R Chandrashekar - Chairman IGBC Green Healthcare Rating and Former Chief Architect with Ministry of Health & F W ,Govt. of India
- Mr Srinivas Valluri - CEO - Director, Synergy infra
- Shri Santosh S Warrick - Director, Maharashtra Fire Service

We thank the following authorities, subject matter experts and institutional heads for investing their precious time and efforts to provide access, niche insights and technical expertise that proved critical in forming the crux of this application note.

- Mr Sandip A Patil-Chief Engineer (Electrical) Public Works Department –Maharashtra State
- Mr D G Khonde Chief Electrical Inspector, Government of Maharashtra
- Mr Shirish D. Mehta - Secretary & Trustee - Lion Tarachand Bapa Hospital & Research Centre
- Mr Hemant Sali - Technical Consultant and Former Executive Engineer, PWD, Maharashtra, Committee Member for National Electrical Code (NEC) of Bureau of Indian Standard

Following are the esteemed stakeholders that we are thankful to, as they enabled us with their important references acting as a catalyst in the process of development of this application note.

- Dr Vinay Kulkarni - Prayas Health Group Pune
- Shri Shantanu Dixit – Prayas Energy Group Pune
- Dr Tushar Negandhi -
- Shri Rajen Mehta – MD Efficienergi and APQI NSN Partner

Acknowledgement

Lastly, we thank Efficienergi Consulting Private Limited and its team members for its contribution in the audits and compilation, as well as our other APQI National Support Network (NSN) partners and our design, editorial team for their noteworthy help in shaping up this Application Note. We had an incredible team that made this possible.

Now that this valuable open access resource is in our hand, we will feel further encouraged if this reaches all the stakeholders in healthcare sector who are planning, designing, maintaining and working tirelessly to keep citizen's health in pink of condition. Do share the word..

Warm Regards, keep safe, stay healthy and remain helpful.

Mr. Manas Kundu
APQI India Co-Ordinator.

Table of Contents

List of Abbreviations

AYUSH	Ayurveda, Yoga & Naturopathy, Unani, Siddha And Homeopathy
CCU	Cardiac Care Unit
CEA	Central Electricity Authority of India
DB	Distribution Board (Electrical)
DG	Diesel Generator
EMI	Electromagnetic Interference
FRLSH	Flame Retardant Low Smoke & Halogen Power Cables
GF	Ground Floor
ICT	Information and Communication Technologies
ICU	Intensive Care Unit
IEC	International Electrotechnical Commission
IIoT	Industrial Internet of Things
IS	Indian Standard
NEC	National Electricity Code
OT	Operation Theatre
PHC	Public Health Centers
PPE	Personal Protective Equipment
PQ	Power Quality
PQES	Power Quality and Electrical Safety
RCD	Residual Current Devices
SLD	Single Line Diagram
SOPs	Standard Operating Procedures

Executive Summary

Electrical network is most critical to patient care and functioning of every healthcare facility. The presence of sensitive medical loads, dynamic loading scenarios and direct impact on human lives requires the healthcare facility to have an electrical network that performs with extremely high levels of power quality and in the safest of electrical environments.

The role of electrical power network is undoubted in supporting the growth and delivery of quality healthcare in every area starting from the Public Healthcare Centers to medical tourism. The primary and secondary research carried out for the purpose of this application note indicates that there are various geopolitical, economical and technical factors along with a variety of stakeholders that affect the power quality and electrical safety of a Hospital's electrical network. While Power Quality and Electrical Safety (PQES) remain critical to modern day healthcare delivery, the awareness and importance attributed to factors impacting the two is very limited.

Risks to PQES were particularly exposed, in all types of hospitals, with the onset of Covid-19 pandemic. Several incidents of accidents and fire, observed especially in ICUs, could be attributed to poor power quality and lapses in electrical safety. Observation of such incidents over the long-term past indicate a similar trend. In view of this, the study aims to help stakeholders in developing clear understanding of the specific risks to hospitals, and their underlying root causes (direct as well as indirect), need to adhere to compliance and standards while stating clearly the lapses and misconceptions pertaining to right practices for electrical networks.

Hospitals must assess PQES in detail. Maintaining a broader and general view may be detrimental as even small lapses could lead to catastrophic events. To achieve good power quality and improve electrical safety at the hospital requires a holistic approach. This begins with knowledge and implementation of standards pertaining to specific locations within the hospitals. Further, regular and detailed monitoring of PQES is essential to mitigate and check risks, if any. The study highlights important standards, critical areas within the facilities and key guidelines specified under various regulations that are binding to electrical networks in the hospital facilities.

The study specifically focuses on small hospitals which constitute the bottom of the pyramid in healthcare delivery. Small hospitals experience a relatively higher exposure to electrical safety risks owing to their limited awareness, resources such as manpower, infrastructure and management bandwidth. The survey and findings of the study provide sharper insights into PQES vulnerabilities for such hospitals. The observations in the application note will serve as a reference to the owners and management of small hospitals to correlate and assess their PQES risks. Above all, the application note provides hospitals with several essential and actionable reference resources in the form of checklists, various types of relatively unknown risks, standards and regulations to significantly reduce the PQES risks. The comprehensive discussion highlights an urgent need, especially for the small hospitals, to act and correct their electrical infrastructure for safe and reliable healthcare delivery.

The PQ audits, ES audits and survey of hospital's management, technical staff bring several sharp insights on the reality of situation on the ground. Out of the 72 hospitals approached with request for participation in the study and survey, only 11 agreed and provided access. The level of awareness, allocation of resources and approach to course correction within the hospitals surveyed are concerning.

Only 1 of the 11 hospitals
have an Emergency SOP accessible, reviewed and updated

Only 3 of the 11 hospitals
carry out periodic electrical testing

Power Quality is not part of any hospital
electrical network maintenance whatsoever

Many of the hospitals carry out
Electrical maintenance on need to repair basis

Out of 11 Hospitals, 6 hospitals do not have any technical person
to look after the hospital's electrical network

Power quality audits showed non-compliance
on several important and critical parameters for every hospital

Electrical safety audits revealed extreme risks to hospital due to poor design, quality of infrastructure workmanship and maintenance
in multiple areae from wiring to power back-ups

Adherence to electrical standards, regulations
was found to be low or absent in a majority of instances, across hospital locations

Lack of awareness
was observed as a critical hurdle in improving power quality

Relatively lesser importance and lack of understanding
the economic impacts of poor maintenance were found to elevate the risks to electrical safety

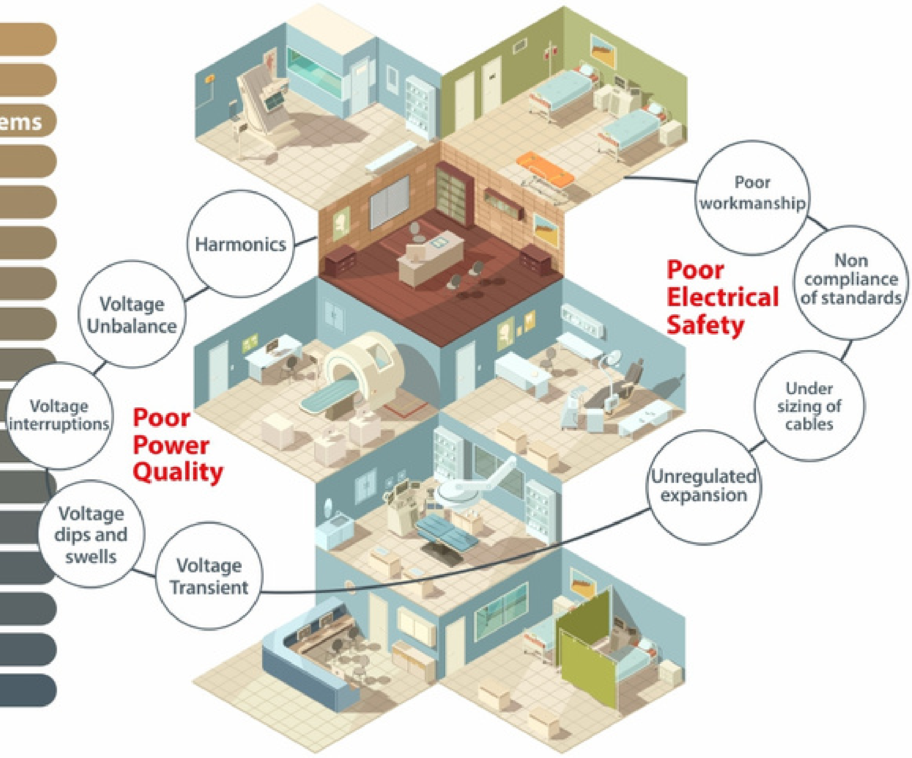
Shared responsibility amongst all stakeholders along with right alignment of goals is required to effectively improve the quality and safety of healthcare delivery system.

The multi-pronged and dependent nature of PQES creates several challenges in placing specific accountability and monitoring performance. Teams with members well aware and respecting the electrical standards and practices in their work is fundamental to ensuring higher reliability and better safety of hospitals. At every stage, the teams of various stakeholders must be in alignment towards achieving the common goal of good power quality, and the highest levels of electrical safety.

This report provides specific and conclusive recommendations to all the important stakeholders concerning the hospital facility to drive a positive impact on PQES. While the need is urgent, the efforts demand fundamental and long-drawn changes in electrical network of the hospitals. The challenge before healthcare industry is acute and vast, solution not easy, but making a start is the only way to prevent further emergencies.

Hospital systems at risk....

- Voice
- Data and Communications
- Hospital Management Systems
- Patient Services
- LED Lighting
- HVAC
- Energy Management
- CCTV and Surveillance
- Access Controls
- Lifts and Escalators
- PA System
- Fire Protection
- Cables
- OTs
- Diagnostic Equipment
- Patient Monitoring
- ICU/NICU



....Exposed by COVID-19 pandemic


The Indian Express
JOURNALISM OF COURAGE
SECOND INCIDENT AT COVID FACILITY IN MUMBAI IN A WEEK
15 of 17 ICU patients killed in Virar Covid hospital fire

15 of 17 ICU patients killed in Virar Covid hospital fire


50 patients evacuated after fire in Safdarjung Hospital ICU

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NEWS • LIVE TV INDIA TODAY APP
Fire at Covid ICU ward in Nagpur hospital leaves three dead

Fire at Covid ICU ward in Nagpur hospital leaves three dead


9 dead as fire sweeps through hospital inside Mumbai mall

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Deep rooted underlying causes

Non Compliance to design standards	Faulty electrical installations in an oxygen-rich environment	Poor quality of wiring and cabling	Power Quality issues

Power Quality & Electrical Safety: Proportionate and Codependent

PQES are critical to modern healthcare delivery

1. Lack of awareness is a key barrier to improving power quality and electrical safety
2. Alignment across healthcare services and equipment required to ensure quality healthcare
3. Recent and historical incidents of fires in hospitals highlight the risks to safe and reliable healthcare

> For the healthcare in India to grow sustainably, PQES of hospitals holds the highest importance

Introduction

Asia Power Quality Initiative and International Copper Association India have been working towards capacity building and advancing the regulatory policy for power quality in India. Several initiatives already introduced include:

- Introduction of PQ regulations through Forum of Regulators
- Development of standards for various elements of electrical infrastructure to improve building safety and energy efficiency
- National Building Codes (NBC) for meeting a minimum safety benchmark in new and existing buildings
- Building awareness on PQ Audits, trainings and seminars/workshops on the topic in partnership with various agencies

In this context, safety of hospitals was identified to be of specific concern. This was based on long-term observations about incidents of fire and accidents in hospitals as well as the sudden increase in such incidents during the time of pandemic. It was therefore considered necessary to address the issue of reliability and safety in hospitals through a detail study of PQES.

This application note will serve as a guide to assess and acknowledge the importance of power quality through:

- Monitoring of PQES in hospitals
- Understanding of current practices to ensure safe and reliable electrical network
- Development of a framework to assess risks to hospitals based on their specific electrical environment
- Recommend actions for hospitals based on the findings of field-studies and risk matrix

Accordingly, this application note has been prepared to address the above focus areas and citing related cases, resources and research from India and global sources.

The application note aims to address three important barriers in improving PQES

Low awareness
in owners and facility managers on the importance of PQ in ensuring safe, reliable and quality healthcare delivery

Limited availability
of external and in-house expertise for identifying risks to PQES

Lack of stakeholder accountability
for ensuring good PQ and overall Electrical Safety of the facility

Targeted beneficiaries

The application note will help improve the understanding of the role of PQES, reliability and performance of critical equipment among

- Hospital management
- Contractors
- Builders
- Facility managers
- Design consultants
- Administrative staff

The study takes inputs from owners, facility managers and on-field assessment of PQES at various hospital facilities.

Scope of application

The approach for the application note focuses on existing hospitals in view of power quality and electrical safety improvements. These improvements can be achieved through the adaptation and implementation of various electrical standards and regulations, along with best practices in view of specific risk profile of the facility. The technical discussions represent the best practices, available technologies for ensuring good PQ which can then be applied to all the existing and upcoming hospital facilities.

Role of reliable electrical infrastructure in healthcare improvement

SUSTAINABLE DEVELOPMENT GOAL 3:
Ensure healthy lives and promote well-being for all at all ages

To achieve better health outcomes, most developing countries have focused on the policy of improving direct factors such as expanding healthcare network, training and use of financial instruments such as insurance. But it is interesting to note that the United Nations Sustainable Development Goal (SDG) 3 recognises that improving health outcomes depends on enabling an environment that integrates health with other basic infrastructure, and most important among these is electricity.

> The World Health Organization (WHO) states that electricity is a 'critical enabler' given that without availability and reliability, many life saving interventions cannot be undertaken.

To achieve a larger impact on health and welfare in general requires expanding access to electricity combined with reliability measured using hours of supply and various other parameters such as voltage and current stability, safety systems, electrical compliances and more. Several studies acknowledge availability of electricity as a critical supply side prerequisite for health facilities to offer safe and quality care.

As India adds capacity on several fronts that matter to healthcare, it has become extremely important to evaluate the strong interconnections between safe and reliable electricity and effective healthcare.

Access to affordable healthcare – reliable and safe power is critical

Affordability and quality of medical care for the 1.38 bn population continues to be a concern in spite of all the efforts. Rising healthcare costs, low penetration of insurance mean many sections of the population are still deprived of quality care. Here, state-of-the-art PHC facilities backed by reliable electrical infrastructure have a key role to play in bringing quality healthcare to people with underprivileged income groups.

PHCs are critical to ensuring affordable healthcare in the Govt funded healthcare network. The penetration of PHCs in India is relatively low at one PHC for 30,000 rural residents. This makes maintenance of essential devices and diagnostic equipment very important in ensuring quality healthcare without disruption. Proper functioning of equipment such as refrigerators, vaccine carriers, diagnostic devices such as X-Rays, Operation Theaters requires reliable power. Several PHCs are now being upgraded with high-end equipment such as ventilators, Diagnostic instruments etc. The improved infrastructure at PHCs must be backed by safe and reliable electrical supply to enable 24X7 access to healthcare and facilitate high-quality care.

Sustaining the growth in medical tourism – electrical safety is fundamental

The recent incidents of fire in hospitals raise concerns on the safety of healthcare in Indian hospitals. In 2018, over 6% of the tourists entering India arrive on a medical visa with a significant percentage from west Asia and Australia. Indian medical e-visa is available for 160 countries. While the pandemic in 2019-2020 has disrupted medical tourism, the proposition remains attractive. However, the perception on the safety and reliability of hospitals in India must remain positive for sustainable growth.

Healthcare in India: Rapid growth on every front

For Hospitals in India, the demand has always outstripped the supply.

558	$6.8 bn	$30 bn	2.37x
Medical Colleges; 393 Ayurveda 221 Homoeopathy	Credit incentive program to boost Hospital Infra	Allocation for Healthcare in FY21	Increase in India's Healthcare facilities in 5 years

Healthcare industry in India comprises hospitals, medical devices, clinical trials, outsourcing, telemedicine, medical tourism, health insurance and medical equipment. The Indian healthcare sector is growing at a brisk pace due to its strengthening coverage, services and increasing expenditure by public as well private players.

> The hospital industry in India is forecast to increase to Rs. 8.6 trillion (US$ 132.84 billion) by FY22 from Rs. 4 trillion (US$ 61.79 billion) in FY17 at a CAGR of 16–17%.

With ~1.5m Doctors, India will reach WHO standard of 1:1,000 doctors (modern medicine) to population ratio in 2022

$9 bn Diagnostics industry in India

is also pitched for rapid growth

6% of total tourists in India arrive on a medical visa

References and Sources

Indian Brand Equity Foundation report on Indian Healthcare - https://www.ibef.org/industry/healthcare-india

Growing demand for medical & diagnostic devices

The Department of pharmaceuticals launched a Production Linked Incentive scheme for domestic manufacturing of medical devices, with a total outlay of funds worth **Rs. 3,420 crore (US$ 468.78 million) for the period FY21-FY28. By Oct 2021, proposals from 13 companies have been approved.**

India is among the top 20 markets for medical devices worldwide, growing at a 37% CAGR to reach US$ 50 billion in **2025, from Rs. 75,611 crore (US$ 10.36 billion) in 2020**

January 2020, National Medical Devices Promotion Council to promote local manufacturing of high-end medical devices

Manufacturing of high-quality and affordable medical devices at Medical Parks

- **Rs. 5,000 crore (US$ 674.36 million)** in Himachal Pradesh's industrial township, Nalagarh, in the Solan
- **Rs. 3,500 crore (US$ 472.05 million)** in Oragadam (Tamil Nadu)
- **Rs. 500 crore (US$ 67.13 million)** in Uttar Pradesh

June 2021 the Quality Council of India (QCI) and the Association of Indian Manufacturers of Medical Devices (AiMeD) launched the Indian Certification of Medical Devices (ICMED) 13485 Plus scheme to undertake verification of the quality, safety and efficacy of medical devices.

The rapid growth in overall healthcare services is shadowed by the rising number of incidents of fires in hospitals, historically and in recent period of Covid-19 pandemic. Reliable and quality power is essential for the efficacy of healthcare services. It is therefore important to understand the risks to safety, reliability and quality of power in hospitals.

References and Sources

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Schemes under 'Make in India' initiatives for medical equipment manufacturers
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Press note by Ministry of Chemical and Fertilisers on PLI Scheme
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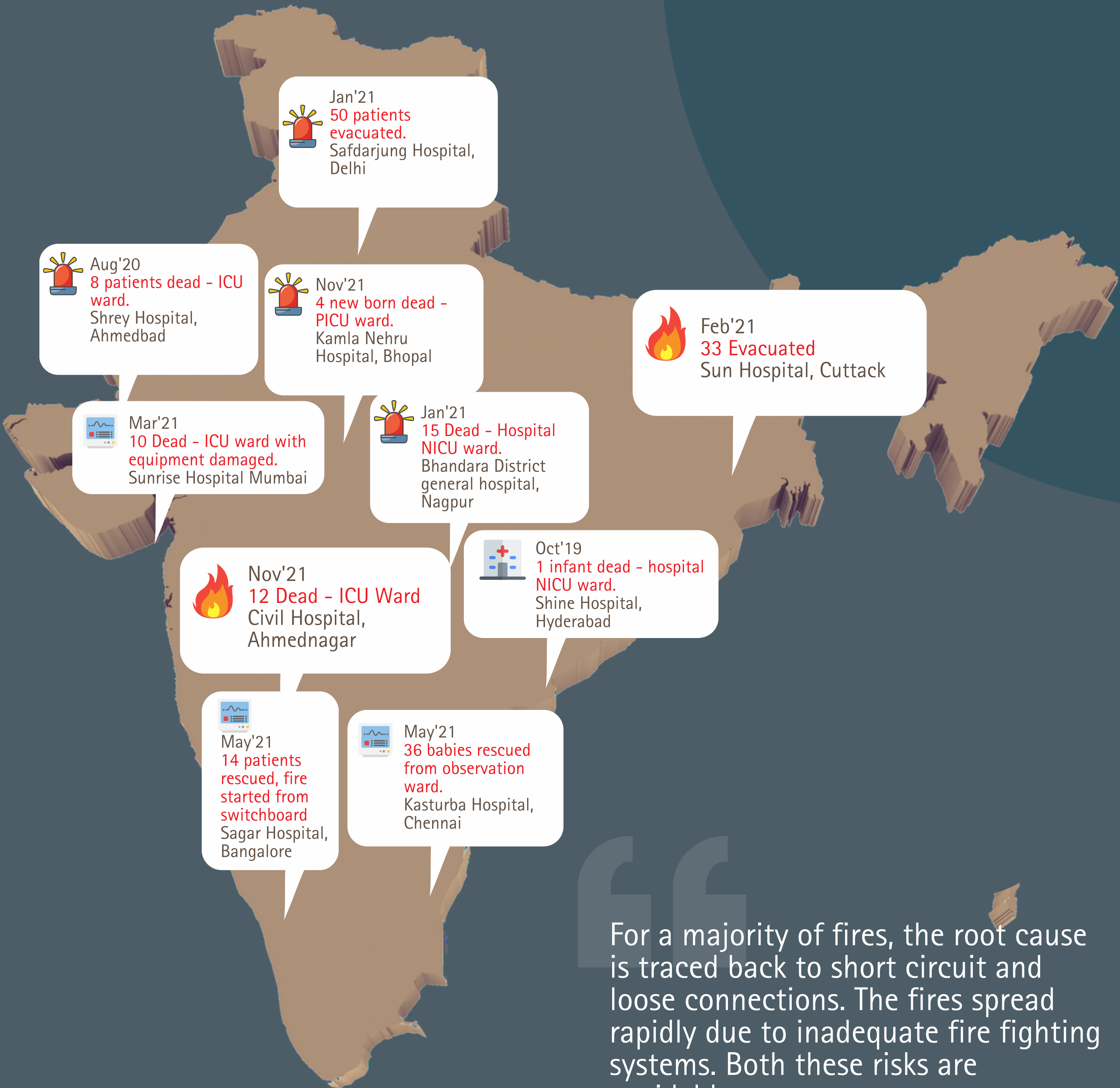
Hospital safety – an emergency!

Major Hospital Fires in India (2019-2021)



> For a majority of fires, the root cause is traced back to short circuit and loose connections. The fires spread rapidly due to inadequate fire fighting systems. Both these risks are avoidable.

Major fire incidents in hospitals (2006–2018)

City	Date	Location of fire	Casualties/injuries
Hyderabad	03-01-2006	Incubator	One baby death
Ahmedabad	13-03-2008	Incubator	One baby death
New Delhi	13-03-2008	Incubator	One baby death
Meerut, UP	16-11-2008	Incubator	One baby burned
Patiala, Punjab	31-01-2009	Incubator	5 babies burned
Allahabad	03-05-2009	Incubator	One baby death
Hyderabad	02-02-2010	Diesel generator/ short circuit	One death, 38 injuries
Mancherial, AP	15-04-2010	Incubator	One baby death
Katni, MP	19-04-2010	Air conditioner	8 babies evacuated
Nashik, Maharashtra	14-05-2010	Electrical short circuit in ICU	One death
Beed, Maharashtra	09-03-2011	Incubator	Two baby deaths
Chennai	24-07-2011	Air conditioner	Two patients deaths
Kolkata	09-12-2011	Air conditioner	93 deaths
Moradabad, UP	01-07-2012	Air conditioner	Two deaths
Bokaro, Jharkhand	08-09-2012	Air conditioner	Three deaths
Bikaner, Rajasthan	13-01-2013	Air conditioner and Heater	4 infants injured
Pune	18-06-2013	Electrical short circuit	No injuries. Equipment burnt

References and Sources

A study on reported fire incidents in major hospitals of India by Shyam Siddharth Rao Patharla Souri Reddy Pyreddy and Shilpa N. Panthagani
https://www.researchgate.net/publication/345661050_A_study_on_reported_fire_incidents_in_major_hospitals_of_India

Major fire incidents in hospitals (2006–2018)

City	Date	Location of fire	Casualties/injuries
Mumbai	17-12-2018	Storage Area	6 deaths, 100 + injuries
Kolkatta	03-10-2018	Dispensery	17 injuries
Bhubaneshwar	20-10-2016	Dialysis Unit	20 deaths, 120 injuries
Murshidabad	27-08-2016	Surgical Ward	3 deaths, 37 injuries
Cuttack	29-11-2015	Neonatal	Major damage to the medical equipment of the NICU
Hyderabad	14-09-2018	Celler	2 injuries
Cuttack	31-05-2016	Cardiac Wing	shift out 104 patients; 20 from ICU
Cuttack	16-10-2015	OT	1 death

Analysis of higher risks to hospitals experienced during pandemic

90+ major and minor fire incidents were reported from Nov 2020 to Sept 2021, as the Covid-19 pandemic was at its peak.

- The most common cause of fire was due to an electrical short circuit.
- A majority of the fires started with loose connections or sparks from ventilators.
- Except for 3 cases, a functional firefighting system was absent in all the incidents.
- Fires originated at or near intensive care units (ICU's) in 85% of the instances.
- 72.72% accidents occurred at night. Casualties were reported in 65% of the fire accidents.

Hospitals have been tirelessly operating in the pandemic, constantly stressed for resources including space, medication and care. Several large make-shift hospital facilities were built at sports stadiums, hotels, convention centers, and even railway coaches. Given the large scale of the pandemic and short availability of time and resources, very little could be assured for standards and underlying quality of work for the electrical systems. The risks to the safety and reliability of power systems thus have been higher than ever before.

Ensuring uptime, safety and proper functioning of all critical devices and systems, mostly driven by electricity, in an extremely challenging situation. Any technical difficulty can become overwhelming for the hospital facility in such a stressed situation. A strong indication of the stressed and crumbling systems is the events of electrical fires in recent times in the hospital facilities that were dedicated to COVID treatment.

High fire safety risks for hospitals post pandemic

Oxygen rich environment is one of the leading causes

Oxygen beds and ventilators increase fire risk

Oxygen leaks from damaged hoses, connections & valves	Valves left open unintentionally lead to increased oxygen	Poor ventilation in ICUs increase oxygen concentration

One liter of pressurized oxygen in a tank at 2,200 psi released in 12 X 12 feet room raise the oxygen level from 21% to 21.5%

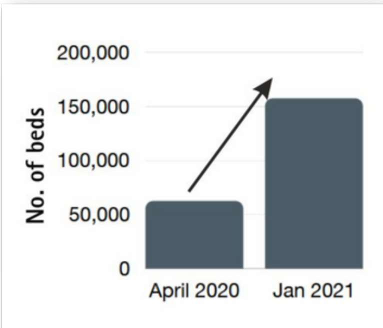
Hospitals increase beds and equipment to cope with the growing patient load, but don't immediately expand the electrical systems and wiring.
This causes equipment or wires carrying current beyond their capacity to overheat.

