Review of the lightning electromagnetic impulse protection measure for smart home and building in smart grid system in Thailand

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Abstract

A failure of a smart grid system can cause huge economic losses. particularly for large systems installed to power smart cities. How can interference from hackers using new techniques such as the superpower electromagnetic pulse, or from natural phenomena such as lightning strikes which intensity increases every year be prevented?, the More than 200 strokes per 1 square-kilometer per year of cloud to ground lightning (CG) had been recorded in some area of Thailand and this is projected to increase since extreme weather events, such more frequent very strong thunderstorms, are also increasing. In depth reviews show that lightning electromagnetic impulse protection measure can be very important for ensuring safety of a smart grid network. The methodologies for the design and installation of smart homes and buildings must conformed with the standards of h EMC/EMI in order for systems to withstand the interferences. As such, the best approach for the protection of the systems against electromagnetic field from both wave propagation and inductance through various conductors is the LEMP protection measure. This consists of the defining the lightning protection zone (LPZ) and lightning protection level (LPL) and the design and installation of the earthing system, lightning protection system (LPS), shielding, equipotential bonding, cable path and the combination of SPDs. This paper has shown the appropriate concept architecture of LEMP protection measure for smart home and building in smart grid system in Thailand.

Keywords:

Smart home, Smart building, Smart grid, Lightning electromagnetic impulse (LEMP), Electromagnetic compatibility (EMC), Power line communication (PLC), Home area network (HAN), Home energy management system (HEMS)

1. Introduction

Smart grid systems aim to make electricity more affordable, at the same make the power grid system more reliable, through an energy management system that allow energy users to own and manage their own energy systems. In smart grid systems, electric equipment and power generating devices can be operated automatically and be controlled remotely, using a large number of sensors and microcontrollers that also allow for immediate collection of energy data and information. Normally, electrical grids must have self-protection from internal transient over-voltage hazard of switching and external lightning surges. The smart grid network which has several electronic devices will have increase damage risks from these surges. Therefore, higher protection measures are needed compared to conventional electrical grids.

Network design for smart grid should emphasized the need for protection against lightning electromagnetic impulse (LEMP) to avoid grid failure. The LEMP protection measure is defined under international standard IEC 62305-4 which consists of earthing system and bonding network, magnetic shielding and line routing, coordinated surge protective device system and isolating interfaces. LEMP protection also prevents damage from other microwave sources such as radio base stations, such as HPM (High power microwave), which is a powerful weapon for criminals and terrorists, and DEW (Directed energy weapon), which is a powerful microwave generator mounted on the cars used by the military.

Smart homes and buildings in smart grid systems are the new expected energy technologies of the future. These aim for, stability and safety of the electrical equipment and comfortability of power consumers. Smart homes and buildings include an energy management system, internal electricity infrastructure, renewable energy sources, energy storage, and intelligence electrical appliances. Energy management systems [1] can be divided into different categories according to type of use and the boundary range of electricity grid. Home energy management system (HEMS) is the smallest system. HEMS manages the various electrical devices and energy equipment s within the boundaries of a residential building or area, behind an electricity meter. HEMS control the power utilization by itself; following or dependent on the conditions of the residence and behavior and lifestyle of the residents. The building energy management systems (BEMS) is more complex because this system is used for larger buildings (e.g.; government/public buildings, shopping centers, office buildings, universities, hospitals/medical centers). BEMS control more energy equipment and devices, and the energy use is more varied. Energy generation can come from solar, wind, and biomass. Energy storage, such as batteries, are also included. Importantly, the electricity infrastructure needs stable and safe transmission system for sensitive information. Errors can cause huge system damages. Therefore, a good protective measure against interferences, such as electromagnetic impulse and electric shock is a must. LEMP protection measures, which is based on the standard of electromagnetic compatibility (EMC), will especially be used to avoid system failure from lightning electromagnetic impulse (LEMP) and electromagnetic waves.

2. Literatures Review

2.1. Effects of LEMP on smart grids

The following discussions is about the damages on of smart grid systems caused by electromagnetic impulse and electric shock and the protection methods against electrical surges.