Beds with oxygen support

grew 152%

between April 20-Jan 21

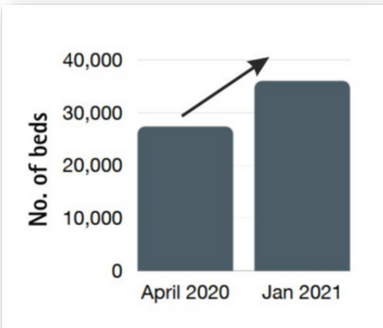
Source: Ministry of health, Feb 2, 2021



Intensive care unit beds

grew by 32%

between April 20-Jan 21



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Down to Earth - Is India's public health infrastructure ready to tackle the second COVID-19 wave?
https://www.downtoearth.org.in/news/health/is-india-s-public-health-infrastructure-ready-to-tackle-the-second-covid-19-wave-here-s-what-data-says-76320

Major fire incidents in hospitals (2020-2021)

City	Fire incident & date	Name of the hospital	Severity and cause
Mumbai	9 dead as fire sweeps through hospital inside Mumbai mall 27-03-2021 (Source: Times of India)	Sunrise Hospital (COVID care facility), Mumbai	9 patients died in the Hospital that operated on a provisional occupation certificate granted by the BMC though the building had received notices for irregularities in construction and violation of safety norms.
Kanpur	Kanpur hospital fire: Survivors recount panic, chaos 28-03-2021 (Source: New Indian Express)	LPS Institute of Cardiology and Cardiac Surgery, Kanpur	Dense smoke filled up the centrally air-conditioned building leading to death of 2 patients. A short-circuit is suspected to have led to the fire, according to police.
Nagpur	Fire at Covid ICU ward in Nagpur hospital leaves three dead 09-04-2021 (Source: India Today)	Hospital in Wadi are of Nagpur	3 people have died in a fire that broke out in the Covid ICU ward of the hospital. The fire reportedly started from an AC unit of the ICU.
Ujjain	Madhya Pradesh: Fire in hospital in Ujjain, patients moved out 04-04-2021 (Source: Livemint.com)	Patidar Hospital, Ujjain	A fire that broke out at the ICCU Department of a private hospital required around 80 patients to be shifted and rescued.
Delhi	Delhi: Fire at Safdarjung ICU, 50 patients evacuated 01-04-2021 (Source: The Hindu)	Safdarjung hospital, Delhi	The fire started due to a short circuit in a ventilator machine. Officials said the wires caught fire, which led to a lot of smoke in the ward.
Bhandara	10 Babies Killed In Maharashtra Hospital Fire; "Heart-Wrenching," Says PM 09-01-2021 (Source: NDTV.com)	Bhandara District General Hospital	10 Babies died after a fire broke out at around 2 AM. Prime Minister Narendra Modi condoled the deaths and called the incident a "heart-wrenching tragedy". While the cause of the fire is yet to be confirmed, a short circuit is believed to have set off the blaze.
Rajkot	Five Covid-19 patients die in fire at ICU of Rajkot hospital 28-11-2020 (Source: The New Indian Express)	Uday Shivananda Covid Hospital, Rajkot	Patients in the ICU were on ventilators and they experienced hypoxia due to smoke in the room. The staff attempted to switch on firefighting system but due to smoke, they couldn't do it and the fire spread rapidly.

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Faulty electrical installations in an oxygen-rich environment increase the risks for hospitals

Areas such as operation theatres and ICU are with a high concentration of oxygen. Any electrical short circuit in these areas, could lead to electrical shock to surgeons or patients. In the worse cases, these electrical faults may result in sparks and could lead to fires. In order to achieve uninterrupted power or for surge control UPS systems are used which are supported by batteries. In many cases, these batteries are installed in close proximity to the Medical equipment. These batteries often release harmful and flammable gases which adds to the threat of fire accidents. Hence, it is important to provide special attention to electrical wiring, earthing and switchboard installation.

With the addition of Ventilators, air-conditioners, air scavenging systems, high-capacity machines in the Intensive Care Units, testing facilities for COVID, the addition of more rooms, and increased use of flammable alcohol-based sanitizers or PPE kits, risks of fire are only going higher. Add to it the poorly designed power systems built with relatively substandard workmanship, it all works like oxygen to start an electrical fire and the poor ventilation systems act like fuel to that fire.

As Hospitals continually equip themselves to serve more patients, reliable electrical supply must be ensured for the seamless and safe functioning of the facility. The addition of new electrical loads, whether it's ventilators or converting the basement to a make-shift healthcare facility, a thorough assessment to check the preparedness of the existing electrical system to function in a safe and reliable manner should always be the first priority. From minor voltage or current disturbances to the emergence of a previously undetected poor grounding issue, Power Quality issues can lead to a spike in risks to the facility that Hospitals may not be in a position to control swiftly.

The World Health Organization (WHO) have defined a 'safe hospital' as one that "will not collapse in disasters, killing patients and staff; can continue to function and provide its services as a critical community facility when it is most needed; and organized, with contingency plans in place and health workforce trained to keep the network operational"

To be safe, hospitals need to be designed for every eventuality.

There are several underlying reasons why hospitals are prone to relatively higher safety and reliability risks from electrical networks

Full load operations from the first day

in hospitals leaves very less time for testing and course correction of electrical systems

24X7 nature of operations

of hospitals with constant need to be ready for emergency demands a very high level of reliability from electrical systems

Oxygen rich and confined environment

in ICUs, Operation Theaters using Oxygen cylinders, ventilators can catch fire even due to a small spark or heat that originates in equipment operating near the zone of application of O2 to patients

Complex electrical load profiles

in hospitals which includes lighting, elevators, UPS, Diesel Generators, to several high-end and sensitive electronic equipment in diagnostics and treatment of patients elevate the risks

EMI - susceptible to typical commercial building

Sensitive medical electronics deviating from their output due to improper earthing or conditioning

Direct risk to life

Hospitals adding capacity

without upgrading the requisite electrical infrastructure

Exceeding the electrical loads

over and above the one considered in design stage poses risks. In hospitals, this could occur because of changes in specification of equipment, modifications done on site to buildings and electrical networks, changes in location of power distribution systems etc.

Low awareness about essentials

of healthy electrical fundamentals among stakeholders such as power quality, earthing systems, cabling etc.

Low levels of enforcement of procedures and systems

to track the safety, reliability and performance of critical equipment and electrical systems on an ongoing basis

There are several underlying reasons why hospitals are prone to relatively higher safety and reliability risks from electrical networks

Lack of clear budgetary provisions

for improving safety and reliability of hospital facility, unless demanded by an untoward incident, keep the risks high

Relatively difficult to identify and resolve

the signals or symptoms indicating the risks to hospital's electrical safety and reliability

Unavailability of budgets to hire dedicated resources

such as trained/certified technicians or domain experts to operate and maintain the complex electrical infrastructure of hospitals further increases the risks

Introduction to Power Quality & Electrical Safety (PQES)

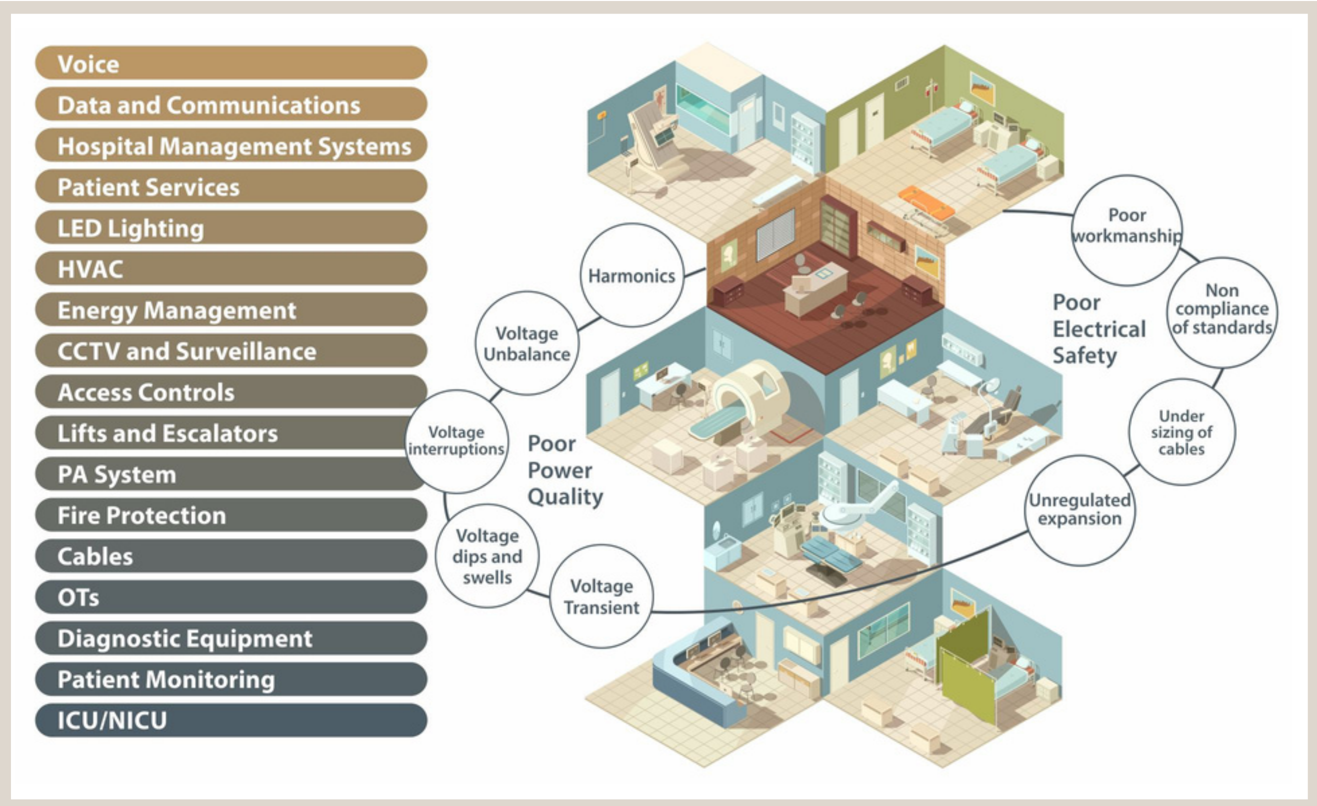
Without good PQES hospitals face risks on several fronts

1. Hospitals include one of the most complex and diverse electrical load profile
2. A Hospitals load could exceed by 25% of the designed capacity on the first day itself
3. The costs of poor power quality in hospitals cannot be quantified accurately in terms of downtime or revenue losses

> India also reported one of the highest instances of hospital fires in times of the pandemic.

Importance of PQ in hospitals and healthcare facilities

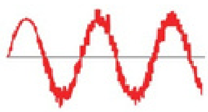
In comparison to a data center, IT services firm or high-speed manufacturing line, it may appear that hospitals need not have the power systems required to deliver very high reliability. But just one look at the complexity of equipment and electrical systems in a small to medium hospital is enough to break this perception. Poor reliability of power in hospitals imposes a direct risk to human life.



> Power quality is the term used for overall voltage quality, current quality and nature of output waveform, which directly or indirectly affect the various loads in a hospital.

The modern hospital facility is totally dependent on highly sophisticated electronic devices in every area, starting from laboratries, ICUs to compliance and maintainence of electronic medical records. The risks to life, due to a malfunction of a critical cardiac equipment such as ventilator for a patient undergoing treatment for heart attack or a flicker in the light in the middle of a surgery, can never be quantified.

Impact of poor PQ in hospital facility

Power Quality Issue	Description of Issue	Wave form	Effects
Interruptions of Power	Power failure or failure of electrical distribution system or components in power distribution		☐ Machine breakdown ☐ Loss of helium gas in MRI system ☐ Loss of life ☐ Safety issues
Sags/ Brownouts	Voltage falls to 90% of nominal value, typically lasts for ½ cycles to 1min		☐ System fault or trip ☐ Poor image quality ☐ Loss of data
Swell	Voltage exceed to 110% of nominal value, lasts for few cycles		☐ Increased failure of electronic cards in medical equipment ☐ Lower life of lighting systems
Harmonic Distortion	Distortion occurs due to the presence of non linear loads on the power line		☐ High levels of harmonic distortion can result in increased transformer, PF, capacitor or generator heating ☐ Other potential effects include incorrect reading on meters, misoperation of protective relays and interference ☐ Devices in parallel with harmonic sources will see a distorted voltage waveform and consequently these electronic devices can trip potentially causing downtime ☐ Malfunction of medical equipment
EMC/EMI	Unwanted additional noise in the electrical system		☐ Artifacts or intermittent image quality problems on the medical diagnostics equipment
Leakage current	Flow of current to earth through ground conductor		☐ Electric shock to patients ☐ Static shock when touching equipment

Sources of poor PQ in hospitals

Hospital facility involves one of the most diverse types of loads in any facility starting from sensitive electronic devices to full scale commercial loads such as lighting and HVAC.

On one hand, poor power quality affects sensitive medical devices, while on the other the non-linear loads in hospitals inject harmonics and other disturbances which lead to poor power quality.

In a healthcare environment, Poor power quality is typically caused due to

- Poor PQ from Utilities
- Improper and/or inadequate wiring and grounding
- Emergency backup generator , UPS
- EMIs, harmonics & other disturbances from diagnostic or imaging equipment, ventilators, MRI machines, CTs, etc.
- Expansion without consideration of design capacity of the hospital facilities from time to time

PQ problems add-up. Even a small PQ event can lead to catastrophic consequences and loss of life.
Another key issue with poor PQ in hospitals is erroneous diagnostic. Symptoms of PQ are often not understood early enough in most cases and misattributed as normal electrical issues in the facility.

These problems could have their roots in poor PQ ... but are often misread

- Software problems
- Hardware failure
- Frequent downtime
- Equipment lockdown, resets
- Errors in data, readings
- Data transmission, storage losses
- Occasionally dysfunctional/frozen screens
- Performance degradation of medical equipment
- Input/Output quality issues such as images
- Unexplained and recurring problems at a known frequency
- Issues encountered after adding new equipment/devices
- Early, premature failure of equipment or critical parts
- Electrical shocks experienced while operating/using the equipment

Key PQ issues

Harmonic distortion

Most of the modern medical equipment inject back a non-sinusoidal current into the electrical network.
Magnetic Resonance Imaging (MRI) | Ultrasound | Computerised Tomography (CT) scan | Laparoscopy/Laser based surgery | X-ray Machines | Robotic surgery | UPS | LED/CFL Lights | VSDs used in HVAC and building automation | Elevators and escalators

Harmonics leads to various kinds of malfunctions starting from distortion of displays to failure of costly microprocessors. Further, high harmonics can lead to interferences with telecommunications and computer processing to lead to loss or corrupt data.

Best way to reduce harmonics is to focus and minimize it at the source

- Choose equipment with lowest harmonic distortion
- Improve the supply transformers and conductors
- Install and use the right type and configuration of passive or active harmonic filters

Electromagnetic interference

EMIs are another major source of poor PQ in medical facilities. Again, most modern medical equipment act as EMI sources. EMIs are observed in medical devices as well as some general purpose devices used in medical facilities:

Ventilators and other life support equipment | Electrosurgical Unit (ESU) | Magnetic Resonance Imaging (MRIs) and X-ray systems | Pacemakers or defibrillators – implanted or external | ECG monitors | Infusion pumps

Other devices with EMIs

Emergency vehicle/services radios | Mobile phones | Radiofrequency identification (RFID) devices | Electromagnets

The major challenges faced on account of electromagnetic interference are artifacts or intermittent image quality problems in the medical diagnostics equipment.

Electromagnetic interference can be reduced by

- Reduce EMCs by buying equipment in compliance with IEC 60601-1-2 which are the recognized standards for testing electromagnetic compatibility of medical devices
- Use of isolation transformers
- Improvements in earthing systems

Key PQ issues

Leakage current

Every electrical equipment has a leakage current which can pass from the metal parts, ground or any components such as console or control systems. In normal conditions, if the patient comes in contact with leakage current it is shunted out via the ground conductor in power cord. However, if the grounding is improper the leakage current values could be higher and pose a risk to patient safety.

Leakage current is particularly of concern in
Intensive care units (ICUs) | Coronary care units (CCUs) | Emergency departments
Special procedure rooms | Cardiovascular laboratories | Dialysis units |
Various wet locations

Protection from leakage current

The Isolated Power Supply (IPS) as recommended by IS 3043:2018,31.1.6.0.

The earth is isolated from both lines in an isolated power system. If a dead short to earth or a leakage current occurs, the circuit breaker will not trip and therefore continuity of supply for the patient monitoring or life support equipment will be maintained. Any patient or staff accidentally touching a line will only experience safe values of capacitive return current.

Touch potential/neutral earth potential

IS:732, IS: 17512

The ground potential in medical locations (Group 1 and 2 facilities as defined in IS: 17512) should not exceed 25V regardless of the earthing system configuration.

Particularly, for Group 2 medical facilities which includes medical location where applied parts are intended to be used in applications such as intracardiac procedures, operating theatres and vital treatment where discontinuity (failure) of the supply can cause danger to life. In this context, an electrical conductor includes insulated wires such as cardiac pacing electrodes or intracardiac ECG electrodes, or insulated tubes filled with conducting fluids. The patients are at a risk of shock hazard. Even less than 25 mA current can be fatal to human heart and therefore must be considered as a high risk.

Key PQ issues

Unbalance/neutral overheating

If the medical-electrical equipment are not loaded in balance, the unbalance current flows through the neutral conductor of the immediate distribution, and if the cable sizing/current carrying capacity is not appropriate to the load connected, it may lead to overheating of the neutral conductor, making it a direct fire hazard

Loads
A/C equipment | Fans/Heaters | Display Screens | Ventilators | CT Machines
X ray machines | MRIs | Freezers

Mitigation is performed post testing

The load unbalance is to be mitigated as per IS 3043 Code for practice of earthing.
The mitigation may be performed on the following lines:

- Redistribution of electric loads
- Adding neutral compensators
- Installation of third harmonic filters
- Oversizing the neutral

Electrical capacity overloading

If there are no breakers in the circuit, an overload would cause the circuit wiring to overheat, which could melt the wire insulation and lead to a fire. If there is a breaker, frequent tripping is observed in case of overloading. Different circuits have different load ratings so that some circuits can provide more electricity than others.

Overloading can be observed in various devices in the electrical network

- Frequent tripping of the Breaker
- Dimming lights, especially if lights dim when you turn on appliances or more lights
- Buzzing outlets or switches
- Outlet or switch covers that are warm to the touch
- Burning odors from outlets or switches
- Scorched plugs or outlets
- Power tools, appliances, or electronics that seem to lack sufficient power

Importance of electrical safety in hospitals

ES hazards are a significant threat to hospitals and healthcare facilities. The ES of hospital facilities must be assessed and improved on an ongoing basis. Consequences of lapses in ES may lead to several problems ranging from health deterioration of patients to catastrophic fires. This study observed several lapses in hospitals for even the basic electrical safety compliances. Lack of knowledge, awareness and relatively lesser importance attributed to ES are the key reasons for such lapses.

In a typical hospital setup, large electrical supplies are found in diagnostic machinery. Working near or with such electrical devices demand high standards of electrical safety. The risks include organ injury, shocks, failure of vital human parts and in extreme cases burns from electrical fire and blasts. Contacts with electrical power due to damaged plugs, wires, missing components, inappropriate installation or unsafe work practices can lead to negative effects on human body. Such risks can be fatal in case of invasive or medical procedure involving high patient contact.

From disability to death, poor electrical safety can be severe. Moreover, the reputation of the facility is at a stake. It is therefore important to establish necessary measures to lessen the electrical safety risks.

The ES assessments should include:

- Assessment of critical electrical points for compliance as per CEA Safety Regulation 2010, IS 732, IS 3043, NBC 2016
- Electrical Safety for personnel and the entire electrical infrastructure right from the point of supply (HT/LT) to the point of use
- The condition of the Electrical Network Components, Electrical Connections, Protection Devices and Loading conditions will be visually inspected to check its safety compliance with the CEA regulations and Industry Standard
- Employee awareness, good/bad practices and operating methods will be reviewed during this audit and appropriate suggestions will be made to promote a safer Electrical Environment
- Faults on the Electrical Network based on mis installations of electrical components, lack of maintenance and wrong SOPs

Key electrical safety issues in healthcare facilites

Deviation in standard installation practices

When the electrical network installation in hospitals is not carried out adhering to design norms and industry standards, it may eventually lead to electrical hazards or failures such as shocks, electrical fires, power failures etc.

Examples

- Wrong earthing type in Group 2 medical facility areas
- No equipotential bonding provided in the electrical network & equipment
- Improper wiring at sockets
- Incorrect phase sequence in DBs
- Not powering emergency lighting with continuous power supply (UPS/DG)
- Not using lugs for the termination of cable
- Not using identification marks like ferrules stickers in the circuit

Mitigation

- IT earthing system should be used for Group 2 locations to increase the reliability of power supply during earth fault conditions. Group 2 includes locations like OT where the patient's body is opened so continuous supply of power is necessary. (IS 17512)
- Supplementary equipotential bonding, in medical locations equipotential bonding busbar, shall be provided near the distribution board to protect it from the earth faults (IS 17512)
- Phase and neutral wire should be placed correctly in the socket to ensure human safety & to avoid the damage of equipment (NEC 2011)
- Color code used for the phases neutral & earth should be as per industry standard to avoid short circuits.
- Group 1 & 2 medical locations should be supplied by alternate/emergency power supply to ensure continuity of the supply. (IS 17512)
- Lugs of proper size to be used for the termination of wires/cables to ensure that electrical connection/contact is made properly, not adhering to the same will lead to the hotspots & cause of fire if gone unnoticed.
- Use of ferrules/identification marks in circuits is very important for tracing of the connections during faults & also it aids in operation & maintenance of panels & DBs.

Non-compliance to design standards

When the electrical network and electrical equipment used in hospitals are not designed complying with national/international design standards, it leads to huge risks involving equipment damage, financial loss, breach of patient safety and more

Examples

- FRLSH cables not recommended in the design
- RCDs of right ratings are not installed in DBs/Sub DBs
- selection of conductors for carrying current is not as per its capacity/maximum load of the system
- Not keeping any room for expansion in the electrical network
- Earthing system not designed as per standards for Group 1 and Group 2 medical facilities
- Protective device coordination not carried out and settings aren't provided with the design

Mitigation

- Wiring used for fuses/breaker should be as per domestic/industrial standard to minimize the risk of fire (Flame retardant cables to be used). (IS 732)
- ELCB/RCD should be provided in the circuit for detecting leakage currents which will ensure safety of instruments and prevention of electrical shock hazards. (NEC 2011)
- wires/cables used in the panels & distribution boards shall be selected as per it's ampacity i.e. current carrying capacity to carry load current without getting heated which will lead to the stressing of insulation & can be cause of fire. (CEA 2010)
- Earthing systems used for group 2 medical systems should be strictly IT if more than one equipment is connected to the feeder to maintain the continuity of the supply & for group 1 & other locations other than TNC type earthing can be used as per standard. (IS 17512)
- Protective device coordination should be carried out to isolate faulty electrical equipment without affecting the supply to healthier one. This would avoid unnecessary trapping & reliability of the supply will be maintained.

Lack of preventive maintenance

It is necessary to carry out preventive maintenance frequently and regularly to ensure continuous & reliable output from the electrical network and the equipment. This also helps in finding out and getting rid of any abnormalities in the electrical network or the equipment before it transforms to be a major incident.

Examples

- Maintenance is carried out only when an issue has arisen
- Earth pits are not maintained
- Panels are not kept clean and dust free
- No breaker/switchgear maintenance is carried out
- Individual equipment maintenance - Transformer, DG, Chillers/ACs, UPS is not carried out
- No preventive maintenance schedule - only reacting with temporary measures when an issue occurs
- No issue log is maintained for future reference

Mitigation

- Temporary arrangements on the occurrence of short circuit like bypassing of switchgear or fuses should not be followed as it can lead to major tragedies like fire. Instead, the root cause of short circuit is to be investigated. Preventive maintenance should be carried out at regular intervals to minimize risk of unplanned interruptions, equipment breakdowns, financial losses, etc.
- Earth pits should not be dry or buried inside soil such that locating it becomes completely impossible. Rusting of earth flat strips should be checked to ensure that earth resistance is minimum.
- Distribution boards should be free from dust, dirt and moisture to prevent any short circuit incidents and space around panels/ distribution board should be free of any scrap/flammable material (CEA 2010)
- Maintenance of switchgear includes checking the trip contacts of breaker, ensuring proper working of the relays for detecting abnormalities, rack-in- rack out of the breakers, etc.
- Transformer should be checked for oil leakages. DG area should be kept free of waste/ scrap material, oil leakages should be arrested, DG batteries & panels should be free of dirt & moisture to ensure efficient operation of DG, similarly for Chillers/ACs, UPS etc.
- Log book consisting of all the records of inspection of electrical networks shall be available to keep the track of the issues & solution for the same. (IS 17512)

Lack of Periodic Testing

Periodic testing is an integral part of efforts to maintain efficiency, performance and reliability of the electrical network and electrical equipment. As an electrical network is a dynamic, ever changing entity, the only way to maintain its functionality is to keep carrying out periodic testing. Lack of electrical testing leads to unpredictability, unplanned interruptions, equipment failure and financial losses.

Examples

- Inspection of electrical panels are not carried out
- Routine testing such as thermography, capacity assessment and ELI as per standards is not carried out
- Electrical equipment such as Transformer, DG, Chillers/ACs, UPS are not routinely tested
- No electrical safety audits are carried out
- Power Quality audits are not carried out
- No testing reports are maintained
- The actionables based on testing reports are not carried out

Mitigation

- Electrical safety officers should carry out periodic inspections like
  - Thermography of panels & distribution boards - This will aid in finding hotspots due to loose connection, load unbalance, abnormalities in earthing.
  - Capacity assessment test-This test will help in finding loading on breakers & cables, load unbalance.
  - Earth loop impedance test for circuit breakers & sockets to be carried out to ensure earth loop impedance is minimum.
  - Three phase symmetry test- To find voltage unbalance, current unbalance, Neutral to earth voltage, leakage currents
- Testing of the equipment should be carried out to ensure efficient output is delivered by the equipment after carrying out maintenance, e.g. transformer should be checked for voltage ratio, output power, insulation resistance, etc.
- Electrical Safety audit is a valuable process in identifying, assessing organizational and operational safety systems, policy, practices and their effectiveness in accident prevention programs. Electrical safety audits shall be conducted to ensure that the facility is adhering to the standards.
- Power quality audits to be carried out periodically to ensure the quality of supply is compatible with the variety of loads connected in a healthcare facility as per national and international standards.
- Records should be maintained for each periodic testing in form of reports to be used as historical data
- The recommendations provided in the testing reports should be applied immediately to mitigate the electrical hazards determined by the the specific test

Long term Electrical Safety and Reliability

Mitigation of immediate risks based on one time Electrical Testing and Safety Audit is merely an initial action. Electrical Networks are dynamic, everchanging entities and the only way to ensure improvement in Electrical Safety and Reliability of the complex dynamics of a Healthcare facility is through continual Risk Management.

The goal should be Continual Electrical Network Risk Management, which using latest ICT and IIoT interventions can very easily help in providing a holistic view of the continual risks that a facility is exposed to and actions that need to be taken on a periodic/continual basis. Mobile and cloud based applications built on the backbone of state, national and international regulations and standards focusing on the electrical infrastructure, are now available.

These provide simple user friendly interfaces for even healthcare administration professionals to use along with their electrical contractors/electricians. These coupled with IIoT based Power analysers, load managers and other sensors, are being deployed on-demand to save on high capital expenditure and thus are easily providing all the data streams that are required to assess the electrical network health akin to the human body requiring various tests/scans to understand the overall health.