Ernst Schmautzer, Stephan Pack, Maria Aigner and Christian Raunig (2011) [2] studied the Integrated Grounding, Equipotential Bonding and Lightning Protection in Smart Grids and Smart Buildings – A Multi-Faced Approach. They studied the methodology for the protection against electric shock and lightning strike effects, to provide safe and reliable operation of smart grids and smart buildings. For new buildings, the concern should be on low and high frequency effects and for existing buildings revitalization. They presented two approaches. The first approach i the construction and electrical installation phase of the grounding, bonding, shielding, and lightning protection systems. The second approach is the integration of a closed-meshed fish trap structure in the grounding, bonding, shielding, and lightning protection systems. They showed the concepts of the integrated grounding, equipotential bonding and lightning protection systems in a smart grid and a smart building with new installations and refurbishing to guarantee the reliable functioning of the required electrical/electronic equipment in the smart building.

Tibor Horvath (2014) [3] studied “Lightning Electromagnetic Impulse”. He found out that the lightning strike phenomenon caused electromagnetic impulses which can make the conductive coupling onto the environment by the radiation of magnetic field and induction of lightning current around its path. The magnetic field can create inductive coupling into electric and electronic systems and cause the damage even if the lightning strike is far away. The protection against lightning electromagnetic impulse should bond the grounding system of a building by equipotential bonding bar (EBB) to all other metallic objects on the ground. The protection against penetration of the electromagnetic field will require full shielding with continuously covered thick metal plane. If the shielding is cracked, the Faraday cage will be penetrated by the electromagnetic field into the structure.

Albert R. Martin (2010) [4] studied “Safety Issues and Damage to Equipment” in both smart grid and home network connections. He found out that when thunder storms are coming to a smart grid area, the appliances connected in a home area network (HAN) getting electricity from the smart grid system can be damaged by lightning strikes. There are the direct strikes to the structure and the indirect strikes with induction of lightning current. The lightning protection is important, as well as, the standards for protection against lightning. If in the installation of the lightning protection, the standard are not considered, it can cause shock hazard and equipment failure. Ground potential rise (GPR) is the main cause of equipment damage. The operation system has two or more grounding systems which are not interconnected between the systems. When the lightning current comes through in the first grounding system, GPR produced and be a potential shock hazard which is then transported into the other grounding system and effect equipment damage.

V. Gurevich (2011) [5] studied “Smart Grid: New Prospects or New Problems? (Part 2)”. He has shown his understanding of the problems, which will occur in a smart grid system and the predictability of these problems, The first is vulnerability of the smart grid network against hacker attacks. There is a significant risk to the control system is being attacked on a TCP/IP protocol network. The second is from the super-power electromagnetic pulses which has been created as a new type of weapon. It can attack and penetrate poorly shielded system and destroy electronic equipment that has high frequency, in the centimeter and millimeter range, by high power emission. Because smart grid uses a lot of microprocessor devices in all component, the smart grid system can be damaged easily with the increasing trend of using microchips combined with remotely-controlled devices for remotely reading data and managing the devices to follow remote commands.

Summarizing, Ernst Schmautzer, Stephan Pack, Maria Aigner and Christian Raunig investigated the methodology for the protection of smart grid against electric shock and lightning strike. Tibor Horvath found out that the lightning electromagnetic impulses can make the conductive coupling onto the environment by the radiation of magnetic field and induction of lightning current around its path. Albert R. Martin found out that the smart grid system will be damaged by lightning strike and V. Gurevich discussed about problems that will occur from hacker attacks and the use of super-power electromagnetic pulse as a weapon.

2.2. Review of home communication technology for smart grid

Smart grid technology has many advantages in the management of the residential energy consumption management as it can control a variety of energy devices, including lighting, electrical appliances, heating, air conditioning, electric vehicles, and home power generating system such as solar rooftops. The development and deployment of home energy management system (HEMS) are in order to manage and control energy consumption, energy storage and energy generation. An HEMS runs on a home area network (HAN) to facilitate communicate among these energy devices and equipment [6]. Communication among the different smart devices in HAN is done using wireline technologies such as power line communication (PLC), or BACnet protocol, and wireless technologies such as Wi-Fi and ZigBee [7].