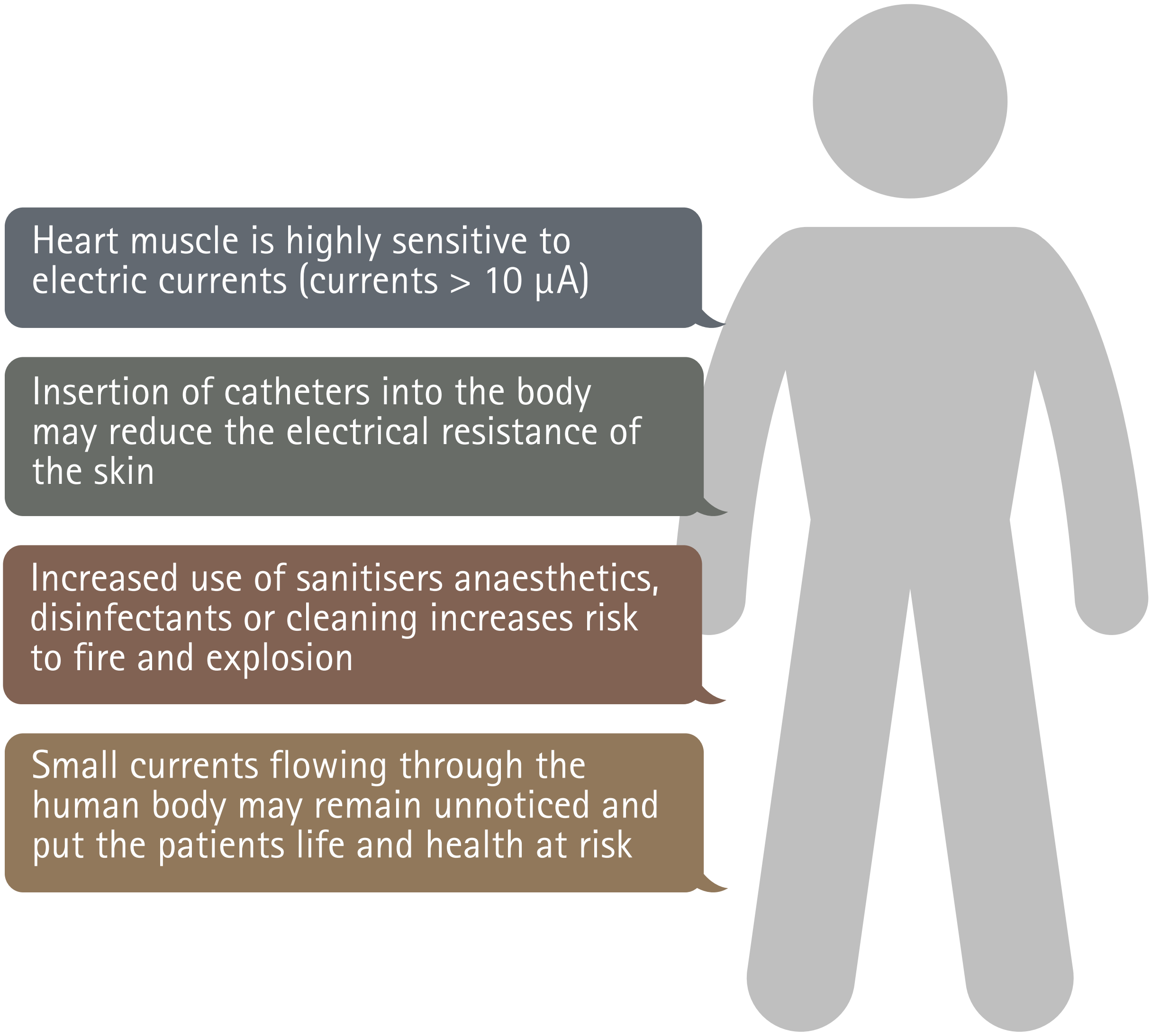
Further automated analytics and report generation engines are able to process the data and generate automated, actionable reports to ensure risk assessment and mitigation actions can be taken on a continual basis, thus ensuring safety of most importantly human lives involved as well as reliability of overall electrical network infrastructure.

Last but not the least, it can help the healthcare facilities to attain compliance with respect to various state and national regulations that can become challenging for small and medium healthcare facilities given the lack of dedicated manpower for managing electrical networks and infrastructure.

Last but not the least... Patient safety

Impact of PQES on patient could lead to accidental deaths.

As modern medical treatment relies on body functions temporarily or continuously supported or substituted by medical electrical devices, the quality of power matters the most:



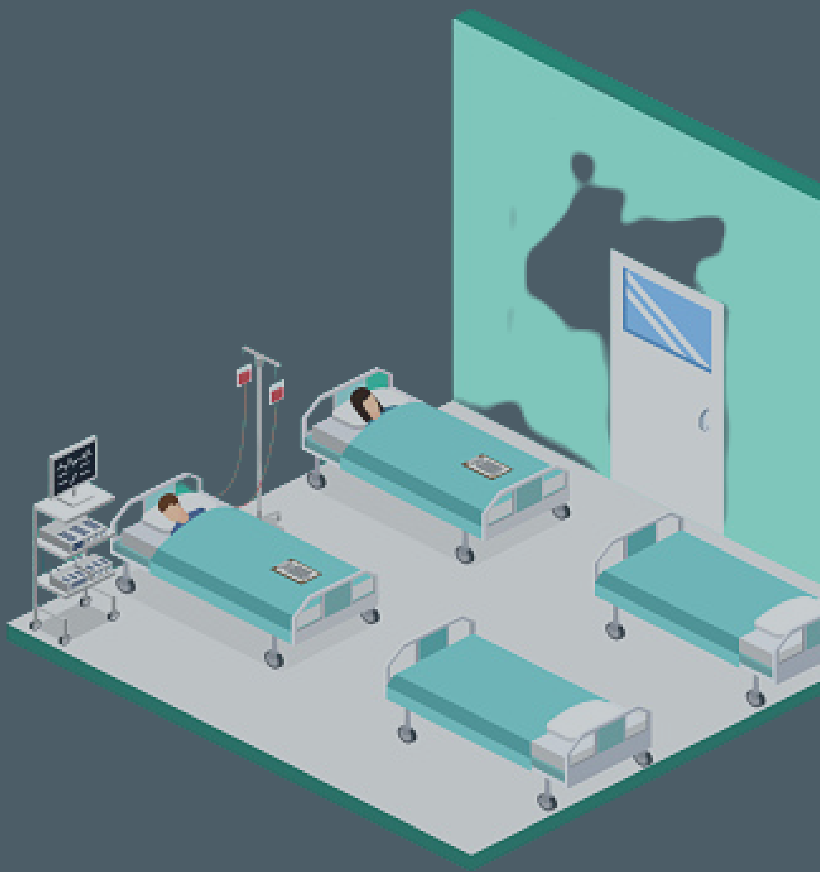
> Above all, the critical care facilities require availability of the quality power supply must be guaranteed, even under fault conditions.

Standards & regulations for Power Quality and Electrical Safety

National Electricity Code specifies the electrical safety norms for Medical Establishments

1. Various PQ standards and regulations
2. IS and National Building code for electrical installations
3. Guidance, regulations and norms issued by local Govt. bodies and Utilities

> A total of 13 standards can be considered to be critical to electrical installations in medical facilities



Electrical Standards for PQES of hospitals

Minimum standards of hospital facilities are defined by the Clinical Establishments (Registration and Regulation) Act, 2010. The act is enacted by the Central Government to provide for registration and regulation of all clinical establishments in the country with a view to prescribe the minimum standards of facilities and services provided by them.

The use of medical electrical equipment on patients undergoing intensive care (of critical importance) has called for enhanced reliability and safety of electrical installations in hospitals so as to improve the safety and continuity of supply which is met by application of this standard. Variations of the standard to further enhance safety and reliability are acceptable.

Clinical Establishment Act Standards for Hospital defines a hospital as a

- Clinical establishment providing patient treatment by qualified and trained staff and equipment through Allopathy - Modern system of medicine; where the patients are 'admitted' and stay overnight or more and they are referred as 'inpatients'
- While some patients may go to a hospital just for diagnosis, treatment, or therapy and then leave, they are referred as 'outpatients' without staying overnight.
- Hospitals have facility to admit and care for inpatients whilst the other clinical establishments are described as clinics/polyclinics or day care centres.

A hospital can be situated in rural or urban setting. It can be run by Public Sector (Central government/State government/Local government/Public Sector undertaking/Registered Society etc) or by Private Sector (Individual Proprietorship/Registered Partnership/Registered Company /Co-operative Society/Trust /Charitable etc).

Hospital Level 1(A) :

General Medical services with indoor admission facility provided by recognised allopathic medical graduate(s) and may also include general dentistry services provided by recognized BDS graduates. Example: PHC, Government and Private Hospitals and Nursing Homes run by MBBS Doctors etc.

Hospital Level 1(B) :

This level of hospital shall include all the general medical services provided at level 1(A) above and specialist medical services provided by Doctors from one or more basic specialties namely General Medicine, General Surgery, Pediatrics, Obstetrics & Genecology and Dentistry, providing indoor and OPD services.
Level 1(A) and Level 1(B) Hospitals shall also include support systems required for the respective services like Pharmacy, Laboratory, etc.

Example: General Hospital, Single/ Multiple basic medical Specialties provided at Community Health Centre, Sub Divisional Hospital, and Private Hospital of similar scope, Nursing Home, Civil / District Hospital in few places etc.

Medical Locations

Locations intended for purposes of diagnosis, treatment including cosmetic treatment, monitoring and care of patients.

Group 0
Medical location where no applied parts are intended to be used and where discontinuity (failure) of the supply cannot cause danger to life.

Group 1
Medical location where discontinuity of the electrical supply does not represent a threat to the safety of the patient and applied parts are intended to be used:
(a) externally; or
(b) invasively to any part of the body, except where Group 2 applies.

Group 2
Medical location where applied parts are intended to be used, and where discontinuity (failure) of the supply can cause danger to life, in applications such as:
(a) intracardiac procedures; and
(b) vital treatment and surgical operations.

Safety Power Supply Sources (Backup Supply)

For Group 2 Medical Locations
Change-over period shall not be > 0.5seconds. The backup time for such safety power supply source (say UPS) should be at least 3 hours on raw power and if backup DG Sets are available, then at least 1 hour.
n medical locations of group 2, the resistance of the conductors, including the resistance of the connections, between the terminals for the protective conductor of socket-outlets and of fixed equipment or any extraneous-conductive-parts and the equipotential bonding bus bar shall not exceed 0.2 Ω. The equipotential bonding bus bar shall be located in or near the medical location

For equipment such as Safety lighting and other Group 1 services
Areas where humans may not be directly in contact with the electrical system, the change-over period shall not be > 15 seconds. The same should be capable of running for at least 24 hours.

For other services such as sterilization equipment, HVAC, waste disposal, cooking equipment, building services etc.
The change-over period can be > 15 seconds and the same should be capable of running for at least 24 hours duration.

While hospital facilities are defined by the central act, several other institutes are engaged in different capabilities to ensure compliance and defining more specific requirements in commissioning, operations and maintenance. Some of the institutions that hospitals must oblige for various approvals include National Accreditation Board for Hospitals and Healthcare Providers (NABH), state regulatory authorities such as Electrical and Fire safety, Food license authority etc.

These requirements are typically much more stringent than commercial or industrial facilities.

Hospitals, like most other commercial buildings, need the following to begin operations

- Occupancy certificate
- Completion certificate.
- Fire NOC, if the building where the clinic/ hospital is established is more than 15 meters tall

Important Electrical Standards for hospitals

The standards mentioned here apply to electrical installations in medical locations so as to ensure safety of patients and medical staff. These requirements, on a high level, refer to hospitals, private clinics, medical and dental practices, health care centres and dedicated medical rooms in the workplace.

This is not an exhaustive list by any means and primarily the attempt is to list the most relevant standards from an electrical safety perspective.

Standards	Indicative scope
IS 17505 (Part 1) – Fire Survival Cables	• Specification for Thermosetting Insulated Fire Survival Cables for Fixed Installation having Low Emission of Smoke and Corrosive Gases when Affected by Fire for Working Voltages up to and including 1100 Vac and 1500 Vdc
IS 17512 Requirements for Electrical Installations in Medical Locations	• This section applies to electrical installations in medical locations to ensure the safety of patients and medical staff. • The requirements refer to hospitals, private clinics, medical and dental practices, healthcare centres and dedicated medical rooms in the workplace. • The standards also applies to electrical installations in medical research.
IS 732: 2019 Code of Practice for Electrical Wiring Installations	• The code regulates the design of installation, selection and erection of equipment and inspection and testing of the wiring system.
NEC SP30 – National Electrical Code – Electrical Installations in non-industrial buildings (Section 4 Medical Establishments)	• Safety requirements for electrical equipment used in medical practice are covered IS 13450 series. • Additional safety provisions in the electrical installations of medically used rooms and medical establishments are covered in this Section of the Code. • Part 3/Section 4 of this Code applies to the electrical installations in medical establishments. This Section is also applicable to rooms for veterinary medicine and dental practice. • Safety measures are further divided into a number of provisions where Provision P0 shall be applicable to all buildings containing medically used rooms and Provision P1 shall be applicable for all medically used rooms. • NEC 2023 has been launched and more detailed provisions with respect to Medical establishments have now been included
IEC 60332-1-2 Electrical Cable Flammability Test	• Insulated cables are designed with flame retardant materials and additives that offer protection against vertical flame propagation. Instead of letting the fire spread, insulated cables and wires can often extinguish flames on their own. The purpose of the IEC 60332-1-2 test is to determine whether your cables can minimize fire damage. • Use of cables with flame retardant additives must pass the IEC 60332-1-2 flame test. The cables passing the test are able to extinguish itself after the flame is removed and the fire goes out before damaging the area within 50 millimeters of the top of the cable.

Standards	Description
Model Power Quality Regulations as proposed by the Forum of Regulators in India and in process of adoption by various state electricity boards and regulatory bodies	• Frequency Deviations (tightened band from 0.5 Hz to 0.15 Hz) • Harmonics (to follow IS 17036, IEEE 519-2014 and IEC 61000-4-30 Class-A for PQ Analysers) • Voltage Variations & Flicker (Short/Long Term Sensitivity as per IS 17036) • Voltage Unbalance (less than equal 2%) • Voltage Dips and Swells (Duration from 10 ms up to and including 1 min) • Voltage Transients (User to apply Surge Suppression Devices) • Supply Voltage Interruption (Voltage drop of 10% - short (20 ms to 1 min) and long (3 mins+) • Maintaining the Power Factor (penalty for injecting Current Harmonics is introduced)
National Building Code of India (2020)	• National Building Code of India is published by Bureau of Indian Standards and it is recommendatory document. Guidelines were issued to the States to incorporate the recommendations of National Building Code into their local building bylaws making such recommendations as mandatory requirement.
Electrical and Fire Safety compliance as per NABH norms	• Hospitals are bound by the NABH guidelines which must be followed in design, construction and operations to ensure safety and quality patient care. Under the Objective 3 of Facility Management and Safety (Chapter 8 - Objective 3) recommendations, conducting electrical safety audits for the facility is considered as an achievement. • Fire NOC • Separate engineering plant with sufficient space for DGs, Compressor and Vacuum Plants • Infrastructure for fire emergencies such as fire water tanks, fire exit routes etc. to be planned as per National Building Codes guideline
Standards references: Relevant clause as per IS 732 near each inspection	• Method of protection against electrical shocks • Selection, location, setting as applicable for • Conductors for current carrying capacity • Coordination of protective and monitoring devices • Overvoltage protective devices (SPD) • Suitable isolating and switching devices • Neutral and protective conductors

Standards	Description
Testing (IS 732:2019 & IS 17512:2021)	• Continuity of conductors • Insulation resistance • Floor and wall resistance/impedance • Insulation resistance (SELV, PELV or electrical separation, floor and wall resistance, polarity test, voltage drop, insulation monitoring deices of medical IT systems, AV systems • Measurements of leakage current of the output circuit and enclosure of medical IT transformers in no-load condition • Polarity test • Effectiveness of automatic disconnection of supply • Effectiveness of addition protection • Phase sequence • Functional Tests • Voltage drops
IS 13450-2-5 (2009): Medical Electrical Equipment, Part 2:	• Particular Requirements for the Safety, Section 5: Ultrasonic Physiotherapy Equipment • Electro-Magnetic compatibility – Equipment is not allowed to cause electromagnetic interference above a certain level under any conditions of practical use nor to degrade in safety and performance in a normal electromagnetic environment' • Actual output power and effective intensity must be indicated directly. The specified accuracy is considered to provide an adequate degree of safety and take into account the errors inherent in ultrasound power measurement. • All equipment should be suitable for treatment of the patient with low power • Modest requirement should protect against excessive output variations with mains voltage fluctuations likely to be encountered in practical use • Accuracy requirement of the timer is considered adequate in view of the accuracy requirement of the output power • The product should be marked with the Standard Mark
IEC 62353	• Medical Electrical (ME) Equipment - recurrent test and test after repair of ME equipment defines the requirements for electrical safety testing of medical electrical (ME) equipment and systems during routine intervals.
ISO/IEC 80601 Series	• Medical electrical equipment basic safety and essential performance • Equipments such as respiratory gas monitors, ventilators, robotic assisted equipment

Documentation as recommended by various standards

- Diagrams, documentation and operating instructions
- Plans of the electrical installation together with records, drawings, wiring diagrams and modifications thereto, as well as instructions for operation and maintenance, shall be provided for the user.
- NOTE Drawings and wiring diagrams should be in accordance As per CEA Chapter 2, Cl. 11 (3), NEC 2011.6 (Design & Installation of Electrical Distribution) 6.1, for single line diagram and IEC 61082-1.

The relevant documents are in particular:

- Block diagrams showing the distribution system of the normal power supply and power supply for safety services in a single-line representation. These diagrams shall contain information on the location of the sub-distribution boards within the building;
- Main and sub-distribution board block diagrams showing switchgear and control gear and distribution boards in a single-line representation
- Schematic diagrams of controls;
- Instructions for operation, inspection, testing and maintenance of storage batteries and power sources for safety services;
- Computational verification of compliance with the requirements of standards (IEC 60364 7-710)
- List of loads permanently connected to the power supply for safety services indicating the normal currents and, in the case of motor-operated loads, the starting currents (IS:17512, Regulation No- 7.1.1.3 Diagrams, documentation and operating instructions)
- A logbook containing a record of all tests and inspections which require to be completed prior to commissioning. (IS:17512, Regulation No- 7.1.1.3 Diagrams, documentation and operating instructions)

Guidelines issued by Directorate General Fire Safety, Civil Defense & Home Guard to hospitals and nursing homes

Key recommendations

- Permanent hospitals should implement all the provisions as stipulated in National Building Code of India
- Temporary Covid hospitals to implement all the provisions as stipulated in IS 8758
- Given the reports of major fire accidents in hospitals are due to the ignition of fire from electrical wiring and equipment, final wiring in all hospitals shall be protected as per recommendations guided by CEA regulations

IoT based systems to ensure protection

- Arcing risk
- Short circuit
- Overcurrent
- Earth leakage
- Overvoltage
- Under voltage
- Phase loss
- Loss of supply to neutral

Power quality to be maintained as

- Detection of loads with high harmonics as per IEEE519
- IS 12360 and high inrush, low power factor and unbalanced loads
- Voltage quality to be maintained as per IS 17036

Periodic tests

Periodic tests of electrical installations in hospitals as recommended by a sample guideline issued by a state in India

36 months

- Equipotential bonding, leakage currents of transformers

12 months

- Functional testing of changeover devices, insulation monitoring, protective devices, tripping of RCDs
- Transformers
- Back-up Power Diesel Generators and UPS
- Critical Diagnostic and Imaging equipment

Wiring systems

- Any wiring system within Group 2 medical locations shall be exclusive to the use of equipment and fittings in that location.
- Use copper wires in the wiring
- Use armoured cables for mechanical durability
- Use minimum joints, ideally, avoid joints
- Find root cause of the fault in case of tripping
- Clauses of IS 732 must be verified during installation and audits and ensure compliance on continual basis. IoT based smart DB/optimiser must be installed immediately to prevent fires
- Submit data and reports, gathered automatically, of compliance to IS 732 each quarter

Switchgear and control gear

- Protection of wiring systems in medical locations of group 2
- Overcurrent protection against short-circuit and overload current is necessary for each final circuit. Overload current protection is not allowed in the feeder circuits upstream and downstream of the transformer of medical IT-system. Fuses may be used for short-circuit protection.

Lighting circuits

- In medical locations of group 1 and group 2, at least two different sources of supply shall be provided for some of the luminaries by two circuits. One of the two circuits shall be connected to the safety service.
- Emergency lighting units to provide lighting in emergency for the specified duration so that the failure of normal supply does not cause a total extinction of lights and allows the normal activities to continue or to be terminated safely.
- An automatic switching system is invariably provided to switch on/off the emergency lighting units in the case of failure/restoration of normal supply.

Emergency Power

- Hospital facilities must maintain generators that will restore operations to any life-critical equipment within 10 seconds of an outage.
- At any instance, generators must have enough fuel to operate at full capacity for at least two hours. Safe fuel storage area that is sufficiently at a distance from the power source must be marked It is recommended that at least enough fuel for 24 hours of operation — and up to 96 hours in areas where longer power outages occur.
- No interruption of the power supply of the essential circuits of the hospital for more than 15s, life-supporting equipment for more than 15s and operating lamp for more than 0.5 s (IS 17512 as per Provision 1)

Earthing

- Generally a power supply system including a separated protective conductor is required (TN-S-system)
- Earthing systems used for group 2 medical systems should be strictly IT if more than one equipment is connected to the feeder to maintain the continuity of the supply
- In its completed form the equipotential bonding network may consist partly of fixed and permanently installed bonding and partly of a number of separate bondings which are made when the equipment is set up near the patient. The necessary terminals for these bonding connections should be present on equipment and in the installation.

Sockets

- Each patient bed location in group 2 medical location shall be provided with a minimum of eight non-locking type 125V 15A or 20A receptacles & at least 4 of which should be supplied by critical branch circuit. (emergency power supply)
- Each patient bed location in group 1 medical location shall be provided with a minimum of fourteen non-locking type 125V 15A or 20A receptacles & at least 7 of which should be supplied by critical branch circuit. (emergency power supply)
- Each operating room shall be provided with a minimum of thirty six non-locking type 125V 15A or 20A receptacles & at least 12 of which should be supplied by critical branch circuit. (emergency power supply)
- Each receptacle shall be wired in accordance with NFPA 70 to ensure correct polarity.
- An isolated ground receptacle shall not be installed within a patient care vicinity.
- Isolated grounding receptacles installed in branch circuits for patient care spaces shall be connected to an insulated equipment grounding conductor in accordance with 250.146(D) o f NFPA 70
- In clinical laboratories: Outlets with two to four receptacles, or an equivalent multioutlet assembly, shall be installed every 0.5 to 1.0 m (1.6 f t to 3.3 ft) in instrument usage areas, and either installation shall be at least 80 mm(3.15 in.) above the countertop.

Hospital Lift/Elevators

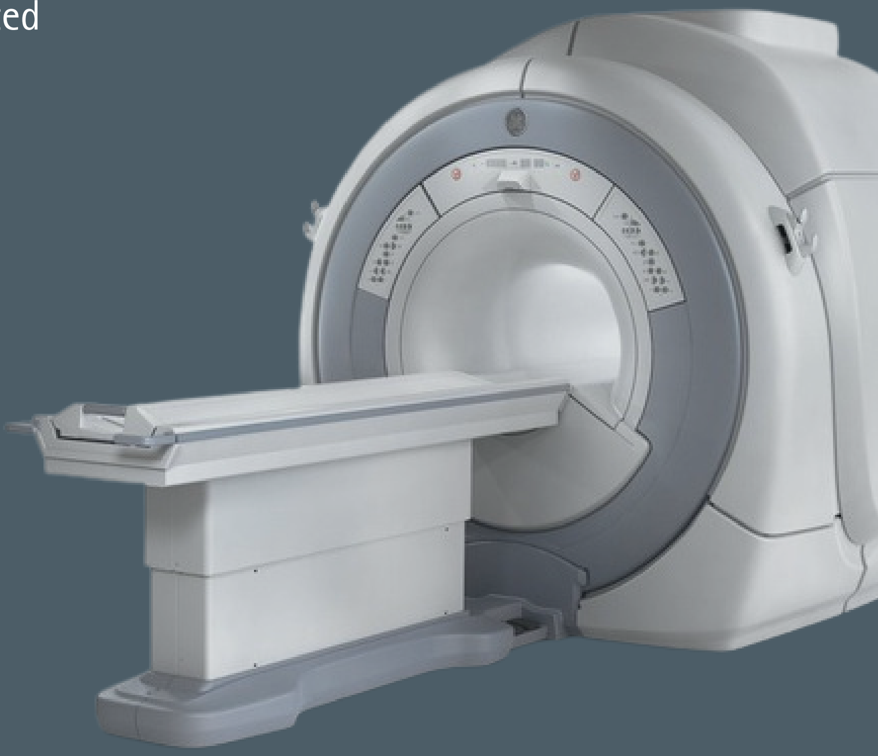
- Properly designed lift should be able to accommodate a bed/stretcher along its depth with three attendants.
- Lift should be supplied with emergency supply & emergency stop switch should be accessible, identifiable & in working condition.
- Lift floor should be free of oil water & other scrap material

Inside the mind of hospital management & staff

Insights from interviews of hospital owners, managers and executives

1. 72 Hospitals were approached: Only 15% of the hospitals agreed to be interviewed for the study
2. Low awareness, lack of dedicated resources emerged as key hurdles in improving ESPQ
3. Economic benefits of preventive maintenance of electrical installations is often not understood well or underrated

"Lack of vendor neutral knowledge source is major challenge in enabling good power quality and improved electrical safety



72 Hospitals were approached: 22 respondents from 11 hospitals agreed to be interviewed for the study

The hospital management agreed and provided the third-party agencies with complete access to their facility on an as-is basis. Considering sensitive characteristics of the data to be collected, it was decided to provide complete anonymity to the hospital facilities that had agreed for the interview and subsequent on-field study. The reports and analysis from the power quality study and recommendations were submitted to the respective hospitals for further action.

The observations presented below attempt to best capture and classify the interview responses from c the 22 respondents. Separate interviews were conducted for management personnel (hospital owners, senior doctors) leading the hospitals and staff responsible towards electrical installations (technical or non-technical team members from related departments).

Only 1 of the 11 hospitals have an emergency SOP accessible, reviewed and updated

PQ is not part of any hospital electrical network maintenance whatsoever

Only one hospital has previously carried out a power quality audit on their electrical network

Only 3 of the 11 hospitals carry out periodic electrical testing

The testing is limited to specific equipment, not adhering to the national and international testing standards, and only once or twice a year. Barring a single hospital, no testing records are maintained.

Many of the hospitals carry out electrical maintenance on need to repair basis

Maintenance is conducted by a local vendor, others carry out maintenance only on specific electrical equipment. None of the hospitals carry out maintenance on the entire electrical infrastructure.

Out of 11 hospitals, 6 do not have any technical person to look after the hospital's electrical network

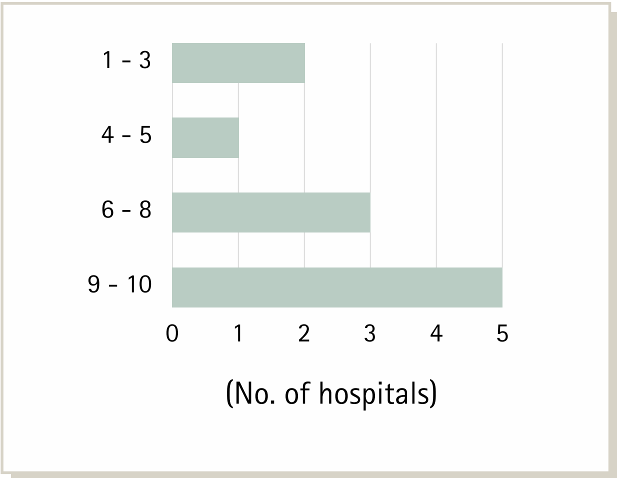
2 hospitals have persons that are not technically trained, and only 3 hospitals have a dedicated technical person

8 of the 11 hospitals do not have any Electrical Personal Protective Equipment (PPE)

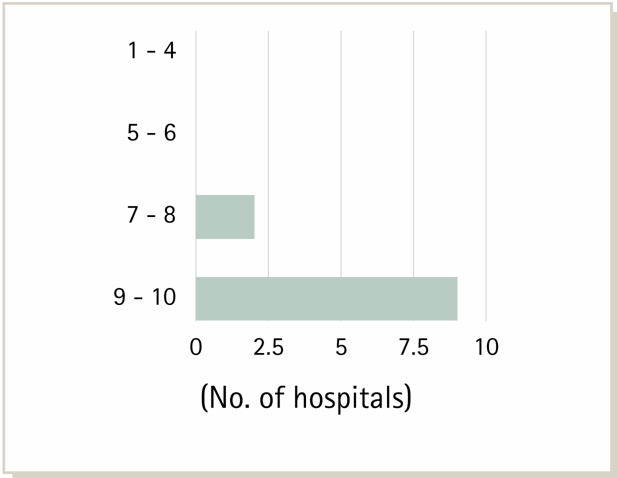
and none of the hosptials audit the PPEs for their health, safety and useability

Analysis of management personnel interviews

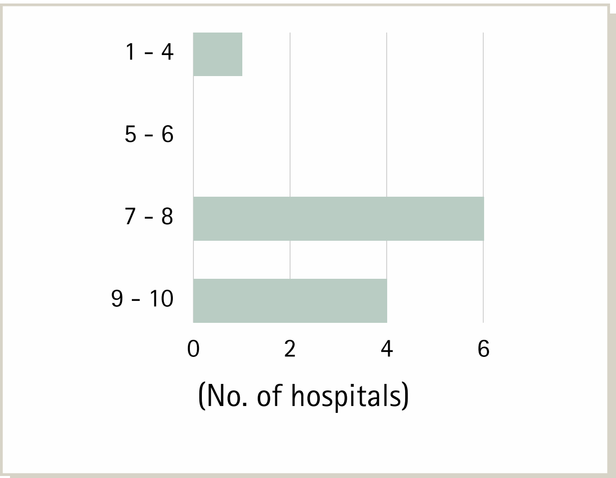
Rate on a scale of 1 to 10 electrical power is one of the most critical resource for healthcare



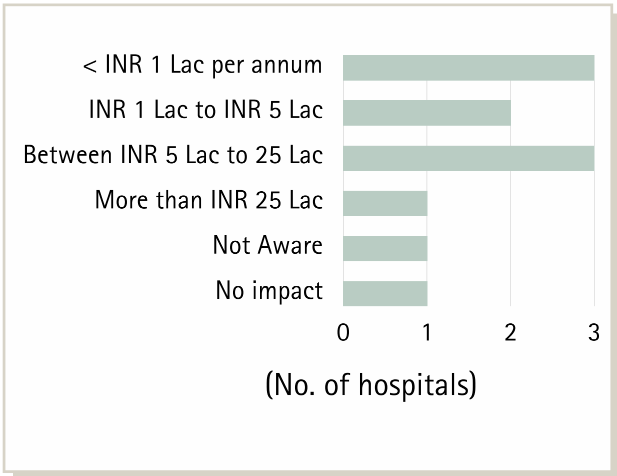
Are you sensitive to the role played by the electrical distribution linked to the daily operations and downtime at your healthcare facility?



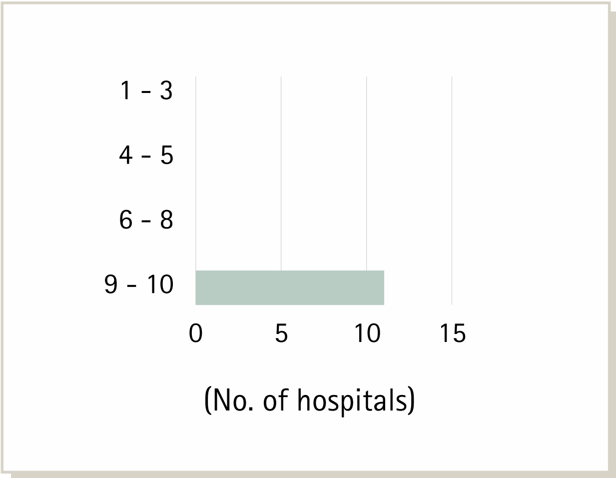
On a scale of 1 to 10, what would you rate as the economic impact of Power Quality on the operations of the healthcare facilities?



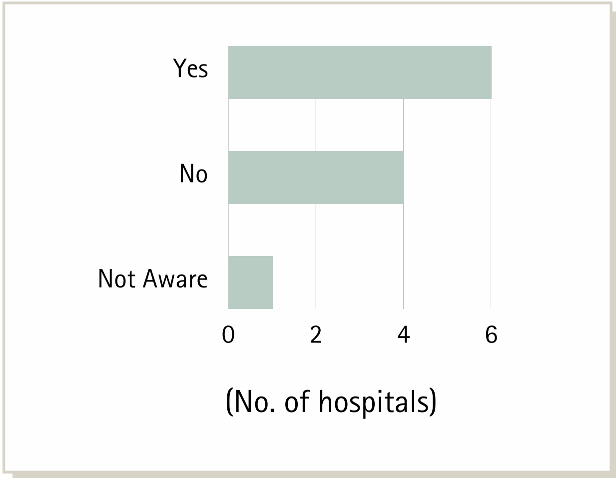
Could you quantify the impact of Power quality in terms of economics (INR)



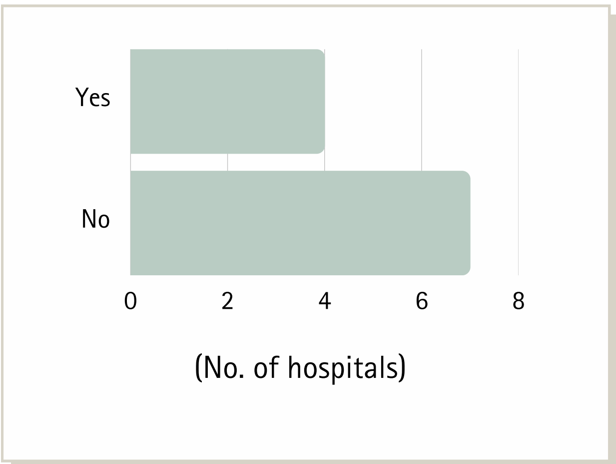
Rate on a scale of 1 to 10 How important is Electrical Safety when it comes to healthcare facilities with 1 being not important and 10 being extremely important?



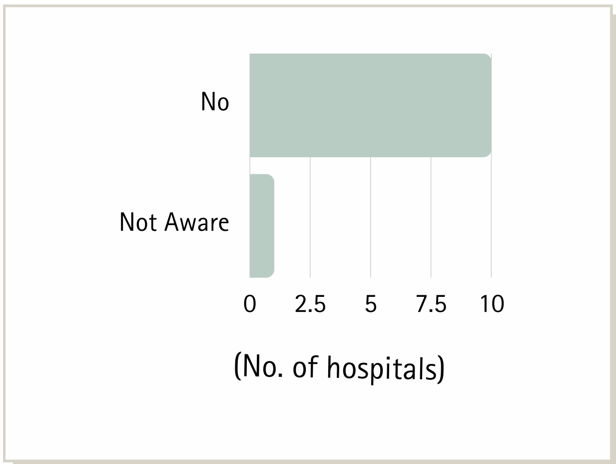
Are there any specific actions taken by the management to ensure Electrical Safety



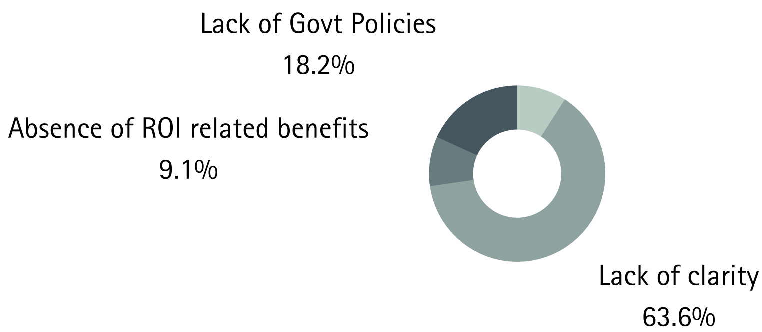
Is there an annual budget allocated for maintaining and upgrading Facility's electrical network?



Is there a Power Monitoring system set up for the network?

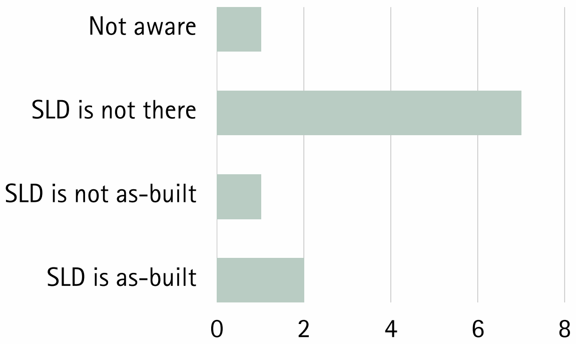


Can you enlist the top challenges your Facility faces in terms of Power quality and reliability?



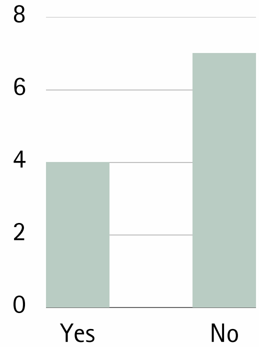
Analysis of staff interviews responsible for electrical installations

Is SLD available?



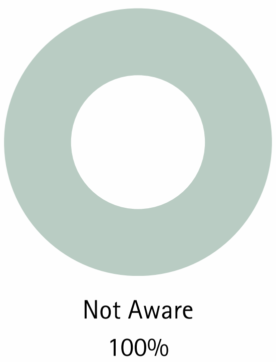
Lapses in SLD are high risk; observed in 9 of the 11 Hospitals

Is there a Safety Power Supply for the critical areas?



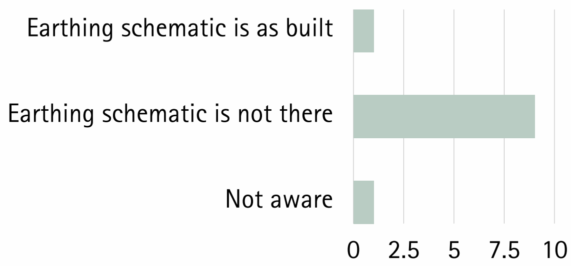
More than 50% hospitals do not have a safety power supply for critical areas

What type of earthing distribution system is installed?



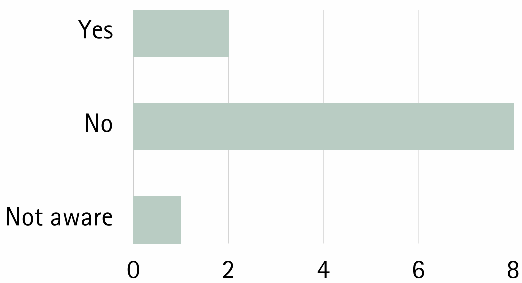
Lack of awareness indicates high earthing related risks that could be left unattended

Has earthing schematic been built?



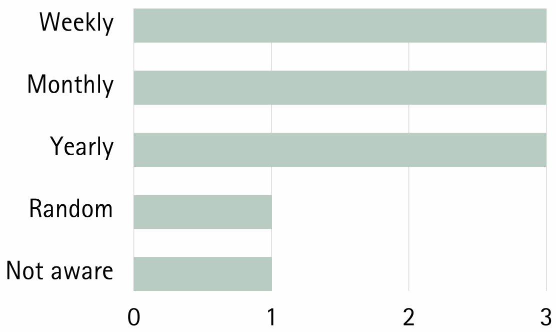
Poor know-how and documentation increases response time and delegation

Are Utility Power Failures commonly observed?



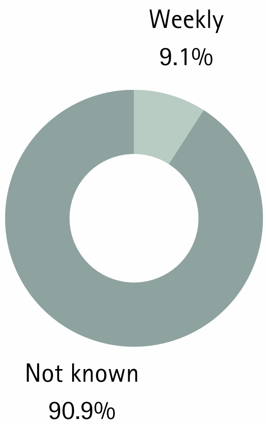
Reliability of power continues to be a risk in healthcare delivery

What is the frequency of Utility Power Failures?



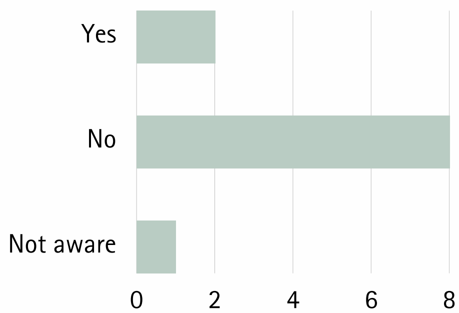
Over 50% of the hospitals experience power failures every month

How frequent has been flickering lights issue?



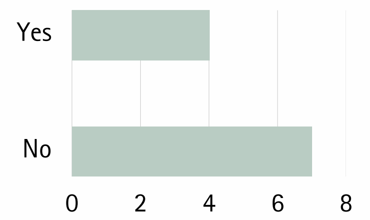
Indication of improper electrical work or serious underlying PQ problem

Have there ever been issues related to excessive voltage and current harmonics



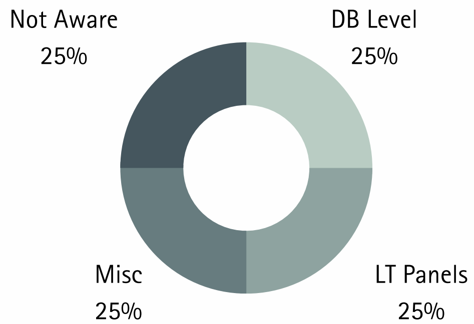
Lack of awareness or availability of data on harmonics - a key reason for poor PQ; observed in all the 11 hospitals

Any breaker tripping situation in the electrical network

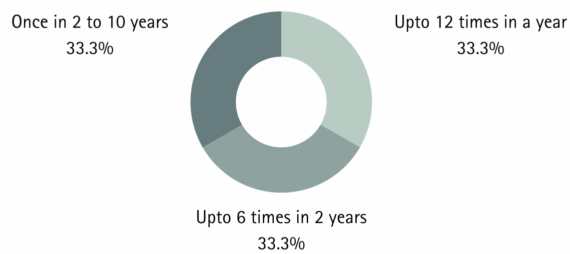


A majority of the facilities do not seem to have information on nuisance tripping - a key indicator of poor PQ

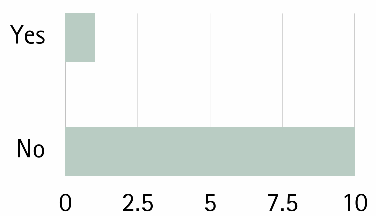
What level does electrical tripping happens



How frequent is the issue of electrical tripping

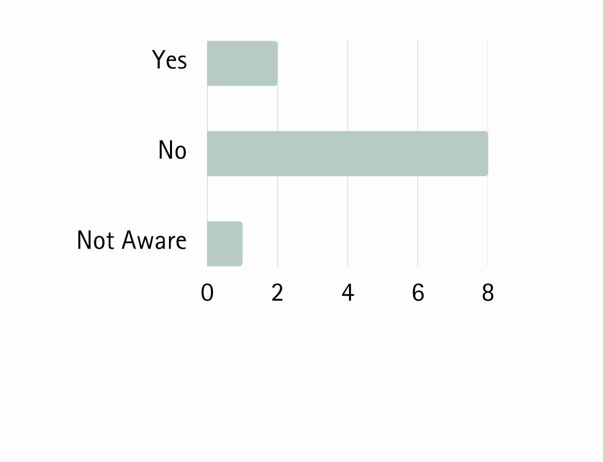


Any actions have been taken to resolve the issue? please describe in detail

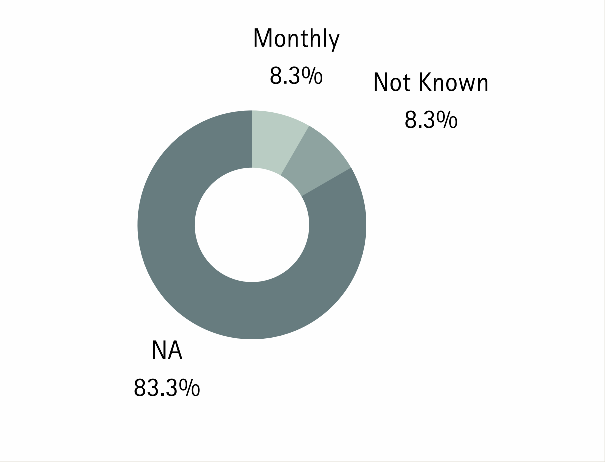


Over 90% of the personnel responsible for electrical installations had taken no action to resolve the nuisance tripping observed in the hospital facility. The tripping event pose a serious and high risk to patient safety.

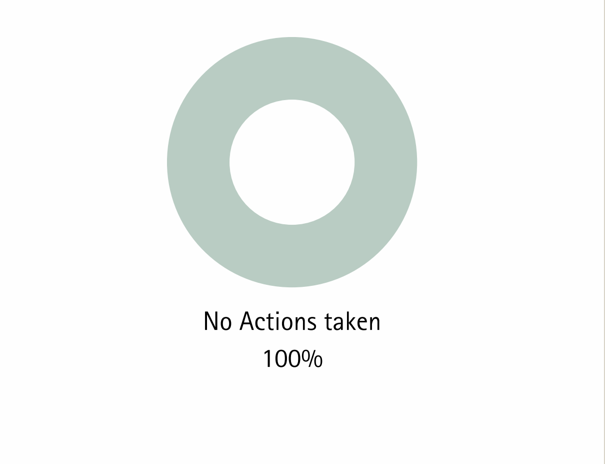
Any electronic equipment malfunction due to electrical supply?



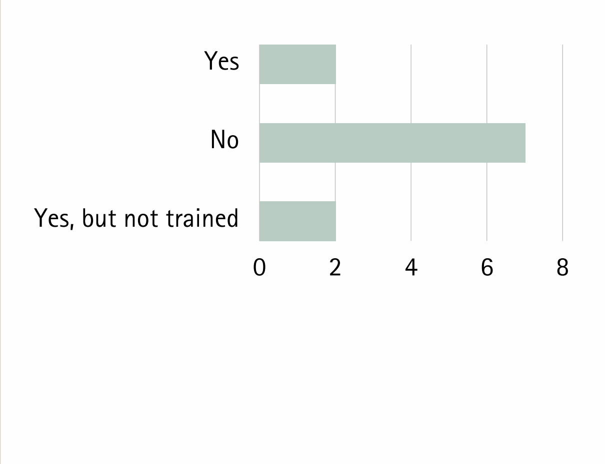
How frequent is the issue...



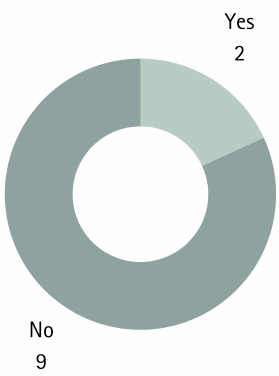
Any actions are taken to mitigate the above issue



Is there a dedicated person to manage electrical network



Has the DG ever tripped due to sudden loading or by any other reason?

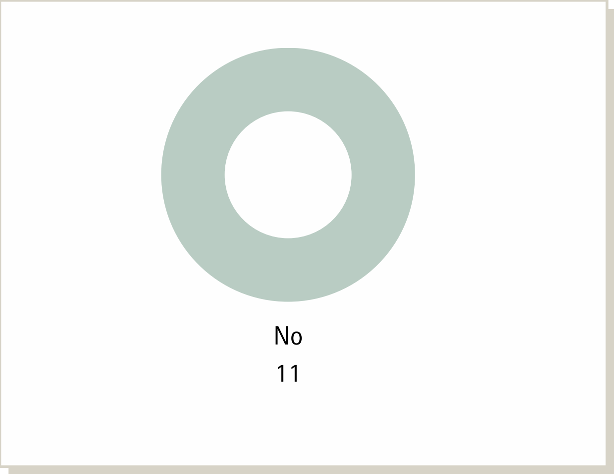


Reasons for DG tripping

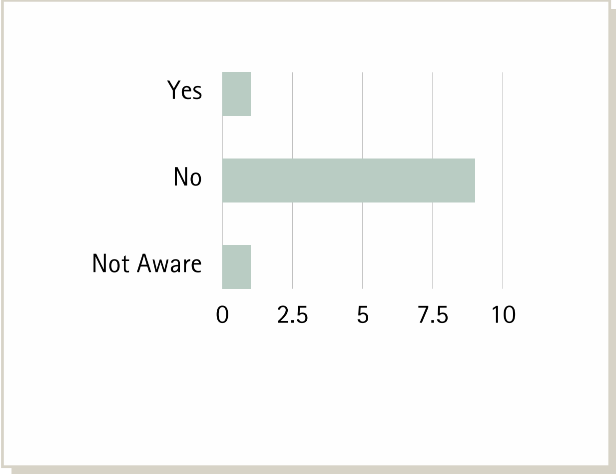
DG cable was damaged by rats, rewiring was done

Trip was due to sensitive imbalance, setting were changed accordingly

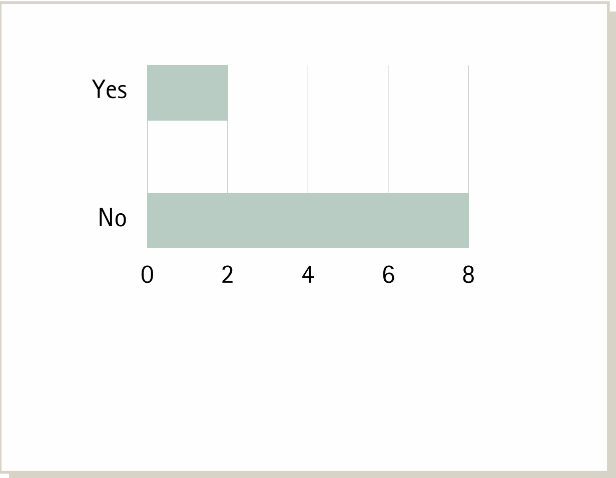
Is power quality a part of the maintenance?



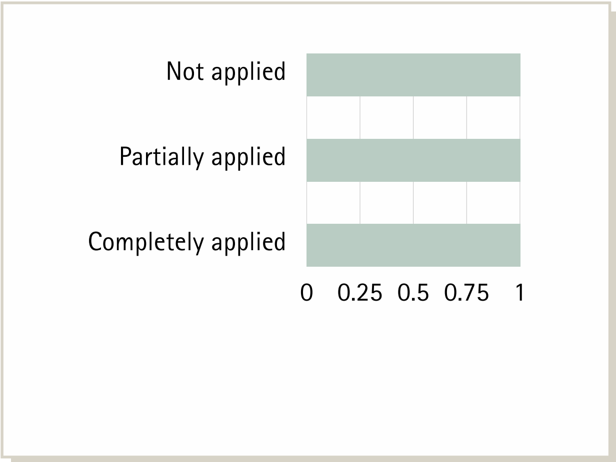
Has there ever been a third party Power Quality Audit on the network?



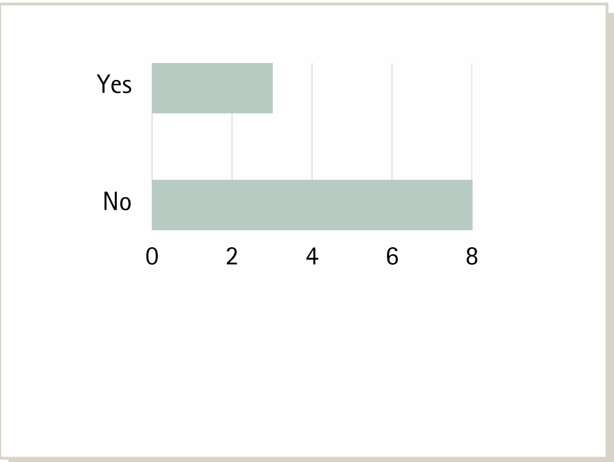
Is Periodic Electrical testing for equipment usually carried out at the Facility?



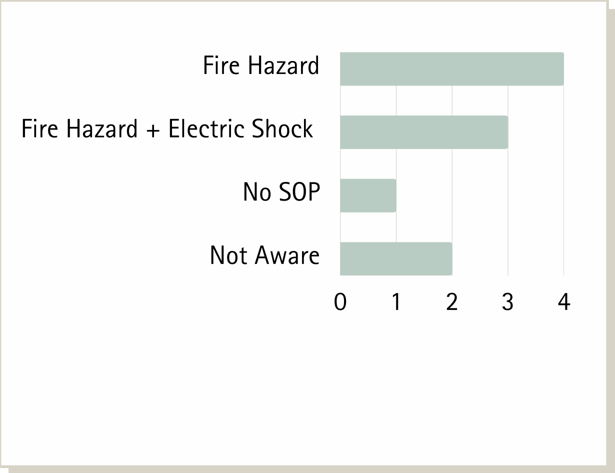
Are recommendations from the safety audit report been applied?



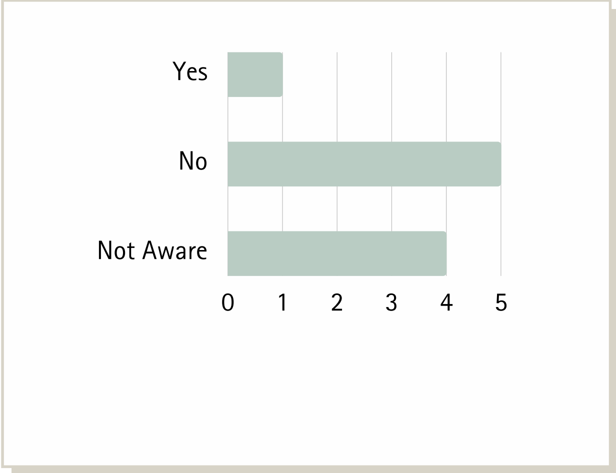
Are there any Electrical Safety Audits carried out on the facility?



Are there any SOPs for operating critical electrical equipment or infrastructure



Is the SOP accessible and routinely reviewed?



Ground Reality: Observations from on-field Power Quality & electrical safety audits

Without safety and reliability, growth is only a risk for patients and staff at the hospital

1. Extensive PQ Audits and Electrical safety audits were conducted at hospitals

2. Poor power quality, at source and within the facility increases risks to safety and reliability

3. Several serious lapses in electrical safety were observed which are easy and quick to prevent

> The poor state of PQ and electrical safety can be transformed significantly with periodic and continuous monitoring

The state of PQ: Insights and observations

In late 2021 and early 2022, PQES audits were carried out on select hospitals in Maharashtra to understand the gaps in compliance, and identify various risks associated with hospital facilities. The detailed field study on these hospitals were conducted by expert third party agencies. This chapter highlights the key insights from these field studies.

A hospital can be situated in rural or urban setting. It can be run by Public Sector (Central government/State government/Local government/Public Sector undertaking/Registered Society etc.) or by Private Sector (Individual Proprietorship/Registered Partnership/Registered Company /Co-operative Society/Trust /Charitable etc.).

PQ Audit

This audit includes analysis of 100+ power quality parameters observed over a duration of 7 days at main incomer of the hospital and critical areas (eg. NICU, ICCU, Dialysis Centers, MRI, Cath Labs etc.) were checked for their PQ profiles.

The audit was conducted using state-of-the-art IEC 61000 A Class power quality analysers. The data was automatically collected, remotely monitored in real-time and analyzed using industry's leading cloud platform – secqr®. This analysis was conducted by reputed experts with years of experience in solving some of the most critical power quality problems in hospital facilities.

List of important PQ Parameters considered for analysis in the audit includes

- Power Frequency
- Supply Voltage
- Neutral to Earth Voltage
- Currents
- Neutral Current
- Zero Sum Current
- Body Earth Leakage Current
- Phase Currents
- Flicker Severity (Pst)
- Flicker Severity (Plt)
- Voltage Unbalance
- Ampere Unbalance
- Voltage THD
- Current THD
- Voltage Harmonics
- Current Harmonics
- Real Power
- Apparent Power
- Reactive Power
- True Power Factor
- Energy (kWh)
- Apparent Energy (kVAh)
- Positive Reactive Energy (kVArh)
- Negative Reactive Energy (kVArh)
- Conducted Emissions(9kHz-150kHz)
- Conducted Emissions(2kHz-9kHz)

Hospital 1: PQ compliance

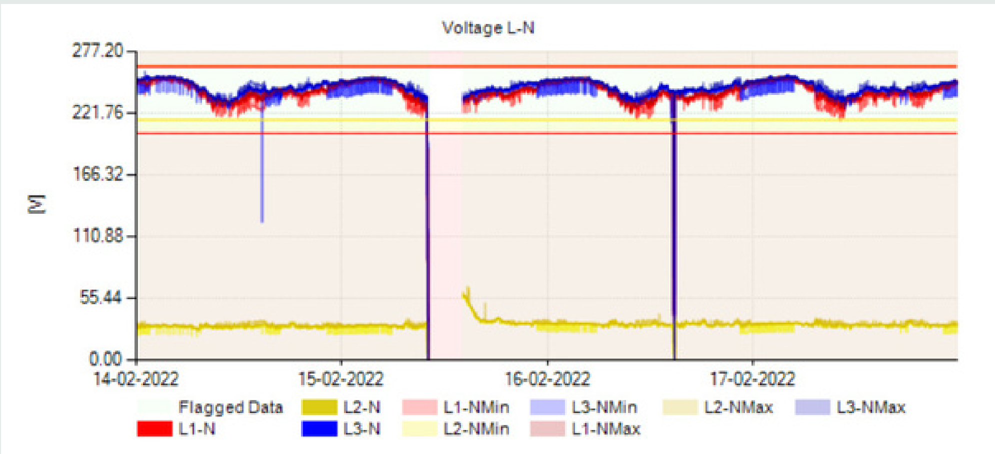
Discovering a major lapses during PQ Audit

1) Y phase was disconnected

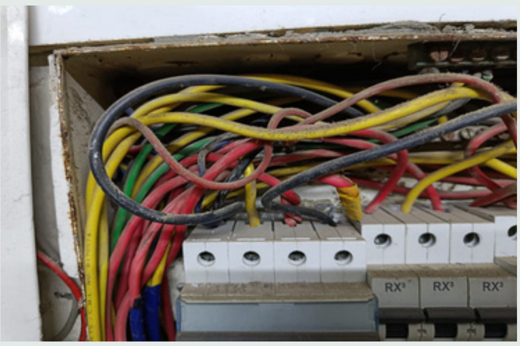
In hospital 1 a voltage unbalance of 60% was observed as voltage on Y phase was 32V. It was found that power supply received from the utility company had Y phase disconnected during some repair work which was noticed during PQ Audit. It was a major lapse in PQ as far as the hospital is concerned which also harmed them economically, as they were paying for three phase supply & were actually receiving 2 phase supply.