In general the communication infrastructure of a smart grid system consists of variety communication technologies to support the management and control of the electrical system in the network. The considerations for selecting a suitable communication technology needs an understanding of the network architecture, communication technology, smart grid system domain and the applications of a smart grid system. The network architecture has several data communication networks such as WAN, NAN and HAN. Wide area network (WAN), the network for the power generation and transmission line, is used to manage generation of sufficient power to satisfy the demand. Neighborhood area network (NAN) is the network of electricity providers to control and read the quality and quantity of the electricity utilization through the automatic meter reading (AMR) [8]. Home Area Network (HAN) is the network for the energy management system within a home for communication between controller and home appliances. For NAN and HAN, the power line communication technology (PLC) is considered mostly for developing the data communication system. Currently, PLC technology has widespread adoption and there are many standards from

Europe and America to support this technology. PLC technology is classified according to the operating frequency band.

Ultra-narrowband Power Line Communication (UNB-PLC) is operated at lower frequencies (3 KHz for the data transmission rate 100 bps). UNB-PLC has low data rates and short coverage distance; it should be used to communicate the information from automation equipment in the network such as automatic meter reading (AMR). [9, 10]

Narrowband Power Line Communication (NB-PLC) has operating frequency range 3-500 KHz and data transfer rate of up to many hundred bps. Although NB-PLC data rates are low, the noise [11] and attenuation of the signal are low too. It is the most interesting for institutions around the world to study and develop. There are many frequencies used for NB-PLC standards, such as CENELEC (European Committee for Electrotechnical Standardization) band A: 3-95 KHz for utility services, band B: 95-125 KHz for any applications, band C 125-140 KHz for home network and band C: 140-148.5 KHz for Alarm and security system in European countries. For other countries: U.S.A use FCC (Federal Communications Commission) band 10-490 KHz, Japan use ARIB (Association of Radio Industries and Business) band 10-450 KHz and China use EPRI (Electric Power Research Institute) band 3-90 KHz and 3-500 KHz. The standards organizations have defined for the features of the physical and medium access control layer for NB-PLC such as G3-PLC was released by the ERDF and Maxim in 2009. G3-PLC has frequency range 35.9-90.6 kHz and maximum data rate 35 kbps. The OFDM technology is the major one to use to integrate the signal with DBPSK and DQPSK in terms of time. It is designed to work with medium voltage and transformers which there are noises and high signal attenuation, therefore G3-PLC is made at a low data rate. PRIME (Power line Related Intelligent Metering Evolution) [10] was formed in 2010 by the PRIME Alliance (Iberdrola and Texas Instruments). It uses a frequency range of 42-89 kHz and a maximum data rate of 128.6 kbps. In terms of frequency, the OFDM technology is used with DBPSK, DQPSK and D8PSK. PRIME is designed for smart meter and work through the low voltage network. Both of 3G-PLC and PRIME are used in the frequency band of the CENELEC A. There are also new standards developed for NB-PLC such as IEEE1901.2 and ITU-T G.hnem. ITU-T G.9955 (Physical Layer) and G.9956 (Data Link Layer) are designed for various smart grid applications. Both standards support the power line communication in low voltage, medium-voltage and transformers with transmission rates up to 500 kbps. KNX (EN 50090, ISO/IEC 14543) [10] is a standard that is designed for intelligent building (HBES: Home and Building Electronic Systems). It resembles home and building automation. The protocol of the communication network is OSI-based. KNX is also the recipient and collect the three standards that came out earlier together; the European Home Systems Protocol (EHS), the BatiBUS, and the European Installation Bus (EIB). KNX standard is administered by the Konnex Association, whose members are electrical equipment manufacturers and are related to as many as 348 companies in 37 countries. ANSI/EIA 709.1 [12] is the standard for controlling home and building automation, industrial, communications and utilities infrastructure. It works on the protocol, LONWORKS (Local Operating Networks).