Requirement	Measured L1 Voltage	Measured L2 Voltage	Measured L3 Voltage	Result
95% of the time: 216.0V ~ 264.0V	229.62V ~ 252.24V	28.90V ~ 34.22V	234.10V ~ 253.25V	NON-COMPLIANT
100% of the time: 204.00V ~ 264.0V	101.99V ~ 254.09V	14.36V ~ 58.04V	104.42V ~ 255.48V	NON-COMPLIANT

	Min	Avg	Max
Voltage L1-N	101.99V	241.17V	254.09V
Voltage L2-N	14.36V	31.60V	58.04V
Voltage L3-N	104.42V	244.42V	255.48V



2) Looping in MCB



In main LT panel mains single phase supply is given through 4 pole MCB by looping method, which is completely wrong practice. If fault had to occur in that particular phase, complete hospital would have come to a standstill. It's recommended to distribute load on all the three phases.

Compliance & informative parameters table tor Main LT panel

Sr. No.	Power Quality Parameter	Compliance	Remarks
1	Power Frequency	COMPLIANT	As per IS 17036
2	Supply Voltage	NON-COMPLIANT	As per IS 17036
3	NEV	NON-COMPLIANT	As per IEEE1159
4	Currents		For informative purpose only
5	Neutral Current		For informative purpose only
6	Potential Earth Leakage Current (IPE)		For informative purpose only
7	Zero Sum Current		For informative purpose only
8a	Flicker Severity (Pst)	COMPLIANT	As per IS 17036
8b	Flicker Severity (Plt)	NON-COMPLIANT	As per IS 17036
9	Voltage Unbalance	COMPLIANT	As per IS 17036
10	Ampere Unbalance	EXCEEDED RECOMMENDED VALUES	For informative purpose only
11	Voltage THD	COMPLIANT	As per IS 17036
12	Current THD	COMPLIANT	As per IEEE 519-2014
13	Voltage Harmonics	COMPLIANT	As per IS 17036
14	Current Harmonics	NOT APPLICABLE DUE TO LOW/NO LOAD	As per IEEE 519-2014
15	Real Power		For informative purpose only
16	Reactive Power		For informative purpose only
17	Apparent Power		For informative purpose only
18	True Power Factor	WITH IN RECOMMENDED VALUES	For informative purpose only
19	Energy		For informative purpose only
20	Interruptions	NON-COMPLIANT	Projected As per IS 17036
21	Sags	NON-COMPLIANT	Projected As per IS 17036
22	Swells	COMPLIANT	Projected As per IS 17036
23	Rapid Voltage Changes	COMPLIANT	Projected As per Norwegian NVE 1157
24	Transient Overvoltages		For informative purpose only
25	Waveshape Changes	COMPLIANT	For informative purpose only

Note : Compliances to different standards may be estimated due to lesser duration monitoring than recommended by standards

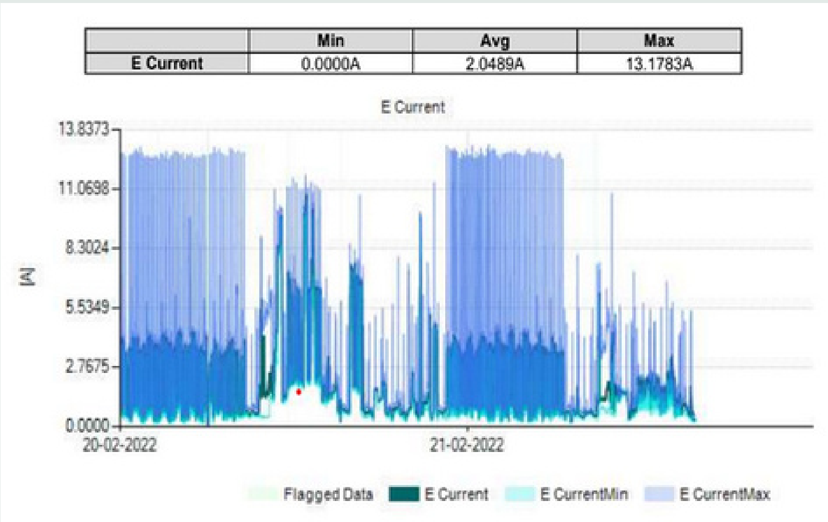
PQ compliance for Hospital 1

Pameter	Finding	Location	Impact	Recommendation
Zero Sum & Body Earth Current	Zero Sum current is observed 13.17 Amp throughout and peaks were observed in the body earth of max 5.39A.	Main LT Panel Mains	May cause failure of electronics loads, tripping of ground breakers Signals the start of deterioration of conductor/equipment insulation which may lead to shock hazards	Checks Insulation Resistance of cables, leakage monitoring devices of downstream circuits,& haphazard wiring if any to find out source of the leakages.
Sag	4 no of voltage sags were found due to input supply by utility & 2 no of voltage sags were due to the load at consumer end with maximum 30.5% magnitude of supply voltage for 311msec.	Main LT Panel Mains	Sensitive equipment may experience intermittent lockups or garbled data Equipment which are not protected by UPS are prone to faster aging and malfunctions Unwanted triggering of UPS units to switch on battery mode	Monitor critical loads to see the impact of such frequent sags . Also, communicate and share the voltage sag data with the utility company by providing a IS 17036 compliance report for implementing sag mitigation strategies at the distribution level.
Interruption	2 number of interruptions were observed over 2 days.	Main LT Panel Mains	Unnecessary tripping of protective devices, overloading of the circuits, wrong operation of alarms	Use Uninterruptible Power Supply (UPS) and other energy storage systems for critical machines.
Neutral to Earth Voltage	Peaks of neutral to earth voltage of 10V were observed throughout.	Main LT Panel Mains	May cause damage or premature failure of the sensitive electronic machinery due to the high unbalance current flowing from neutral to earth	Continuous simultaneous monitoring is required to find whether the same is from downstream(i.e. load connected) or some neighboring feeder triggering ground potential and subsequent disturbance in the ground/phases.

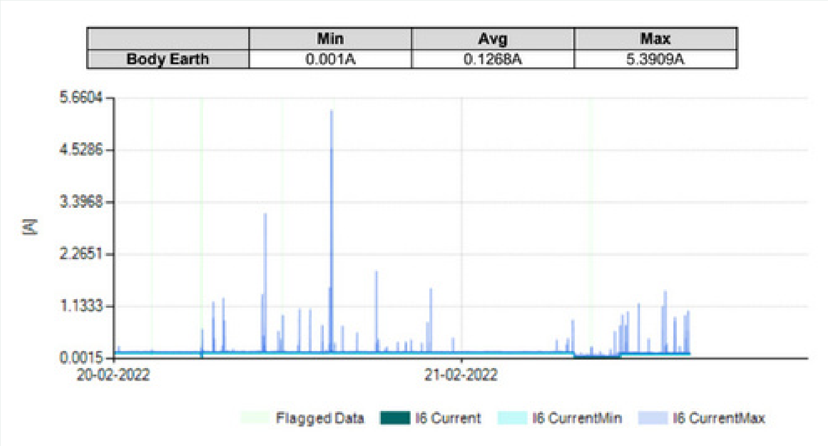
PQ compliance for Hospital 1

Pameter	Finding	Location	Impact	Recommendation
Long term & Short term Flickers(Pst & Plt)	Short term & Long term Flickers are exceeding limits by a significant margin	Main LT Panel Mains	May cause failure of lights and other sensitive equipment which are susceptible to rapid voltage fluctuations Will also cause faster aging of assets	Find out the source of these flickers by doing a further detailed Power Quality study by monitoring for a longer duration and/or incorporate a permanent Power Quality monitoring scheme to find out whether these are sporadic / intermittent rise in Plt or a continual phenomena.
Supply Voltage	The Y-Phase voltage which was 32V was rectified by the utility and now the voltages in all 3 phases are present.	Main LT Panel Mains	No Impact	Do power quality analysis on a quarterly or yearly basis.
Frequency	95% of the time frequency was found to be 52 Hz.	DG Mains	Damage sensitive hospital machinery with electronic circuits in it due to high frequency at source end	Carry out proper maintenance of Diesel Generator(DG)Set & also the same to be informed to DG manufacturer.

Zero sum current for Hospital 1



Body earth current

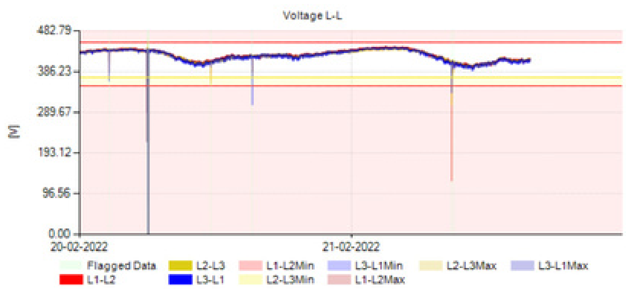


It can cause circulating currents which may increase NE-V potential downstream which might cause failure of electronics loads, tripping of ground breakers if provided. This may also signal the start of deterioration of conductor/equipment insulation, giving rise to leakage currents periodically which may cause shock hazards..

Voltage sags

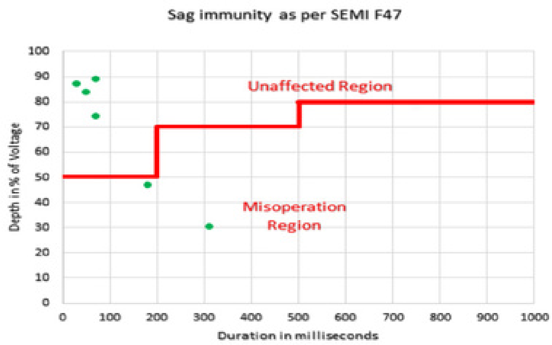
Requirement	Measured L1 Voltage	Measured L2 Voltage	Measured L3 Voltage	Result
95% of the time: 373.5V ~ 456.5V	**403.65V ~ 443.03V**	**402.35V ~ 441.11V**	**401.12V ~ 441.50V**	**COMPLIANT**
100% of the time: 352.75V ~ 456.5V	**309.06V ~ 445.45V**	**308.45V ~ 443.57V**	**308.46V ~ 443.61V**	**NON-COMPLIANT**

	Min	Avg	Max
Voltage L1-L2	309.06V	425.58V	445.45V
Voltage L2-L3	308.45V	424.39V	443.57V
Voltage L3-L1	308.46V	423.85V	443.61V

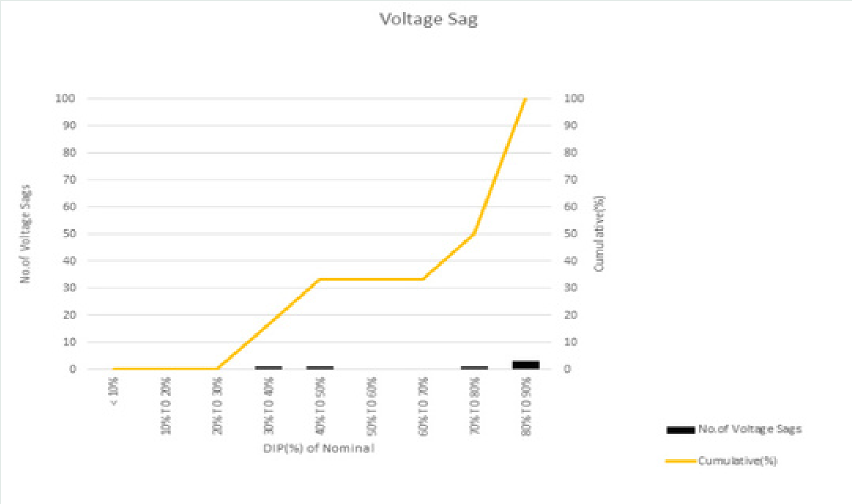


Input voltage profile

For 100% of the time supply voltage is non-compliant as per IS 17036; all the three phase voltages are below the lower limit of 352.75V



Two sags were found in the misoperation region out of 6 events which pose great risk to the hospital.



This trend shows the number of sag events occurring along with its magnitude for hospital 1 which is drawing supply from utility.

Sags can have impact on:

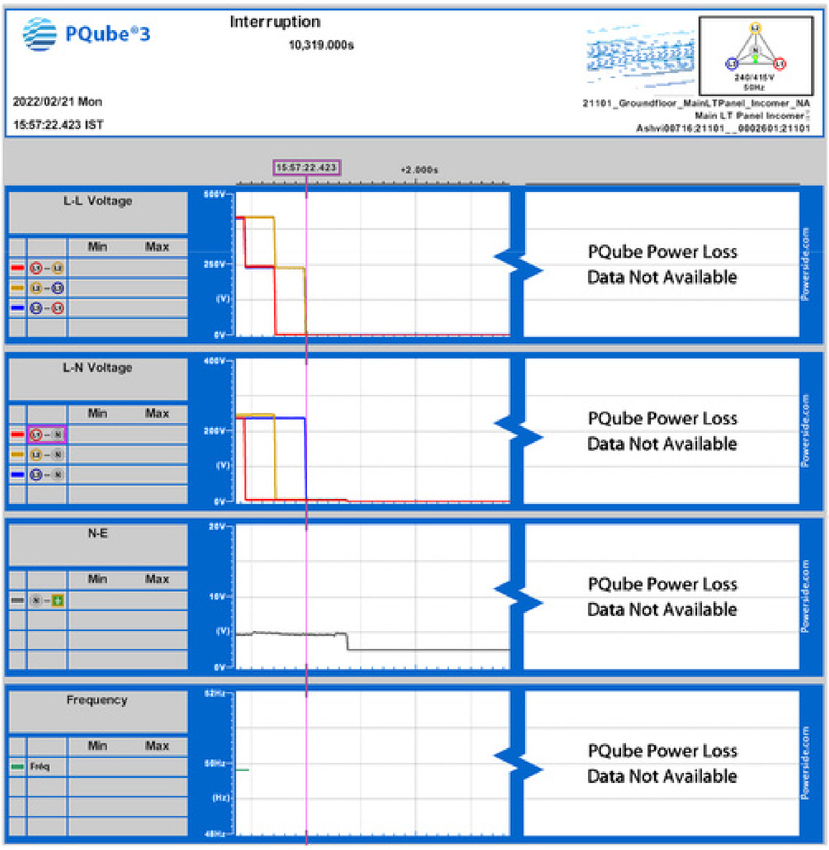
- Loss of data in data storage devices .
- Weak control relay operation in motor control circuit.
- Unnecessary tripping & maloperation of protective devices.
- Motors get stalled
- Premature failure of electronic equipment

Mitigation for the Sags in hospitals

1. Installation of UPS/ stabilizers.

Interruption

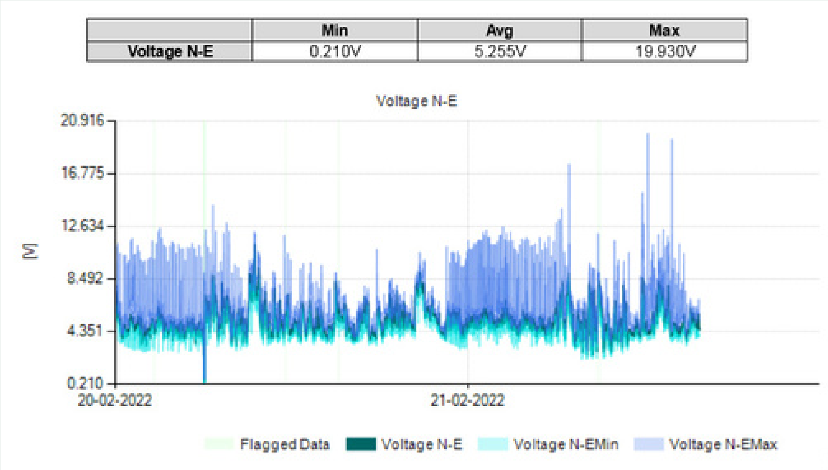
Interruption Event Recorded @2022/02/21 - T 15:57:22.423



PQ Analyser showing fall in supply voltage due to interruption

As DG & UPS are not covering all the group 2 medical locations like OT in hospital 1, interruption will lead to abrupt cut off of power supply.

Neutral to earth voltage



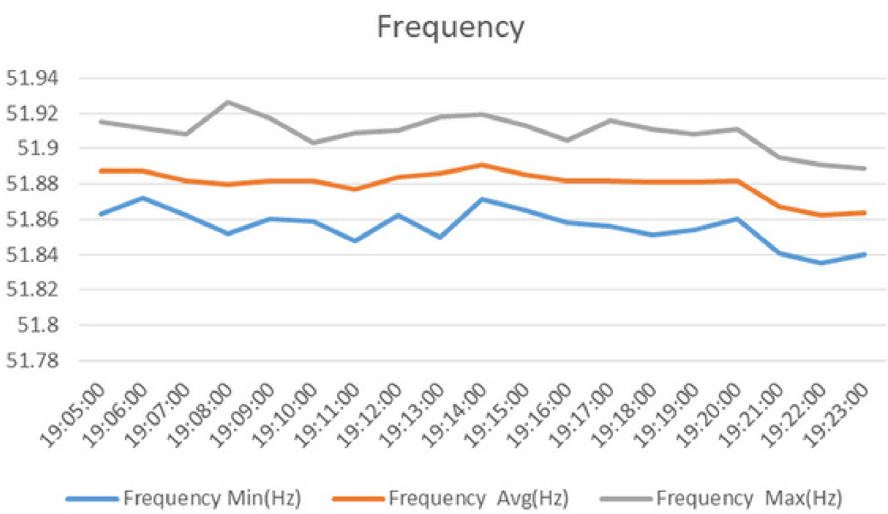
Excess residual ground Voltage can cause damage or premature failure of the sensitive electronic machinery due to the high unbalance current flowing from neutral to earth which stresses the insulation.

Frequency at DG mains

Requirement	**Measured Frequency**	**Result**
95% of the time: 49.00Hz ~ 51.00Hz	**51.7Hz~51.9Hz**	**NON-COMPLIANT**
100% of the time: 47.00Hz ~ 52.00Hz	**51.7Hz~51.9Hz**	**COMPLIANT**

	Min	Avg	Max
Frequency	51.83	51.88	51.92

Frequency



95% of the time frequency was found to be 52 Hz, instead of 49 to 51 Hz which can damage sensitive hospital machinery with electronic circuits in it due to high frequency at source end.

Electrical safety risks

Capacity overloading observed at OT main incomer switch

Two feeders of the hospital located at ground floor in main power panel is highly overloaded (138% & 129%) with respect to cable as 2.5 sq mm has max load of 30 A & 28 A respectively.

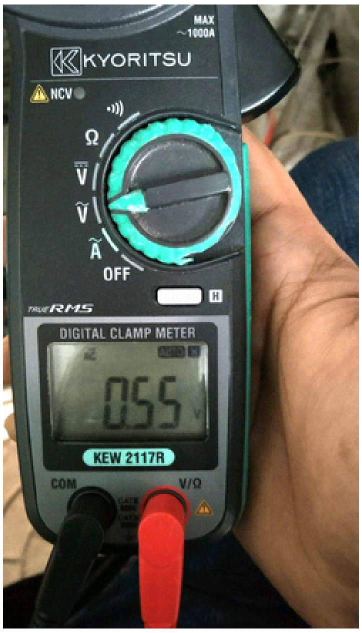
Risk **High**

Problem

Capacity expansion, addition of new loads over and above designed capacity

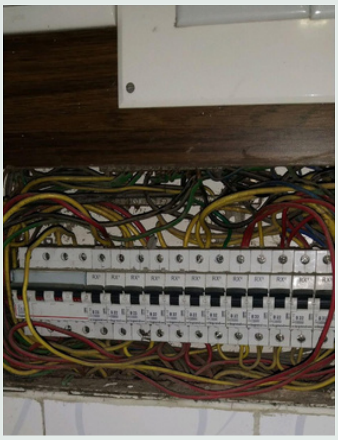
Impact

4	Main power panel	Gr Floor	Lighting Main Switch	Critical	2	PVC (60°C)	Cu	2.5	3P+N	16.75	30.00	63.00	47.62	Partially Loaded	138.89	Highly Overloaded
5	Main power panel	Gr Floor	ICU & O.T Main IncomerSwitch	Critical	1	PVC (60°C)	Cu	2.5	3P+N	16.75	28.00	63.00	44.45	Partially Loaded	129.63	Highly Overloaded



Touch potential being taken at casualty room at the hospital which is well within limit. (In medical locations of Group 1 and Group 2, for Isolated Terre (IT),Terre Neutral (TN) and earthed-Terre (TT) Earthing systems, the conventional touch voltage is less than 25 V.)
As per IS:17512:2021,6 Protection for safety, regulation no 6.1.3.1.1.1 the ground potential in medical location should not exceed 25V regardless of the earthing system configuration.

No luminary for emergency signage
In medical locations of Group 1 and Group 2, at least two different sources of supply shall be provided for some of the luminaries by two circuits. One of the two circuits shall be connected to the safety service. In escape routes, alternate luminaries shall be connected to the safety service



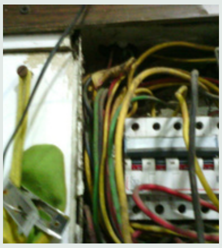
Risk **High**

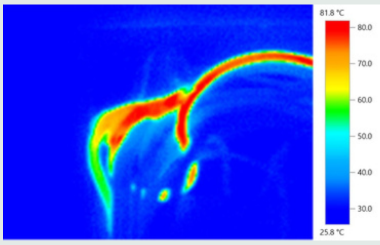
Problem

Shabby wiring at Distribution Board

Impact

This wiring increases difficulties in tracing of faults and can lead to shock or fire hazards.





Hotspot of priority 1 in R phase cable joint of the main distribution board at the hospital

Hotspot temperature is 91 degree Celsius

Risk **High**

Problem

Loose connection

Impact

May lead to interruption in supply, short circuit in turn causing fire

Hidden Risks observed across Hospital 1

Mumbai, Maharashtra

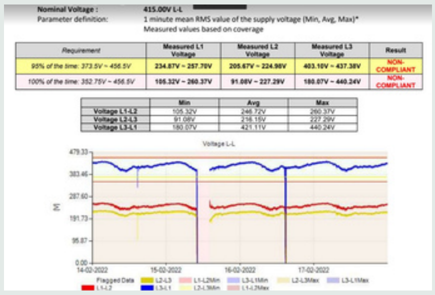
The fear of needing a compliance certificate certifying that "all is ok" is paramount irrespective of the actual health of the hospital, which is inappropriate when it comes to risk management

Impact

The purpose of an electrical audit is not met with such mentality, no doubt that it has come into picture due to plethora of reasons such as lack of knowledge, lack of means, fear that the hospital getting shut down if the reality of the electrical network is discovered, etc. ultimately leading the hospital to remain unsafe.

There are quite a few equipment failures occurring and the supply from the utility is observed to be poor with interruptions occurring almost on a regular basis

4		**Interruption**	2 No of Interruptions are observed over 2 days.	Wrong operations of fire alarms, excessive circuit over loading. Unnecessary tripping of protective devices.	Use Uninterruptible Power Supply (UPS) and other energy storage systems for critical machines.	4


Nominal Voltage : 415.00V L-L
Parameter definition: 1 minute mean RMS value of the supply voltage (Min, Avg, Max)*
Measured values based on coverage

Requirement	Measured L1 Voltage	Measured L2 Voltage	Measured L3 Voltage	Result
95% of the time: 373.5V ~ 456.5V	234.87V ~ 257.70V	205.67V ~ 224.98V	403.10V ~ 437.38V	NON-COMPLIANT
100% of the time: 352.75V ~ 456.5V	105.32V ~ 260.37V	91.08V ~ 227.29V	180.07V ~ 440.24V	NON-COMPLIANT

	Min	Avg	Max
Voltage L1-L2	105.32V	246.72V	260.37V
Voltage L2-L3	91.08V	216.15V	227.29V
Voltage L3-L1	180.07V	421.11V	440.24V

Impact

Equipment damage - 1. Sizeable financial losses 2. Interruptions in patient treatment, may affect patients permanently 3. Might cause interruptions in OT procedures

The electrical installation is done by looping just a single phase in the 3 phase circuit breakers and DBs thereby falsely giving a sense of 3 phase infrastructure, with no regard to compliance whatsoever

2		**Looping in MCCBs**	Single Phase Supply is observed in all 3phase MCCBs using loops which is a wrong practice.	If Fault occurs in that phase, the whole source will get blackout.	It is recommended to kindly distribute the load in 3-Phase instead of single phase which will also be helpful in case of any fault on single phase, the contingency of network will remain.	1

Impact

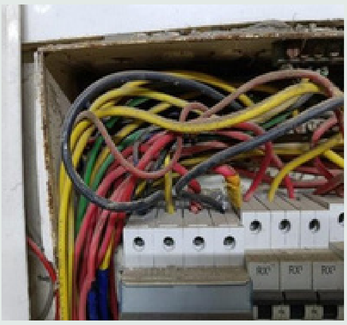
Totally wrong way of wiring. No third phase means only single phase equipment may work and the 3 Phase equipment might get damaged. While the hospital is made to think they have 3 phase connections, in reality the facility has is a single phase connection.

Observations
All extraneous conductive (such as metallic gas pipe, metallic water pipe & metallic structure) parts are not connected to the system of protective conductors.

Locations: #OT 2

Recommendations
All metallic pipe/ structure inside the hospital has to be connected to ground through equipotential bonding.

High risk



Observations
Rust and peel off paints were found in DB.

Locations: #DB2

Recommendations
As per CEA Regulations 2010, Chapter III, Regulation No.19 (6),it is highly recommended for the safe operation of the facility and sensitive equipment to provide the electrical panels without rust & with proper paint.

High risk

Hospital 2: PQ compliance

PQ issues

Section 1: Compliance & Informative Parameters Table

Sr. No.	Power Quality Parameter	Compliance	Remarks
1	Power Frequency	COMPLIANT	As per IS 17036
2	Supply Voltage	COMPLIANT	As per IS 17036
3	NEV	NON-COMPLIANT	As per IEEE1159
4	Currents		For informative purpose only
5	Neutral Current		For informative purpose only
6	Potential Earth Leakage Current (IPE)		For informative purpose only
7	Zero Sum Current		For informative purpose only
8a	Flicker Severity (Pst)	COMPLIANT	As per IS 17036
8b	Flicker Severity (Plt)	COMPLIANT	As per IS 17036
9	Voltage Unbalance	COMPLIANT	As per IS 17036
10	Ampere Unbalance	Exceeding limits	For informative purpose only
11	Voltage THD	COMPLIANT	As per IS 17036
12	Current THD	NOT APPLICABLE DUE TO LOW/NO LOAD	As per IEEE 519-2014
13	Voltage Harmonics	COMPLIANT	As per IS 17036
14	Current Harmonics	NOT APPLICABLE DUE TO LOW/NO LOAD	As per IEEE 519-2014
15	Real Power		For informative purpose only
16	Reactive Power		For informative purpose only
17	Apparent Power		For informative purpose only
18	True Power Factor	WITH IN RECOMMENDED VALUES	For informative purpose only
19	Energy		For informative purpose only
20	Interruptions	COMPLIANT	Projected As per IS 17036
21	Sags	NON-COMPLIANT	Projected As per IS 17036
22	Swells	COMPLIANT	Projected As per IS 17036
23	Rapid Voltage Changes	COMPLIANT	Projected As per Norwegian NVE 1157
24	Transient Overvoltages		For informative purpose only
25	Waveshape Changes	COMPLIANT	For informative purpose only

Note : Compliances to different standards may be estimated due to lesser duration monitoring than recommended by standards

PQ compliance for Hospital 2

Pameter	Finding	Location	Impact	Recommendation
Sag	12 no of voltage sags were found with a maximum of 79.7% magnitude of supply voltage for 90 msec time duration monitored over 9 days.	Ground Floor Mains	Damage to critical loads which are not protected by UPS Chances of protective device malfunction	Monitor critical loads to see the impact of such frequent sags . Also, communicate and share the voltage sag data with the utility company by providing a IS 17036 compliance report for implementing sag mitigation strategies at the distribution level.
	3No of downstream voltage sags are observed.	ICU mains		

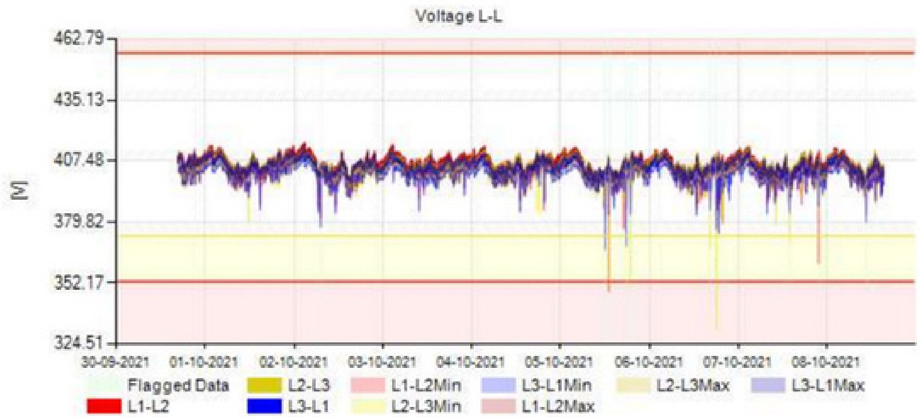
Although priority 4 sags were found at ICU mains, it can be cause of concern for critical loads if not connected by UPS or stabilizers.

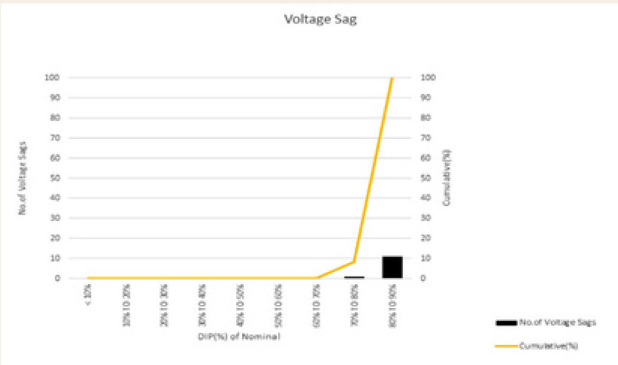
Sags

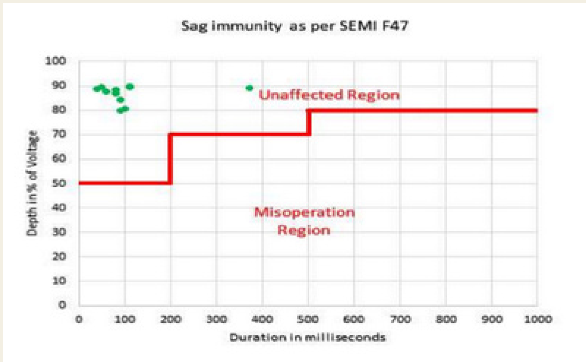
1. Ground floor mains

Requirement	Measured L1 Voltage	Measured L2 Voltage	Measured L3 Voltage	Result
95% of the time: 373.5V ~ 456.5V	399.13V ~ 411.56V	398.92V ~ 410.00V	399.09V ~ 409.34V	COMPLIANT
100% of the time: 352.75V ~ 456.5V	394.53V ~ 415.19V	393.74V ~ 413.02V	395.05V ~ 412.83V	COMPLIANT

	Min	Avg	Max
Voltage L1-L2	394.53	405.46	415.19
Voltage L2-L3	393.74	404.52	413.02
Voltage L3-L1	395.05	404.26	412.83







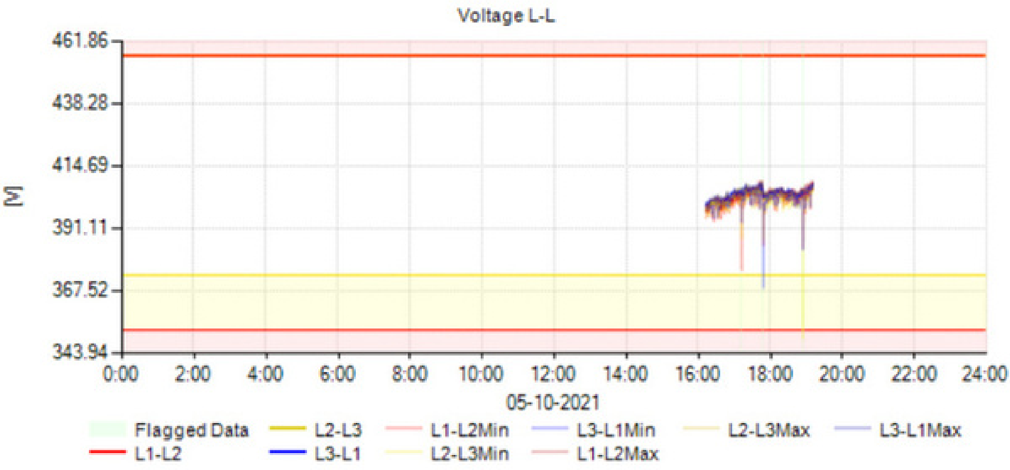
This trend shows the number of sag events occurring along with its magnitude for hospital 2 which is drawing supply from private utility and as seen majority of sags are in the unaffected region signaling a good voltage control from the Private Utility provider.

12 no of low risk sags were observed which should not affect critical equipment as they are compliant to SEMI 47 standards.

ICU mains

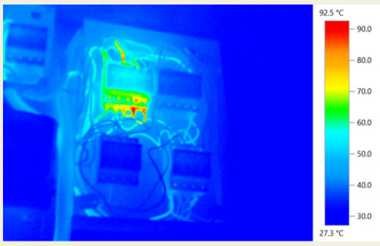
Requirement	Measured L1 Voltage	Measured L2 Voltage	Measured L3 Voltage	Result
95% of day: 373.5V ~ 456.5V	**397.98V ~ 406.08V**	**398.86V ~ 406.21V**	**400.08V ~ 406.80V**	**COMPLIANT**
100% of day: 352.75V ~ 456.5V	**397.63V ~ 407.45V**	**397.86V ~ 406.39V**	**398.51V ~ 407.15V**	**COMPLIANT**

	Min	Avg	Max
Voltage L1-L2	397.63V	402.81V	407.45V
Voltage L2-L3	397.86V	402.68V	406.39V
Voltage L3-L1	398.51V	403.86V	407.15V



Electrical Safety risks

Mains incomer



Hotspot of priority 2 in R phase lug of the main distribution board placed at 5th floor dialysis room

Hotspot temperature is 81 degree celsius

Risk High

Problem

Loose connection & crimping at joint

Impact

Fire might catch on sooner or later, directly inside the Dialysis room itself because of the position of the DB

Distribution Boards

10	1st Floor OPD	OPD 1st Room	Single Phase	Monitor Board	16	Fixed Load Equipment	232	1	19.9	0.01	Poor earthing	4.388	FAIL
11	1st Floor OPD	OPD 1st Room	Single Phase	Monitor Board-2	16	Fixed Load Equipment	233	1	19.6	0.011	Poor earthing	4.407	FAIL
12	5th FLoor Dialysis Department	Dilyasis Center Room	Single Phase	Weight machine	16	Fixed Load Equipment	232	1			No earthing provide	4.388	FAIL
13	1st Floor OPD	OPD 1st Room	Single Phase	Patient overhead board	16	Fixed Load Equipment	231	1			No earthing provide	4.369	FAIL

Risk High

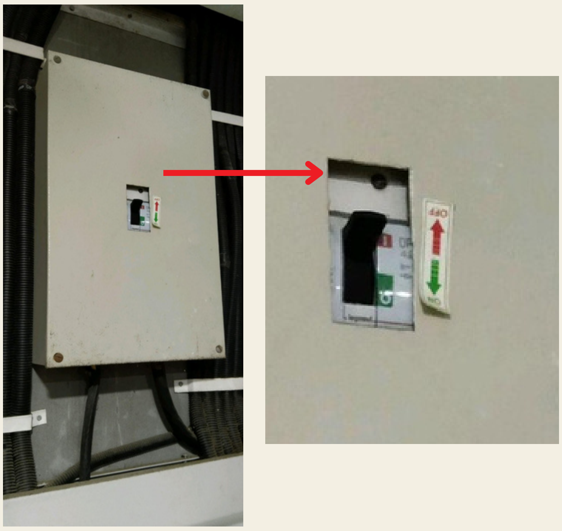
Problem

The DBs supplying to group 2 facilities are not provided with earthing

Impact

High risk of electric shock to patients/doctors/hospital staff

Distribution Boards



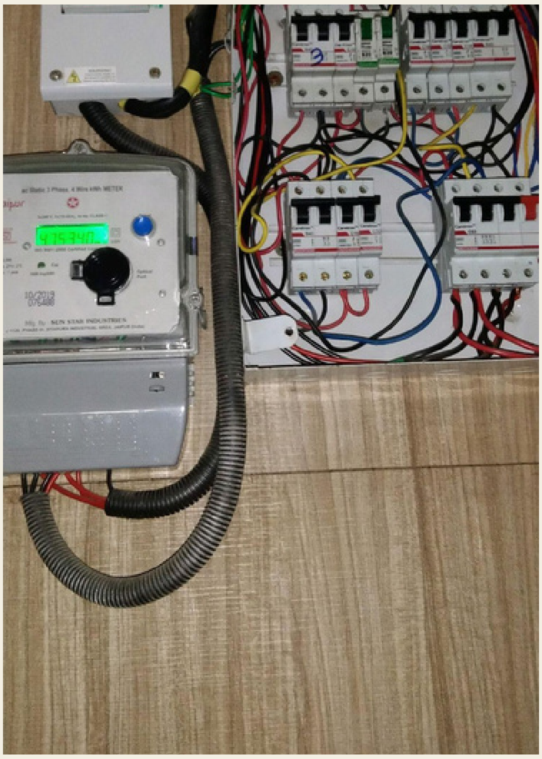
Risk High

Problem

DB 1 at the CT Center of the hospital is not provided with body earthing with 2 separate & distinct body earth conductors. Nameplate is not there.

As per Regulation No. 41 (xii), all metallic parts, apparatus used for regulating or controlling electricity shall be earthed by two separate and distinct body earth conductors with the earth

As per CEA Regulations 2010, Chapter III, Regulation No.19 (6).The inscription plate of SS/Aluminum make shall be legible with correct language / script conforming to the updated single line diagram.



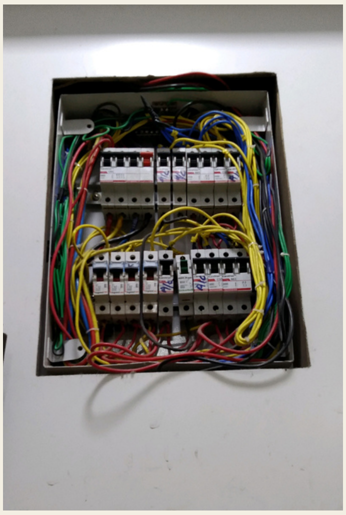
Risk High

Problem

DB installed inside the Group 2 medical locations

As per IS:17512, Regulation No-7.1.Common Rules 7.1.1.1.1 Transformer for Medical IT system, which states that in the Group 2 medical location distribution board shall be installed outside the medical location in order to reduce the chance of human shock to critical patients.

Hidden risks observed across Hospital 2



The 4th Floor ICU DB, which is inside the ICU room, is completely open with no cover, the main MCB of which is not properly installed and moves around, and the Cables itself are so loose it could be removed with no effort at all. This in effect shows the complete apathy towards the electrical infrastructure and its maintenance.

Impact

The cable is loose to the extent that any physical stress even while operating the breaker might cut off the power supply to the entire ICU, furthermore as the DB has no cover, patients, Doctors and other personnel are directly in danger of electric shock

The DG of the hospital has not been active for about 3 years. The administration doesn't know if its functioning or not, nor do they have a technical person who knows how to switch it on and connect it to the network. The hospital right now is functioning with EB as the primary and only source of power, meanwhile most of the critical areas do not have a dedicated backup supply system such as the UPS, meaning those critical areas solely depend on EB as the power source, and are vulnerable to power outages, however less frequent they are.

DG Area 1

Observations
Dirt, Dust, moisture is observed on the surface of the DG.
Locations
#DG Area 1

Recommendations
As per Regulation No. 109 (1), DG should be reasonably free from dust, dirt and moisture.

DG Area 1
Auditor Observations :
This dust and moisture lead to early corrosion of D.G which is clearly visible

DG Area 1
Auditor Observations :
D.G wiring required some maintenance since some cable had lost their insulation due to poor handling

Observations
Internal wiring is not done properly.
Locations
#DG Area 1

Recommendations
As per CPWD regulation No. 2.4.2.2, control and small wiring inside the panel shall be by copper conductor which is 2.5 sq mm and pvc insulated. Suitable color coding shall be adopted and wiring shall be neatly formed and segregated voltage wise.

Impact

If there is an outage from the Electricity board side for say of 2 hours duration, for the time it takes the hospital to call a rental DG and connect it to the Electrical Network, lets assume it to be 20 mins, the entire hospital remains without any power whatsoever.

1st Floor DB 2 (Staff Washroom)

3rd Floor Deluxe Room DB 1

4th Floor Frontside ICU DB

5th Floor Backside Dialysis Department DB

Observations
Suitable capacity Fire extinguishers are not provided.

Locations
#1st Floor DB 2 (Staff Washroom)
#3rd Floor Deluxe Room DB 1
#4th Floor Frontside ICU DB
#5th Floor Backside Dialysis Department DB
#5th Floor Frontside Dental Department DB
#Basement DB 1
#Ground Floor DB 1 (Canteen)

Recommendations
As per CEA Regulation 2010,Chapter III, Regulation No. 27(2),It is recommended to provide fire extinguishers for prevention of electrical fire. The same shall be tested once in a year as per relevant Indian standard & records shall be maintained.

High risk

Observations
In the OT there is no backup supply system in the form of UPS.

Locations
#4th Floor OT 1 - Major

Recommendations
As per IS:17512 Regulation No- 7.4.3 Architecture of Special Safety Supply System in Operation Theater, operating room should be provided with UPS system to ensure the back-up power for at least 3 hours

High risk

Hospital 3: PQ compliance

Compliance and informative parameters table

Power Quality Parameter	Compliance	Remarks
Power Frequency	COMPLIANT	As per IS 17036
Supply Voltage	COMPLIANT	As per IS 17036
Neutral to Earth Voltage	NON-COMPLIANT	As per IEEE1159
Currents	-	For informative purpose only
Neutral Current	-	For informative purpose only
Zero Sum Current	-NON-COMPLIANT	For informative purpose only
Body Earth Current	-	For informative purpose only
Flicker Severity (Pst)	NON-COMPLIANT	As per IS 17036
Flicker Severity (Plt)	NON-COMPLIANT	As per IS 17036
Ampere Unbalance	ABOVE SATISFACTORY LIMIT	For informative purpose only
Voltage THD	COMPLIANT	As per IS 17036
Current THD	-	For informative purpose only
Current TDD	-	As per IEEE 519-2014
Real Power	-	For informative purpose only
Apparent Power	-	For informative purpose only
Reactive Power	-	For informative purpose only
True Power Factor	-	For informative purpose only
Energy (kWh)	-	For informative purpose only
Apparent Energy (kVAh)	-	For informative purpose only
Positive Reactive Energy (kVArh)	-	For informative purpose only
Negative Reactive Energy (kVArh)	-	For informative purpose only
Conducted Emissions(9kHz-150kHz)	-	For informative purpose only
Conducted Emissions(2kHz-9kHz)	-	For informative purpose only

Note 1: Compliances to different standards may be estimated due to lesser duration monitoring than recommended by standards

Note 2: Flagged data was excluded for compliance in this report

Pameter	Finding	Location	Impact	Recommendation
Neutral Earth Voltage	Peaks of Neutral to Earth Voltage are observed with an average of 2.26 V and max 18.28V.Even during no load condition, peaks in neutral to earth voltage are observed which is probably due to neighboring loads.	Modular OT	High neutral to earth voltage damages or leads to premature failure of the sensitive electronic equipment	1. Regular maintenance of earth pit to ensure minimum resistance. 2. Overall earthing schematic should be assessed
Neutral Earth Voltage	Peaks of Neutral to Earth Voltage are observed of average value 24.52 V and max 238.33 V .	2F OT Electrical Room	High neutral to earth voltage damages or leads to premature failure of the sensitive electronic equipment	1. Regular maintenance of earth pit to ensure minimum resistance. 2. Overall earthing schematic should be assessed
Neutral Earth Voltage	Peaks of Neutral to Earth Voltage are observed of average value 5.05 V and max 45V which was mainly due to issues in earthing distribution.	1F SNCU	High neutral to earth voltage damages or leads to premature failure of the sensitive electronic equipment	1. Regular maintenance of earth pit to ensure minimum resistance. 2. Overall earthing schematic should be assessed
Zero Sum Current/ Ampere Unbalance	Zero Sum Current observed is of average value of 1.78 Amp and max of 12.23 Amp.	Modular OT	Can cause circulating currents leading to failure of electronics loads, tripping of ground breakers Signals the start of deterioration of conductor/equipment insulation which may lead to shock hazards	checks such as Insulation Resistance on cables, leakage monitoring of downstream circuits, haphazard wiring to find out the source of these leakages.
Zero Sum Current/ Ampere Unbalance	Zero Sum Current observed is of average value of 0.61 Amp and max of 9.47 Amp.	1F SNCU	Can cause circulating currents leading to failure of electronics loads, tripping of ground breakers Signals the start of deterioration of conductor/equipment insulation which may lead to shock hazards	checks such as Insulation Resistance on cables, leakage monitoring of downstream circuits, haphazard wiring to find out the source of these leakages.
Zero Sum Current/ Ampere Unbalance	Zero Sum Current observed is of average value of 2.56 Amp & max of 8 A	Ward no.5 Electrical Room	Can cause circulating currents leading to failure of electronics loads, tripping of ground breakers Signals the start of deterioration of conductor/equipment insulation which may lead to shock hazards	checks such as Insulation Resistance on cables, leakage monitoring of downstream circuits, haphazard wiring to find out the source of these leakages.

Pameter	Finding	Location	Impact	Recommendation
Potential Earth Current	Peaks of Potential Earth Current are observed of max value 12 A.	Electrical Room GF	Nuisance Tripping of Residual Current Circuit Breakers, Earth Leakage Relays Premature failure and reduced Life span of Electronics Equipment Computer Hard drive/CPU failures, Rebooting of Servers. Electronics Equipments' onboard Power supply failures In case of break in enclosure earthing With high leakage currents flowing shock hazard exists if a person is simultaneously touching the enclosure and another earthed object	Trace the roots of potential earth currents, if those are due to circuit wiring errors - rectify the same, if those are due to Weak Cables or Weak Insulators - replace those Insulators / Cables, if those are due to connected Load Equipment - insist respective OEMs to rectify those extra leakages generated by their Equipment. If those are due to Multiple Ground Loops - eliminate those Ground Loops by providing a Radial Earthing Path from Equipment to Earth Grids. If errors are due to 1. Circuit wiring, then rectify the same. 2. insulators & cables, if found weak to be replaced. 3. Connected load equipment, insist respective OEMs to rectify those extra leakages generated by their equipment. 4. Multiple ground loops, eliminate ground loops by providing a radial earthing path from equipment to earth grids.

Pameter	Finding	Location	Impact	Recommendation
Flickers (Long term & Short term)	Short term flickers & long term flickers are exceeding limits by a significant margin.	Modular OT, 2F OT Electrical room & 1F SNCU	It may cause failure of lights and other sensitive equipment which are susceptible and will also cause faster aging of assets Fluctuations in lights may affect group 2 locations such as Operation Theaters	Find out the source of these flickers and to study for longer duration or incorporate a permanent monitoring scheme to find out whether these are sporadic / intermittent or continuous.
Voltage Variations	While the voltage limits are within IS 17036, as per MERC Regulations 2014, voltage variation limits are +/- 6% and hence are non-compliant to the same.	Electrical Room GF & 1F SNCU	Can cause various impacts such as more losses, overheating due to overcurrents, critical equipment malfunctions/failure etc	To share this data with the utility to bring the voltage variation under limits of +/- 6%

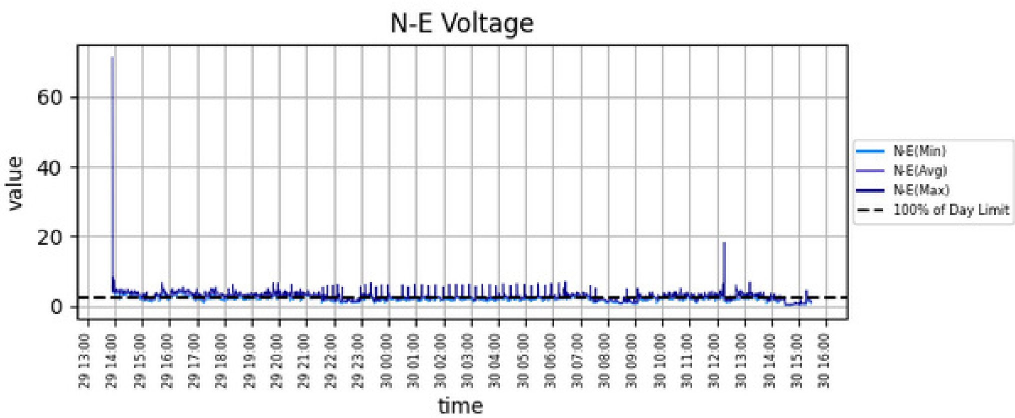
Note:
Modular OT,2F OT Electrical Room & IF SNCU were given supply from DG due to which voltage unbalance, current unbalance, zero sum current and flickers have increased significantly as DG neutral was found open with respect to the earth.

Neutral to earth Voltage

Modular OT

Requirement	Measured Neutral to Earth Voltage	Result
100% of day:0V ~ 2.4V	4.25	NON-COMPLIANT

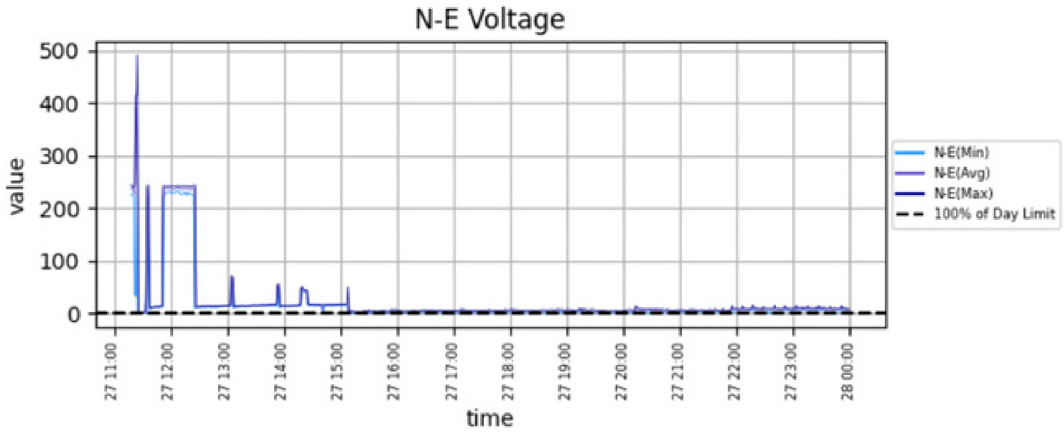
Requirement	Min[V]	Avg[V]	Max[V]
Neutral to Earth Voltage	0.21	2.26	18.28



OT Electrical Room

Requirement	Measured Neutral to Earth Voltage	Result
100% of day:0V ~ 2.4V	238.33	NON-COMPLIANT

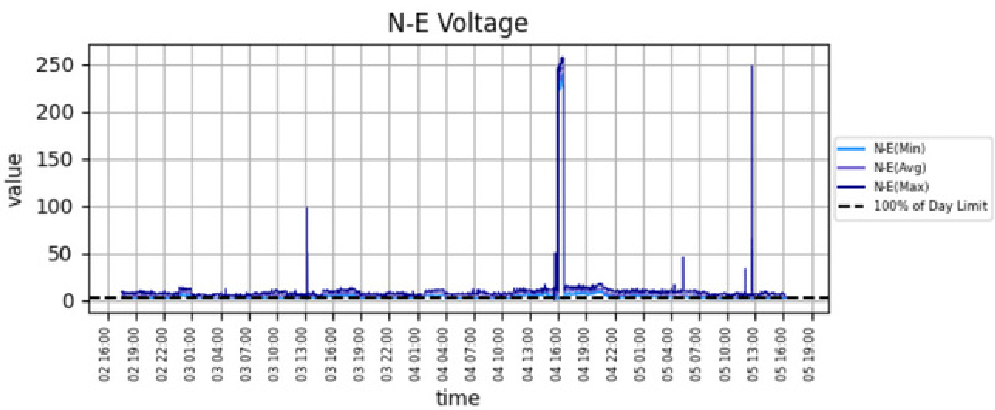
Requirement	Min[V]	Avg[V]	Max[V]
Neutral to Earth Voltage	1.3	24.52	244.33



SNCU

Requirement	Measured Neutral to Earth Voltage	Result
100% of day:0V ~ 2.4V	13.13	NON-COMPLIANT

Requirement	Min[V]	Avg[V]	Max[V]
Neutral to Earth Voltage	0.7	5.05	45.9

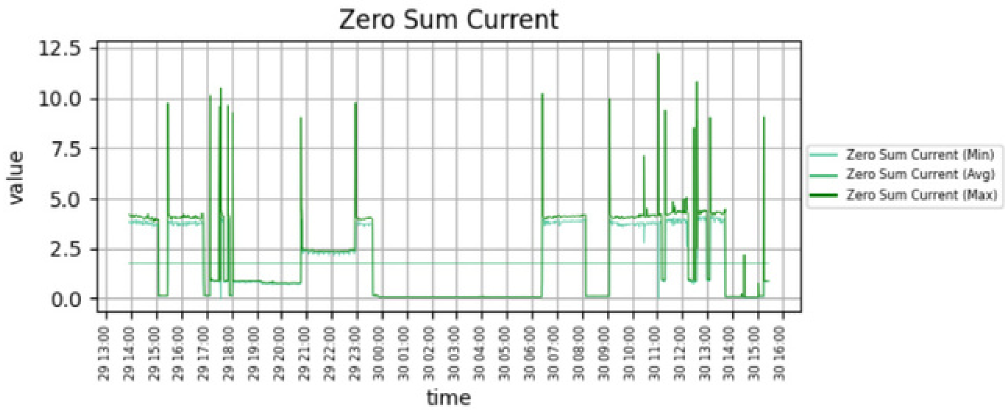


High neutral to earth voltage damages or leads to premature failure of the sensitive electronic equipment

Zero Sum Current

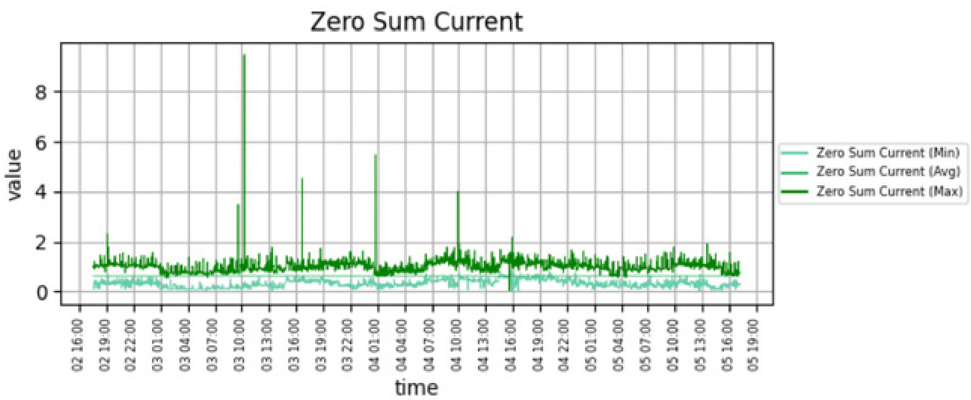
Modular OT

Parameter	Min[A]	Avg[A]	Max[A]
Zero Sum Current	0.0	1.7809	12.2341



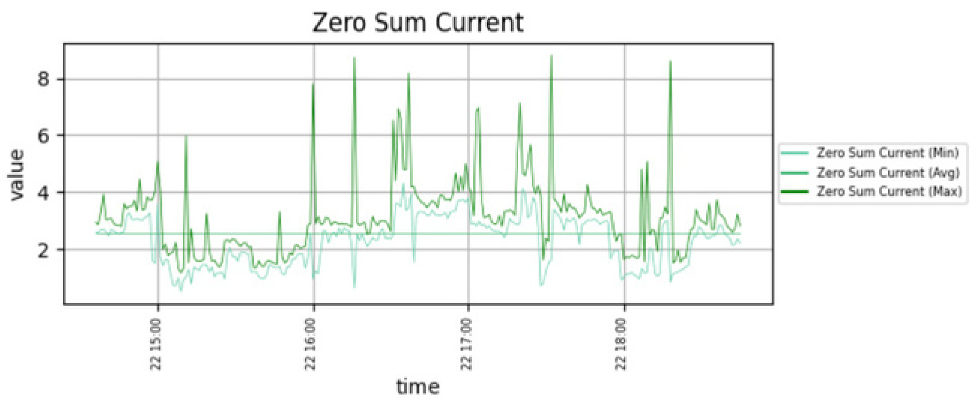
SNCU

Parameter	Min[A]	Avg[A]	Max[A]
Zero Sum Current	0.0031	0.6127	9.4727



Ward No.5 electrical room

Parameter	Min[A]	Avg[A]	Max[A]
Zero Sum Current	0.5264	2.5658	8.8028

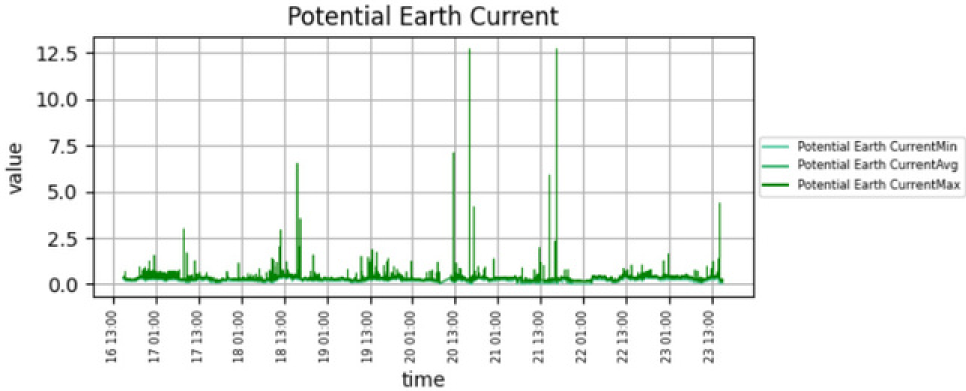


It will cause circulating currents which may increase NE-V potential downstream which might cause failure of electronics loads, tripping of ground breakers if provided. This may also signal the start of deterioration of conductor/equipment insulation, giving rise to leakage currents periodically which may cause shock hazards.ck hazards.

Functional earth current

Electrical Room GF

Parameter	Min[A]	Avg[A]	Max[A]
Potential Earth Current	0.0031	0.2449	12.7243



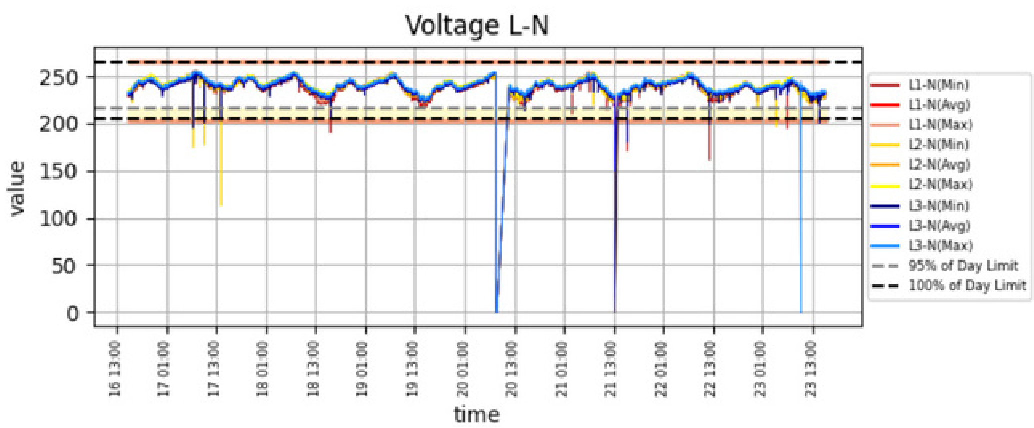
Nuisance Tripping of Residual Current Circuit Breakers, Earth Leakage Relays, Premature failure of electronic equipment. Reduced Life span of electronic equipment. Computer Hard drive/CPU failures, Rebooting of Servers. Electronic equipment' onboard power supply failures In case of break in enclosure earthing, with high leakage currents flowing shock hazard exists if a person is simultaneously touching the enclosure and another earthed object.

Voltage Variation

Electrical Room GF

Requirement	Measured L1 Voltage	Measured L2 Voltage	Measured L3 Voltage	Result
95% of day:216.0V ~ 264.0V	227.95V ~ 251.7V	230.2V ~ 251.0V	231.8V ~ 250.8V	COMPLIANT
100% of day:204.0V ~ 264.0V	217.9V ~ 256.9V	217.8V ~ 255.4V	221.5V ~ 255.5V	COMPLIANT

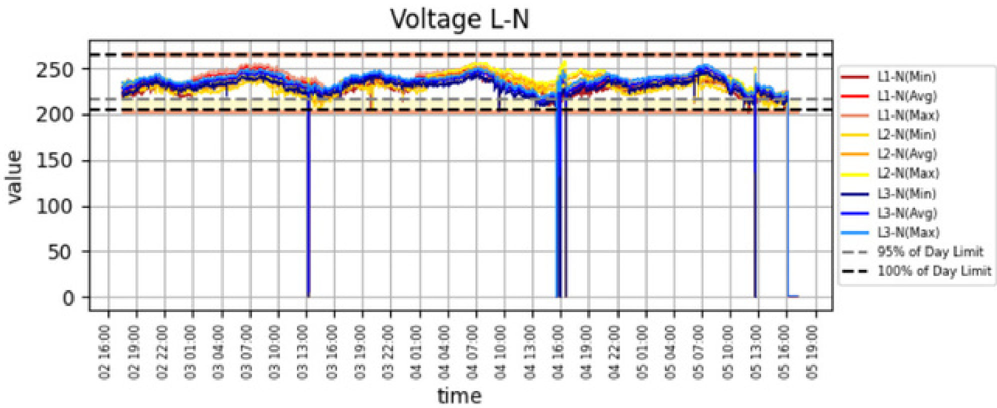
Parameter	Min[V]	Avg[V]	Max[V]
Voltage L1-N	217.9	240.61	256.9
Voltage L2-N	217.8	241.58	255.4
Voltage L3-N	221.5	241.31	255.5



SNCU

Requirement	Measured L1 Voltage	Measured L2 Voltage	Measured L3 Voltage	Result
95% of day:216.0V ~ 264.0V	226.1V ~ 249.8V	225.4V ~ 245.7V	225.5V ~ 245.2V	COMPLIANT
100% of day:204.0V ~ 264.0V	216.1V ~ 256.6V	216.0V ~ 256.9V	216.1V ~ 254.7V	COMPLIANT

Parameter	Min[V]	Avg[V]	Max[V]
Voltage L1-N	216.1	236.69	256.6
Voltage L2-N	216.0	234.78	256.9
Voltage L3-N	216.1	236.03	254.7



Electrical Safety risks

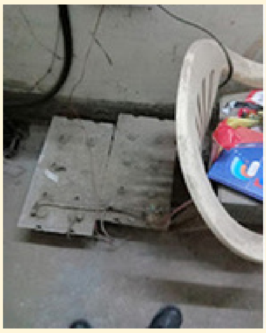
As per IS:17512,31.1.2,Provision P1:Medical TN-S System,31.1.2.6, the impedance between socket & protective earth conductor should be less than 0.2 ohms to provide low resistance path for fault current & prevent the shock hazards but the same is not maintained in Hospital 3 as seen from below Earth loop impedance report for sockets of OT & SNCU area (neonatal ward).

Sr No.	Location Name	Number of Phase	Socket Reference	Socket Amp Rating (A)	Curve Type	Connected Load Equipment Type	P-N-E position	Measured Line to Neutral Voltage V - L1N (V)	Measured Neutral to Earth Voltage V - NE (V)	Is the Test able to be executed?	Measured Earth Loop Impedance "L1-N-E(Ω)"	Psc (kA)	Required Max Earth Loop Impedance	Test Result
328	OT no.4	Single Phase	Socket no.2	15	Medical Group II	Moving or Portable Load Equipment	Okay	231	2	YES	1.5	0.153	0.2	NOT FOUND SATISFACTORY
329	OT no.4	Single Phase	Socket no.3	5	Medical Group II	Moving or Portable Load Equipment	Okay	229	2	YES	1.23	0.186	0.2	NOT FOUND SATISFACTORY
330	OT no.4	Single Phase	Socket no.4	5	Medical Group II	Moving or Portable Load Equipment	Okay	229	2	YES	1.5	0.153	0.2	NOT FOUND SATISFACTORY
331	OT no.1	Single Phase	Socket no.1	5	Medical Group II	Moving or Portable Load Equipment	Okay	236	10	YES	2.63	0.087	0.2	NOT FOUND SATISFACTORY
332	OT no.1	Single Phase	Socket no.2	15	Medical Group II	Moving or Portable Load Equipment	Okay	226	8	YES	1.85	0.125	0.2	NOT FOUND SATISFACTORY
333	OT no.1	Single Phase	Socket no.3	15	Medical Group II	Moving or Portable Load Equipment	Not Okay	226	118	NO	9999	9999	0.2	NOT FOUND SATISFACTORY
334	OT no.1	Single Phase	Socket no.4	5	Medical Group II	Moving or Portable Load Equipment	Okay	226	8	YES	1.98	0.116	0.2	NOT FOUND SATISFACTORY
335	OT no.1	Single Phase	Socket no.5	15	Medical Group II	Moving or Portable Load Equipment	Not Okay	226	125	NO	9999	9999	0.2	NOT FOUND SATISFACTORY
336	OT no.1	Single Phase	Socket no.6	5	Medical Group II	Moving or Portable Load Equipment	Okay	238	6	YES	2.18	0.105	0.2	NOT FOUND SATISFACTORY
337	OT no.1	Single Phase	Socket no.7	15	Medical Group II	Moving or Portable Load Equipment	Okay	235	6	YES	1.99	0.116	0.2	NOT FOUND SATISFACTORY
338	OT no.1	Single Phase	Socket no.8	15	Medical Group II	Moving or Portable Load Equipment	Okay	226	8	YES	2.15	0.107	0.2	NOT FOUND SATISFACTORY
339	OT no.1	Single Phase	Socket no.9	5	Medical Group II	Moving or Portable Load Equipment	Okay	225	6	YES	2	0.115	0.2	NOT FOUND SATISFACTORY
340	OT no.1	Single Phase	Socket no10	5	Medical Group II	Moving or Portable Load Equipment	Okay	228	9	YES	1.81	0.127	0.2	NOT FOUND SATISFACTORY
341	OT no.1	Single Phase	Socket no.11	15	Medical Group II	Moving or Portable Load Equipment	Okay	223	7	YES	1.73	0.133	0.2	NOT FOUND SATISFACTORY
342	OT no.1	Single Phase	Socket no.12	15	Medical Group II	Moving or Portable Load Equipment	Okay	238	5	YES	1.72	0.139	0.2	NOT FOUND SATISFACTORY
343	OT no.1	Single Phase	Socket no.13	15	Medical Group II	Moving or Portable Load Equipment	Okay	238	8	YES	1.41	0.163	0.2	NOT FOUND SATISFACTORY
382	1F SNCU Inborn Unit 2	Single Phase	Socket no.1	16	Medical Group II	Moving or Portable Load Equipment	Okay	234	7	YES	3.42	0.67	0.2	NOT FOUND SATISFACTORY
383	1F SNCU Inborn Unit 2	Single Phase	Socket no.2	16	Medical Group II	Moving or Portable Load Equipment	Okay	215	6	YES	3.33	0.69	0.2	NOT FOUND SATISFACTORY
384	1F SNCU Inborn Unit 2	Single Phase	Socket no.3	16	Medical Group II	Moving or Portable Load Equipment	Okay	234	5	YES	3.54	0.65	0.2	NOT FOUND SATISFACTORY
385	1F SNCU Inborn Unit 2	Single Phase	Socket no.4	5	Medical Group II	Moving or Portable Load Equipment	Okay	216	5	YES	3.14	0.73	0.2	NOT FOUND SATISFACTORY
386	1F SNCU Inborn Unit 2	Single Phase	Socket no.6	16	Medical Group II	Moving or Portable Load Equipment	Okay	230	4	YES	3.69	0.62	0.2	NOT FOUND SATISFACTORY
387	1F SNCU Inborn Unit 2	Single Phase	Socket no.7	5	Medical Group II	Moving or Portable Load Equipment	Okay	225	7	YES	3	0.76	0.2	NOT FOUND SATISFACTORY
388	1F SNCU Inborn Unit 2	Single Phase	Socket no.8	5	Medical Group II	Moving or Portable Load Equipment	Okay	232	5	YES	6.03	0.38	0.2	NOT FOUND SATISFACTORY
389	1F SNCU Inborn Unit 2	Single Phase	Socket no.9	16	Medical Group II	Moving or Portable Load Equipment	Okay	210	8	YES	6.85	0.33	0.2	NOT FOUND SATISFACTORY
390	1F SNCU Inborn Unit 2	Single Phase	Socket no.10	5	Medical Group II	Moving or Portable Load Equipment	Okay	218	5	YES	6.38	0.36	0.2	NOT FOUND SATISFACTORY
391	1F SNCU Inborn Unit 2	Single Phase	Socket no.11	16	Medical Group II	Moving or Portable Load Equipment	Okay	231	4	YES	7.53	0.3	0.2	NOT FOUND SATISFACTORY
392	1F SNCU Inborn Unit 2	Single Phase	Socket no.12	16	Medical Group II	Moving or Portable Load Equipment	Okay	231	4	YES	6.66	0.34	0.2	NOT FOUND SATISFACTORY
393	1F SNCU Inborn Unit 2	Single Phase	Socket no.13	5	Medical Group II	Moving or Portable Load Equipment	Okay	231	4	YES	7.11	0.32	0.2	NOT FOUND SATISFACTORY
394	1F SNCU Inborn Unit 2	Single Phase	Socket no.14	16	Medical Group II	Moving or Portable Load Equipment	Okay	214	6	YES	7.31	0.31	0.2	NOT FOUND SATISFACTORY
395	1F SNCU Inborn Unit 2	Single Phase	Socket no.15	5	Medical Group II	Moving or Portable Load Equipment	Okay	217	7	YES	6.98	0.33	0.2	NOT FOUND SATISFACTORY
396	1F SNCU Inborn Unit 2	Single Phase	Socket no.16	16	Medical Group II	Moving or Portable Load Equipment	Okay	232	7	YES	7.12	0.32	0.2	NOT FOUND SATISFACTORY
397	1F SNCU Inborn Unit 2	Single Phase	Socket no.17	5	Medical Group II	Moving or Portable Load Equipment	Okay	232	5	YES	7.49	0.37	0.2	NOT FOUND SATISFACTORY

1. An OT area did not have an equipotential bonding earth busbar for equalizing potential difference between the protective conductors,extraneous conductive parts ,screening devices, conductive floor grids(if provided) located in the patient environment which is a major concern being group 2medical location.
2. Earth continuity test shows that earth continuity is not found for some of the distribution boards in the SNCU area.

Sr. No.	Location Name	Ref Earth Pit No.	Earth Conductor Connected From	Earth Conductor Connected To	No of runs of Earth Conductor	Earth Conductor Type	Earth Conductor Size (WXT) (Sqmm)	Continuity Path Resistance (OHMS)	Is Earth Continuity found?	Remarks
13	SNCU Electrical Room to SNCU Lighting DB-A	NA	SNCU Electrical Room	SNCU Lighting DB-A	1	GI		999999999.00	Not Found	GI Guage not identifiable.
14	SNCU Electrical Room to SNCU Lighting DB-A	NA	SNCU Electrical Room	SNCU Power DB-B	1	GI		999999999.00	Not Found	GI Guage not identifiable
15	SNCU Electrical Room to SNCU Lighting DB-A	NA	SNCU Electrical Room	SNCU AC DB	1	GI		999999999.00	Not Found	GI Guage not identifiable

The above proof shows the apathy of the earthing system in the hospital for group 2 medical location which happens to be very critical, thus inviting risk of fire incident,shock hazards,malfunction of critical equipment.



Electrical INV Room OT

SNCU UPS Room

Observations
The accumulation of dirt, dust & moisture is observed on the UPS batteries.

Locations
#Electrical INV Room OT
#SNCU UPS Room

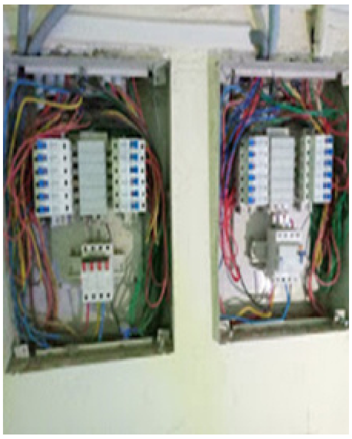
Recommendations
As per Regulation No. 109 (1), UPS batteries should be free from dust, dirt and moisture to improve its efficiency & life.

Auditor's observations
Rack was not provided for the placement of batteries & inverter.

High risk

Maintenance of batteries is very important with respect to the safety of the hospital. The batteries placed in the SNCU & OT for UPS are not provided with a rack as well as the battery cabinet is not provided with double earthing. Ventilation is also not provided in the UPS room. These are the major lapses in safety.

Single strand aluminum & non-flame retardant cable is used in the SNCU Lighting DB A and Power DB B.



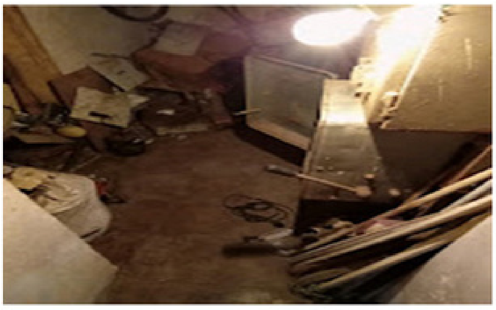
SNCU Lighting DB A and Power DB B.

Electrical panel rooms & Electrical panels found in extremely pathetic condition which needs immediate attention are listed below with photographs

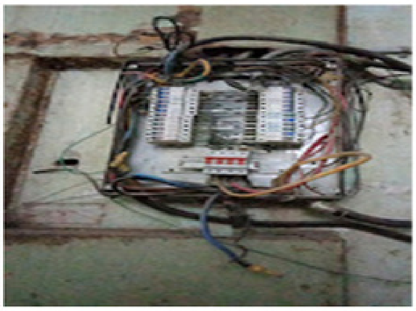
Main Electrical Panel Room

Generator Switch Room

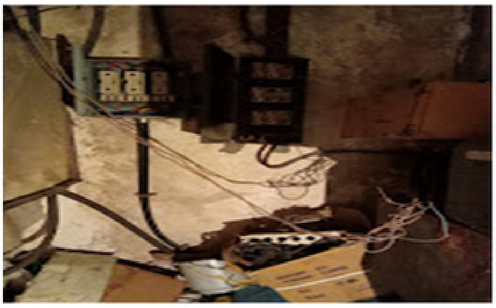
Ward 5 & NRC Electrical Room



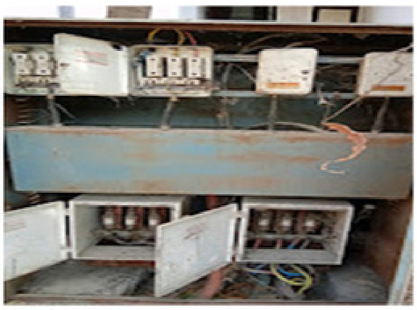
Electrical Complaint Room



OPD & Sonography Panel Board



Electrical Complaint Panel GF

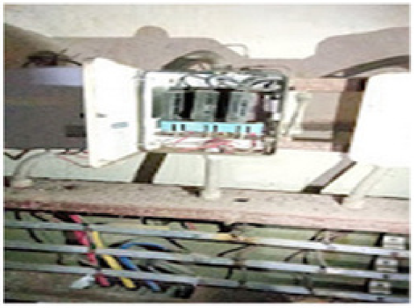


Doctors Quarter Feeder Pillar Panel

SNCU Electrical Panel

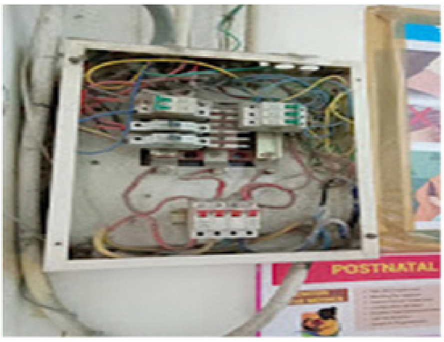
PWD Office Feeder Pillar Panel

Ward 5 & NRC Electrical Panel

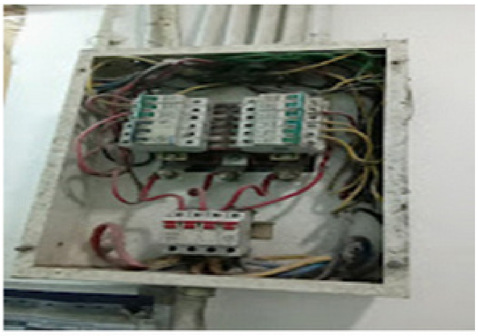


Ward No 6 Electrical Panel

LT Panel 2 Generator Switch Room



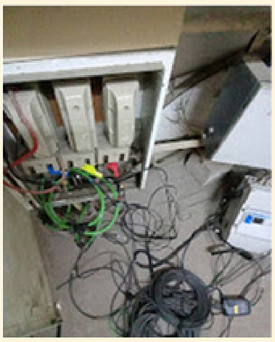
Navjat Shishu Room DB 1



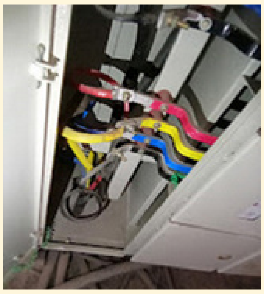
Nursing Station DB (FF)
Delivery Room 1

LR1 Research Room DB

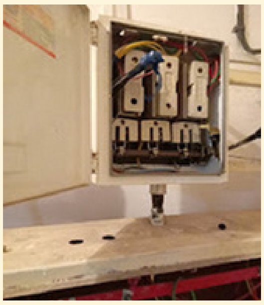
FF Children Specialist DB (Fuse is bypassed here with bare conductor which was found live)



Electrical OT Panel



Main Electrical Panel & Incomer Breaker



SNCU Electrical Panel

Ward No 6 Electrical Panel

Observations
Extra knockouts in the gland plate are not plugged.

Locations
#Electrical OT Panel
#Main Electrical Panel & Incomer Breaker
#SNCU Electrical Panel
#Ward No 6 Electrical Panel

Recommendations
As per NEC 2011, Part 1, Section 22, 14.11 (c),panels and switchgears should be vermin and damp proof and all unused openings or holes shall be blocked properly and it should be ensured that appropriate IP protection is provided to switchgear / panel / equipment depending on location of installation.

Auditor's observations
Ward No 6- Short circuit happened due to the presence of a rat inside the panel.

High risk

Component Storage DB 1 & Storage DB 2

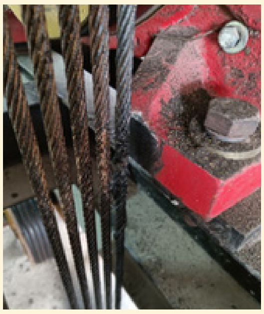
Navjat Shishu Room DB 1

Observations

Fuses/isolators have to be replaced on an immediate basis with RCD in distribution boards & electrical panels.

Recommendations

As per NEC 2011, Part 1 General And Common Aspects Section 6 Standard Values, 6.7 Switchgear & Protective Device, ELCB/RCD should be provided in the circuit for the safety of instruments and prevention of shock hazards.



OPD Lift Area (Wear & Tear of ropes)

Main Lift Area (greasing of ropes)

Observations

Operation & maintenance activity of lift is not carried out periodically.

Locations

OPD Lift Area
#Main Lift Area

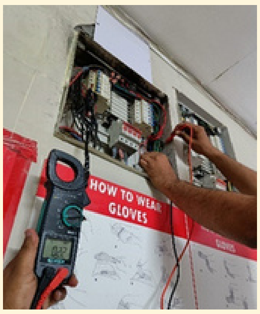
Recommendations

As per "NEC 2011,CL 6.1.b, scheduling protective / preventive and routine maintenance of equipment should be carried out periodically.

Auditor's observations

1. Wear & tear of the rope of the lift trolley was observed due to friction.
2. Greasing of the ropes of the main lift was not carried out.

High risk



OT Area

LR1 OT

Observations

Potential difference between exposed conductive parts and the protective conductor busbar is exceeding 10 mV in normal condition.

Location

#OT Area

Recommendations

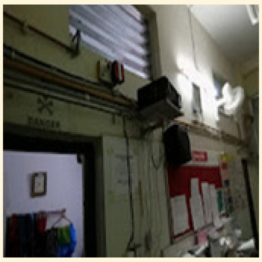
As per IS:3043,31.1.4 Provision P3: Restriction of Touch Voltage in Rooms Equipped for Direct Cardiac Application, potential difference between exposed conductive parts and the protective conductor busbar shall not exceed 10 mV in normal condition to minimize the risk of electric shock to human beings.

Auditor's observation

Metal plug of AC was found live, which is posing danger of electric shock to the users.

High risk

OT Area



OT Area

SNCU Area

Observations
Minimum 200 mm distance is not maintained between medical gas outlets & electrical lines/switchboards.

Location
#OT Area
#SNCU Area

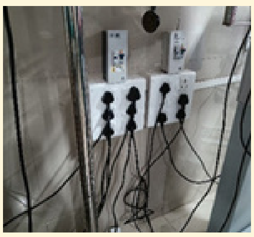
Recommendations
As per IS:17512, Regulation No- 7.1.Common Rules 7.2.1.2.1, explosion risk, minimum distance of 200 mm shall be maintained between electrical lines/switchboards & medical gas outlets to prevent explosion.

Auditor's observations
OT Area & SNCU Area - Oxygen pipe is not maintained at the distance from the electric line.

High risk

SNCU Area (cable insertion without socket)

SNCU Area (Electric board mounting)



SNCU Area (distance between the plugs)

Observations
1. Cable is inserted in a 16 Amp AC socket in the SNCU area without a main plug.
2. Electric board mounting was not done in the proper location with respect to the SNCU trolly of the baby.
3. Distance between the plugs is not appropriate for plugging the cable into the socket with respect to ease of operation.

Locations
#OT Area
#SNCU Area

Recommendations
1.It is recommended to provide a 3 pin plug to the cable of appropriate rating for the safety of the human being.
2. It is recommended to mount an electric board in an accessible location for ease of operation.
3. It is recommended to maintain proper distance for smooth operation of plug in & plug out.

High risk

Hidden risks observed across hospital 3

Nagpur, Maharashtra

Electrical room which is supplying OT & OPD does not have space even to stand, so carrying out O&M activity is next to impossible

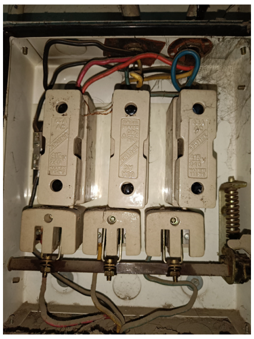
Impact

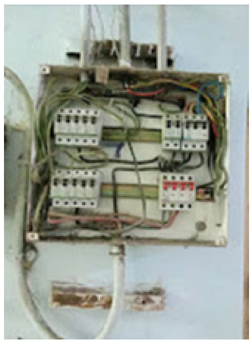
Extremely dangerous in case of an emergency/any work in progress can lead to fatal accidents

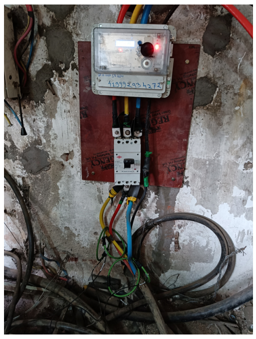
Panels are rusted, incoming cables are stressed as no loop is kept while connecting cables inside the panel

Impact

Immediate hazard of electrical fires given the condition of the cable insulation and no panel maintenance







Electrical panel installed in ladies washroom

Impact

1. Accessibility is limited as no technical person can enter directly in case of an emergency
2. Puts the life of the people using the room in danger

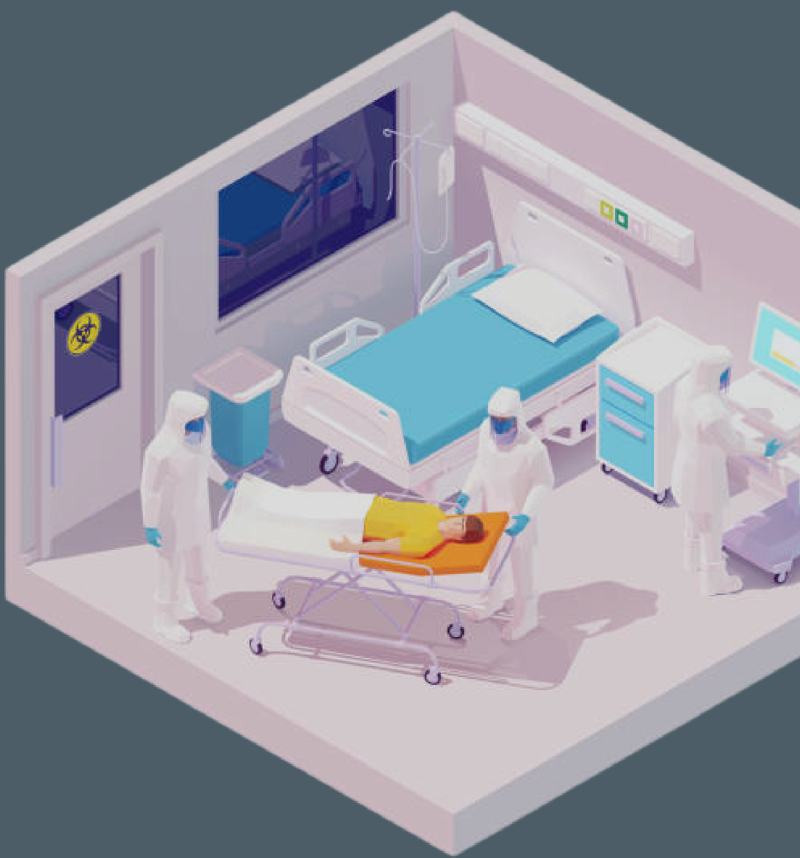
Ward No 6 Electrical Panel
Short circuit happened in the above panel due to the presence of rat inside the panel, as panel was found open

Recommendations for the Stakeholders

Recommendations to improve power quality and electrical safety in hospitals

1. Challenges from multi-pronged nature of PQ and electrical safety
2. Placing specific accountability and monitoring of risks is a key to improve
3. The costs of poor power quality in hospitals cannot be quantified accurately in terms on downtime or revenue losses

> While improving safety and reliability, it is important that the stakeholders understand their individual responsibility and the connections within which impact as a collective outcome



The state of PQES: Insights and observations

The multi-pronged and dependent nature of power quality and electrical safety creates several challenges in placing specific accountability and monitoring performance. Teams with members well aware and respecting the electrical standards and practices in their work is fundamental to ensuring higher reliability and better safety of hospitals. At every stage, the teams of various stakeholders must be in alignment towards achieving the common goal of highest electrical safety, reliability and power quality.

Here, based on the analysis and insights from the study, key guidelines for responsibility are enlisted for each of the stakeholders in view of improving the hospital's electrical safety and power quality.

Owner/Builders/Hospital Trust

- Making sure that standards specific to installation of Electrical Network in healthcare facilities are followed by the design consultants while designing the Electrical Network
- Ensuring equipment procured is in line with required Power quality norms (e.g. transformer voltage regulation, drive/UPS specifications for harmonics)
- Ensuring each critical infrastructure/machinery is tested at Factory/Site
- Ensuring utility regulations on power quality are well understood in sync with our infrastructure requirements
- Making sure periodic Electrical Safety and Power Quality Audits are carried out on the hospital facility and the recommendations/actionables discovered in the audits are followed through
- Guiding/managing all stakeholders in a way that optimum due diligence is carried out to maintain Electrical Safety and Reliability in the hospital facility

Design Consultant

- Ensuring that that power availability, quality and reliability are of prime focus for the electrical network design and the electrical design guidelines specific to a hospital facility are incorporated in the same
- Allowing a backup supply of sufficient capability to be present at all times to facility areas where loss of power may directly result in loss of life/severe injury
- Including equipotential bonding in the Earthing design of critical facility areas to ensure better fault handling and safer electrical environment for all occupants
- Using IT earthing for group 2 medical facilities in accordance with IS 17512 and IS 3043 as an imperative for patient safety
- Making sure there is enough scope for expansion later on in the life of the Electrical Network, and these initial cautious design choices are implemented in such a way that they will still be allowed to be followed while expanding
- While choosing the protective devices for the Electrical Network, RCDs, MCBs, SPDs should be chosen for effective fault isolation, and in such a specification that it has high precision, and will not allow the fault to travel upstream, thereby increasing the safety of patients and personnel
- Ensuring that the monitoring of power quality and energy is inbuilt at the PCC (point of common coupling)
- Special design considerations are required for -
    - Protective earthing
    - Equipotential bonding and earthing
    - Differential and overcurrent protection
    - Use of very low safety voltage
    - Safety supplies (batteries & DG sets)
    - Isolation transformers
    - IT power supply systems for Group 2 medical facilities
    - UPS Power supply panels and DBs (along with proper identification on the end use switches/sockets)
    - Hospital ground panels and electrical outlets
    - Downstream distribution for critical areas

Electrical Contractor (installation)

- Design considerations provided by the consultant should be followed diligently, with a reliable verification mechanism in place
- The material/components used for installations should be of high quality, it is to be kept in consideration that it is probably one of the most critical types of Electrical Networks that they are installing
- Internal checks shall be conducted after finishing each installation, especially at the end connections like sockets, DBs, and at the locations where sensitive electronic equipment will be installed to make sure that the Electrical Network is built correctly
- Once the installation is finished, accurate as built SLD and Earthing Schematic must be provided by the contractor to the Hospital management
- As a technical entity, Electrical contractor should emphasize on the importance of routine maintenance and testing to the hospital management

Electrical Contractor (maintenance)

- Electrical maintenance should be carried out on specified intervals based on industry standards and practices
- Preventive testing of electrical network should be done along with the routine maintenance as per frequency of testing for each test
- The issues determined through testing should be taken care of immediately to make sure the electrical network is maintained to be reliable
- Visual inspection once a month carried out on major facility areas to check if there are any noticeable problems in installation and can be addressed
- making admin/hospital technician aware of the progress and the work done so that there is no gap in communication

Administration/ Technicians

- Electrical issues should be dealt with immediately
- if the issue is too big to handle or a potential hazard detected by the technician himself, it should be reported to the management and maintenance contractor should be called ASAP
- Operations of various electrical elements should be observed and tracked by the technician
- Promoting safe electrical practices to the personnel who deal with medical instruments should be persistent
- Proactively trying to find the blind spots in the electrical network and reporting them to management

Annexures

A simple checklist that can make a difference!

1. Tasks spread over the lifecycle of an electrical network
2. Adherence to Standards at every possible step
3. Whichever lifecycle stage your facility is at, it has a chance to improve

“Actionable recommendations that are useful in improvement of Electrical Safety and Reliability

PQES checklist for healthcare facilities

Checklist for Primary Health Centre / Community Health Centre (PHC/CHC)

Design (IS732)

- Check if wires/cables used in panels/distribution boards for internal wiring & in breaker & fuse are fire retardant & low smoke.
- Check if fuses ,MCBs/switches used in the circuit are as per IEC standard.
- Check if ELCB/RCD is provided in the circuit for the safety of instruments and prevention of electrical shock hazards
- Check if fuses ,MCBs/switches used in the circuit are as per IEC standard

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Installation

- Check if fire extinguishers & fire buckets are provided in electrical panel rooms & UPS rooms as per fire safety norms.
- Check for danger notice boards, restricted access notice boards placed on UPS rooms, electrical panel rooms & panels.
- Check if cable dressing is done properly using suitable accessories like glands, clamps, support and pvc cable ties etc in distribution boards
- Check if earthing provided to the distribution boards has a continuity till the earth pits
- Check if aluminum conductors are not used for earthing.
- Check if protection is provided against the live part to prevent the direct contact in panels/distribution boards
- Check if OFF & ON markings on switches are properly visible & are in an accessible position.
- Check if TN-C type earthing is not provided for medical location
- Check if cables used in the circuit are insulated against the highest voltage present.
- Check if insulating floor mats are provided in the panel/UPS rooms.
- Check if proper Type selection of MCBs/RCDs is done based on load type
- Check if the cable/wire used for the AC is of appropriate rating.

- ☑ Check if the nameplate provided is having name & rating mentioned on diesel generator, UPS, motor, pump etc.
- ☑ Check if the body earthing of UPS battery cabinet & UPS is connected using two separate & distinct body earth conductors.
- ☑ Check if adequate ventilation is provided for the UPS room.
- ☑ Check if UPS batteries are properly placed on the rack & have adequate illumination.
- ☑ Battery rooms should be well ventilated to escape gasses which are released during charging or discharge of batteries to minimize the risk of gasses being accumulated & thus resulting in fire.
- ☑ Check if emergency lighting fixtures are provided in critical areas like panel room, control room, battery room, passages, stairs etc.
- ☑ Check if double earthing is provided to the distribution board & panel body which are connected to two distinct earth pits.
- ☑ Check if incoming & outgoing feeder names are clearly mentioned on the panel.
- ☑ Check if identification tags are provided for power & control cables /wires in distribution boards & panels
- ☑ Check if protection is provided against the live part to prevent the direct contact in panels/distribution boards
- ☑ Check if the lift/pump motor's frame & body are connected with the two separate and distinct connections with the earth.
- ☑ Check if suitable sized earthing wire is used for the motor.
- ☑ Check if the cable/wire used for the AC is of appropriate rating.
- ☑ Check if extraneous conductive parts such as metallic oil pipe, metallic gas pipe, metallic water pipe & metallic structure in a building are connected to supplementary equipotential bonding earth conductor provided in medical locations.
- ☑ Check if medical locations have supplementary equipotential bonding connected to the equipotential bonding busbar
- ☑ Check if equipotential bonding earth busbar is located near the Distribution Board.
- ☑ Check if Impedance between the individual socket & protective conductor/earth busbar in the distribution board doesn't exceed 0.2 Ohms.
- ☑ Check if the protective conductor used has dimension as below
- ☑ a) If the cross sectional area (S) of cable is less than 16 sq mm then the size of the protective earth conductor is the same as the size of the main conductor(S)?

b) If cross sectional area (S) is between 16 sq mm & 35 sq mm then size of protective earth conductor is 16 sq mm

c) If 2·5 sq mm cable is used , then check whether mechanical protection is provided to the protective earth conductor?

Operations & Maintenance

- ☑ Check if adequate illumination is provided in the UPS room.
- ☑ Check if the UPS room & electrical panel rooms are free from any scrap , dirt, dust & moisture.
- ☑ Check If neutral is not used as a protective earth conductor.
- ☑ Check if outdoor/indoor equipment & panels are complying with the proper degree of protection against dust & water.
- ☑ Check if an updated single line diagram is provided in the electrical panel room along with a load list consisting of critical loads.
- ☑ Check if indication of heating is observed on cables, contacts, MCBs terminals of panel / distribution board.
- ☑ Check if panels/distribution boards are vermin proof(extra holes are sealed) to prevent the entry of the rodents.
- ☑ Check if cables/ wires are provided with lugs & properly terminated.
- ☑ Check if PVC flexible cables without armor are not in the open without any protection to prevent the damage from rodents.
- ☑ Check if MCBs & fuses are locked/shielded.
- ☑ Check if neutral is appropriately distributed among three/single phase circuits.
- ☑ Check if OFF & ON markings on switches are properly visible & are in an accessible position.
- ☑ Check if operating devices for emergency switching are marked with bright color & contrasting background.
- ☑ Check if ventilation is provided for the UPS room & electrical panel room.
- ☑ Check if designated personnel to observe the implementation of safety measures in the facility provided.
- ☑ Check for the photocopies of certificate of competency or electrical work permit license issued by appropriate government to the designated employee.
- ☑ Check if removable links for testing the earth resistance of an individual earth electrode have been provided.

- Check for the earthing layout of the hospital.
- Check if Potential difference between exposed conductive parts and the protective conductor busbar is not exceeding 10 mV in normal conditions.
- Check if all equipment, so arranged in medical location to facilitate its operation, inspection and maintenance and access to its connections
- Regular servicing & maintenance of DG is carried out & records of the same are maintained.

Periodic Testing

- Tests and its sequence of Mainly LV system
  It is important to keep the sequence of testing as follows. In case of failure in a test, retesting from the previous test onwards after rectification is necessary. Testing in a potentially explosive atmosphere requires appropriate safety precautions in accordance with IEC 60079-17.
  1. Insulation resistance of the electrical installation
  2. Protection by SELV, PELV or by electrical separation through Insulation resistance measurements
  3. Automatic disconnection of supply using tests such as Fault Loop Impedance, Earthing Continuity, protective device coordination, earth resistance measurement,
  4. Additional protection such as RCD tests,
  5. Polarity/phase sequence test
  6. Functional and operational tests on protection devices such as Primary/Secondary injection etc
  7. Verification of voltage drop
  8. Advanced tests
     a. Power Quality Analysis which might include some of the following parameters
        i. Active power (P) and active energy (Ea),
        ii. Reactive power (QA, QV) and reactive energy (ErA, ErV),
        iii. Apparent power (SA, SV) and apparent energy (EapA, EapV),
        iv. Frequency (f)
        v. RMS phase current (I) and neutral current (IN, INc),
        vi. RMS voltage (U) measurements,
        vii. Power factor (PFA, PFV)
        viii. Short term flicker (Pst) and long term flicker (Plt),
        ix. Voltage dip (Udip) and voltage swell (Uswl),
        x. Voltage interruption (Uint),
        xi. Transient overvoltage (Utr) measurements,
        xii. Voltage unbalance (Unb, Unba),
        xiii. Voltage harmonics (Uh) and voltage THD (THDu and THD-Ru),
        xiv. Current unbalance (Inb, Inba),
        xv. Current harmonics (Ih) and current THD (THDi and THD-Ri),
        xvi. Minimum, maximum, peak, three-phases average and demand

b. Electricity bill analysis and Reactive Power Compensation efficacy

c. Thermal imaging in compliance to NETA-MTS standards

d. Capacity Assessment w.r.t actual loading vs. design rating of various protective devices and conductors

- Ground potentials and leakage current measurements

Power Quality

- Analyze voltage trend pattern.
- Check the loading on all the three phases.(find out unbalance if any)
- Check the neutral current if it matches with the unbalance in current.
- Check the Monthly PF fluctuations to understand APFC efficacy.
- Monitor current & voltage harmonics periodically
- Check the ground potential trend with respect to the percentage of phase neutral voltage.

Sub District Hospitals / District Hospitals / Hospitals

Design (IS732)

- Check if suitable current carrying capacity power cables & control wires are used in circuits in panels, distribution boards.
- Check if wires/cables used in panels/distribution boards for internal wiring & in breaker & fuse are fire retardant & low smoke.
- Check if fuses ,MCBs/switches used in the circuit are as per IEC standard.
- Check if ELCB/RCD is provided in the circuit for the safety of instruments and prevention of electrical shock hazards.
- Check if cables used in HVAC systems are fire retardant & low smoke cables.
- Check if Group 2 medical locations have a dedicated RCD connected in circuit only with single equipment.(if TN,TN-S & TT type of earthing is used)
- Medical Equipment intended to operate in conjunction with an oxygen rich environment should be designed to minimize the probability or occurrence of ignition of flammable materials.

Installation

- Check if fire extinguishers & fire buckets are provided in Main Electrical rooms, DG area electrical panel rooms, UPS rooms and other medical locations as per fire safety norms.
- Check for danger notice boards, restricted access notice boards placed on DG, UPS room, electrical panel room & panels.
- Check if laying of power & control cables is done separately.
- Check if proper fencing, locking arrangement & shed is provided for DG.
- Check if sufficient space is available in the DG area,UPS rooms , electrical panel rooms for repairs & maintenance
- Check if cable dressing is done properly using suitable accessories like glands, clamps, support and pvc cable ties etc in distribution boards, panels & DG.
- Check if the nameplate provided is having name & rating mentioned on diesel generator, UPS, motor, pump etc.
- Check nameplate is provided on panels & distribution board as per updated single line diagram.

- Check if body & neutral earthing of DG is done by two separate & distinct conductors.
- Check if cable trenches/trays are provided for DG /transformer.
- Check if the stack provided for DG for exhaust gasses is proper in terms of height & direction as per Central Pollution Control Board.
- Check if an emergency switch is provided for DG set.
- Check if provision for diesel storage is provided for DG.
- Check if SOP is provided for DG set operations.
- If a separate oil tank is provided for the DG set, then check that its frame is connected to the earth at minimum two locations.
- Check if cables used in the circuit are insulated against the highest voltage present.
- Check if insulating floor mats are provided in the panel/UPS/DG rooms.
- Check if the body earthing of distribution boards, electrical panels, UPS battery cabinet & UPS etc is connected using two separate & distinct body earth conductors.
- Check if adequate ventilation is provided for the UPS room.
- Check if UPS batteries are properly placed on the rack & have adequate illumination.
- Battery rooms should be well ventilated to escape gases which are released during charging or discharging of batteries to minimize the risk of gases being accumulated & thus resulting in fire.
- Battery compartments of ME EQUIPMENT shall be designed to prevent accidental short circuiting of the battery where such short circuits could result in a hazardous situation.
- Check if cable trays are provided for laying of the cables.
- Check if emergency lighting fixtures are provided in critical areas like panel room, control room, battery room, passages, stairs etc.
- Ensure selection of cables is as per their current carrying capacity
- Check if incoming & outgoing feeder names are clearly mentioned on the panel.
- Check if identification tags are provided for power & control cables /wires in distribution boards & panels.
- Check if aluminum conductors are not used for earthing.
- Check if protection is provided against the live part to prevent the direct contact in panels/distribution boards

- Check if the lift/pump motor's frame & body are connected with the two separate and distinct connections with the earth.
- Check if suitable sized earthing wire is used for the motor.
- Check if HVAC motor's frame & body are provided with two distinct earth connections.
- Check if the cooling fan provided for the VFD is in working condition.
- Check if suitable Type MCBs/RCDs are provided for various end load uses such as AC etc.
- Check if the cable/wire used for the AC is of appropriate rating.
- Check the earthing system of medical location equipped with insulation monitoring device for group 2 medical location to get the information regarding insulation strength of the cable.
- If Insulation monitoring device is installed, check if audible & visual indications are provided for the same in an IT earthing system.
- Check if IT type of earthing is provided for group 2 medical locations.
- Check if the rated phase to neutral voltage value (Un) on the secondary side of isolation transformers is not exceeding 250 V a.c.
- Check if the provided single-phase Isolation transformer in isolated terre earthing system is having kVA rating above 0.5 kVA and below 10 kVA.
- Check if an overload current protection device is not installed in the upstream for feeder circuits and downstream of the isolation transformer in isolated Terre Earthing system to avoid disconnection of supply to all the equipment of group 2 medical location.
- Check if the distribution boards are installed outside group 2 medical locations thereby safely guarded against unauthorized persons..
- Check if Group 1 & 2 medical locations have provision of alternate/ emergency power supply.(OT/ICU/Dentist)
- Check if extraneous conductive parts such as metallic oil pipe,metallic gas pipe,metallic water pipe & metallic structure in a building are connected to supplementary equipotential bonding earth conductor provided in medical locations.
- Check if medical locations have supplementary equipotential bonding connected to the equipotential bonding busbar
- Check if screening devices(Electrically operated like sonography machines) used against electrical interference fields are connected to the supplementary equipotential bonding in medical locations.
- Check If supplementary equipotential bonding earth conductor provided in medical location is connected to the conductive floor grids.

- Check if equipotential bonding earth busbar is located near the Distribution Board.
- Check if fixed and permanently installed equipment having a rated power input of more than 5 kVA which includes all X Ray equipment (even with a rated power input of less than 6 kVA) is protected by RCD.
- Check if TN-C type earthing is not provided for medical location.
- Check if Impedance between the individual socket & protective conductor/earth busbar in the distribution board doesn't exceed 0.2 Ohms.
- Check if the protective conductor used has dimension as below

  a) If the cross sectional area (S) of cable is less than 16 sq mm then the size of the protective earth conductor is the same as the size of the main conductor(S)?

  b) If cross sectional area (S) is between 16 sq mm & 35 sq mm then size of protective earth conductor is 16 sq mm

  c) If 2·5 sq mm cable is used , then check whether mechanical protection is provided to the protective earth conductor?

Operations & Maintenance

- Check if adequate illumination is provided in the DG & UPS room.
- Check if the UPS room,DG area & electrical panel rooms are free from any scrap , dirt, dust & moisture.
- Check if DG batteries are free from dirt, dust & moisture.
- Check If neutral is not used as a protective earth conductor.
- Check if cable trenches/trays provided for DG/ transformer are free from waste material.
- Check if no oil & diesel leakages are there on the D.G set and nearby flooring inside the canopy.
- Check if air inlet louvers are free from any blockage for intake of air from outside for DG.
- Check if outdoor/indoor equipment & panels are complying with the proper degree of protection against dust & water.
- Check if an updated single line diagram is provided in the electrical panel room along with a load list consisting of critical loads.
- Check if indication of heating is observed on cables, contacts, MCBs terminals of panel / distribution board.
- Check if panels/distribution boards are vermin proof(extra holes are sealed) to prevent the entry of the rodents.

- ☑ Check if cables/ wires are provided with lugs & properly terminated.
- ☑ Check if PVC flexible cables without armor are not in the open without any protection to prevent the damage from rodents.
- ☑ Check if MCBs & fuses are locked/shielded.
- ☑ Check if neutral is appropriately distributed among three/single phase circuits.
- ☑ Check if OFF & ON markings on switches are properly visible & are in an accessible position.
- ☑ Check if operating devices for emergency switching are marked with bright color & contrasting background.
- ☑ Check if ventilation is provided for the UPS room & electrical panel room.
- ☑ Check for the wear & tear of the rope of the lift trolley.
- ☑ Check if the protection system provided for the control circuit in HVAC is regularly monitored.
- ☑ Check if designated personnel to observe the implementation of safety measures in the facility are present.
- ☑ Check for the photocopies of certificate of competency or electrical work permit license issued by appropriate government to the designated employee.
- ☑ Check if removable links for testing the earth resistance of an individual earth electrode have been provided.
- ☑ Check for the earthing layout of the hospital is available.
- ☑ Check if there is automatic changeover provided to standby emergency power service to maintain the continuity of power to the connected medical equipment in the case of failure of main supply voltage within the period of not exceeding 0.5 sec.
- ☑ Check if an emergency power supply is capable of providing power supply through UPS only(in the absence of DG) for at least 3 hours to critical loads like luminaries on operating theater tables,endoscopes, monitors,critical life supporting Medical electrical(ME) equipments in case of failure of main power supply.
- ☑ Check if Potential difference between exposed conductive parts and the protective conductor busbar is not exceeding 10 mV in normal conditions.
- ☑ Check if all equipment, so arranged in medical location to facilitate its operation, inspection and maintenance and access to its connections
- ☑ Regular servicing & maintenance of DG is carried out & records of the same are maintained.
- ☑ Check if operation & maintenance activity of lift is carried out periodically.
- ☑ Check if preventive maintenance of all the motors of the HVAC system is carried out.

Periodic Inspection and Testing

Below listed points are for both inspection and testing periodically for ensuring safer and reliable electrical network. Testing in a potentially explosive atmosphere requires appropriate safety precautions in accordance with IEC 60079-17.

1. Protection against electric shocks are in place
2. Continuity of live, neutral and earthing conductors
3. Insulation resistance of the electrical installation
4. Protection by SELV, PELV or by electrical separation through Insulation resistance measurements
5. Floor and wall resistance/impedance
6. Automatic disconnection of supply using tests such as Fault Loop Impedance, Earthing Continuity, protective device coordination, earth resistance measurement,
7. Additional protection such as RCD tests,
8. Polarity/phase sequence test/Verification of voltage drop
9. Functional and operational tests on protection devices such as Primary/Secondary injection etc
10. Portable Appliance Tests
11. Check the functioning of the insulation monitoring device if installed.
12. Check the leakage current of the IT transformer every 3 years.
13. Advanced tests
    a. Power Quality Analysis which might include some of the following parameters
        i. Active power (P) and active energy ,
        ii. Reactive power and reactive energy
        iii. Apparent power and apparent energy ,
        iv. Frequency
        v. RMS phase current and neutral current ,
        vi. RMS voltage measurements,
        vii. Power factor ,
        viii. Voltage interruptions, transients, dips, swells, flickers ,
        ix. Voltage unbalance ,
        x. Voltage harmonics and voltage THD ,
        xi. Current unbalance ,
        xii. Current harmonics and current THD ,
        xiii. Minimum, maximum, peak, three-phases average and demand
    b. Electricity bill analysis and Reactive Power Compensation efficacy
    c. Thermal imaging in compliance to relevant standards such as NETA-MTS, IS 16168
    d. Capacity Assessment w.r.t actual loading vs. design rating of various protective devices and conductors
    e. Ground potentials and leakage current measurements

Quick Inhouse Power Quality Checks

- Analyze voltage trend pattern.
- Check the loading on all the three phases.(find out unbalance if any)
- Check the neutral current if it matches with the unbalance in current.
- Check the Monthly PF fluctuations to understand APFC efficacy.
- Monitor current & voltage harmonics periodically
- Check the ground potential trend with respect to the percentage of phase neutral voltage.

Disclaimer

RELIABILITY

SAFETY QUALITY

EFFICIENCY

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