Broadband Power Line Communication (BB-PLC) is a technology for high-speed data communications. It has a frequency range of 1.8-250 MHz for home networks and multimedia. About 2,000 industries have made the configuration of the BB-PLC and have released them it the early years. There are several standards such as the family of HomePlug. The most widely used is HomePlug AV [9, 13] with data rate of 200 Mbps to support multimedia applications as HD Video / Audio. Later developments expanded access to higher data transmission rates up to 1 Gbps, which is the standard of HomePlug AV2 (Next Gen Multimedia Networking) [13]. There are also standard HomePlug Green PHY for use in energy management, and to control applications in electric vehicles. ITU-T G.hn (G.9960, 61) is a standard for home network. This standard is made to use for all types of wired communication technologies for homes and buildings, such as PLC, telephone line and coaxial cables with data rates up to 1 Gbps. So it helps the BB-PLC, can support high data rates, however, the transmission distance is limited to only about a hundred meters. IEEE1901 is a standard to support BB-PLC There are two modes as follows: the OFDM [14] of scheme PHY/MAC which is consistent with the properties of HomePlug AV and the wavelet OFDM of the pattern of PHY/MAC, that is compatible with HD-PLC. Under IEEE1190.1 standard, it can transfer data up to 200 Mbps [9, 15].

2.3. Electricity system in Thailand

The electricity system in Thailand has three main service providers. These are the Electricity Generating Authority (EGAT), Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA).

Table 1 The electricity system in Thailand

Generation	Transmission				Distribution			Utilization
	HV Transmission Line	Substation	HV Sub-transmission Line	Substation	MV Distribution Line	Distribution Transformer	LV Distribution Line	End User
EGAT - Electricity Generating Authority of Thailand								
			MEA – Metropolitan Electricity Authority					
Thermal 3,647 MW Combined Cycle 9,210 MW Hydropower 3,448 MW Diesel 30 MW Renewable Energy 40 MW Total 16,376 MW	500 KV 230 KV	500 / 230 KV 230 / 115 KV 115 / 69 KV	230 KV 115 KV 69 KV	230, 115, 69 KV to 24, 12 KV	24 KV 12 KV	24, 12 KV to 416 V	416/240 V	3P 416 V 1P 240 V
			PEA – Provincial Electricity Authority					
Purchase 24,721 MW Grand Total 41,097 MW			115 KV 69 KV	115, 69 KV to 33, 22 KV	33 KV 22 KV	33, 22 KV to 400 V	400/230 V	3P 400 V 1P 230 V

EGAT is the only agency responsible for electricity generation and supply the electricity to the other utilities. They maintain the power plants, high voltage transmission lines, substations and distribution systems that transmit electricity to MEA and PEA, including large industrial customers. MEA is responsible for electricity distribution and service in Bangkok and two surrounding provinces (Nonthaburi and Samutn Prakan). They also maintain the transmission lines, substations, distribution lines, distribution transformers and low voltage distribution lines in these areas, purchasing electricity from EGAT at 69 KV, 115 KV and 230 KV. The PEA has served the rest of the provinces and purchased electricity from EGAT at 11 kV, 22 KV, 33 KV, 69 KV and 115 KV. Electrical power systems is composed of four operating systems; generation, transmission, distribution and utilization (or consumption.) The owner generation mix in Thailand consist of the following; Thermal = 3,674 MW, Combined cycle = 9,210 MW, Hydropower = 3,448 MW, Diesel = 30 MW, Renewable energy = 40 MW, and independent power producers plus imported electricity = 24,721 MW. In total, EGAT total power supply is 41,097 MW. Details of the power generation mix is given in Table 1.

2.4. Occurrence & Frequency of lightning strikes in Thailand

Occurrences and frequency of lightning strikes in Thailand is increasing annually, as frequency of stronger thunderstorms are also increasing. This is due to more frequent extreme weather events resulting from climate change.

Figure 1 shows the lightning flash density (Ng) in Thailand for first half of the year 2018 by the lightning detection system of Kumwell Corporation Public Company Limited. The lightning detection network has been installed in all of Thailand by Kumwell Nowcast (Thailand) which is a technology from Nowcast GmbH., Germany. The recorded lightning strikes are of the type "cloud-to-ground (CG). In some areas, the frequency of lightning strikes is more than 200 times per 1 square-kilometer per year. As can be seen on the map below, those spots with darker shades represent areas where the lightning flash density is between 200 to 500 flashes per 1 square-kilometer per year. A smart grid system should be safeguarded to protect it from LEMP and ensure safety from these lightning strikes.

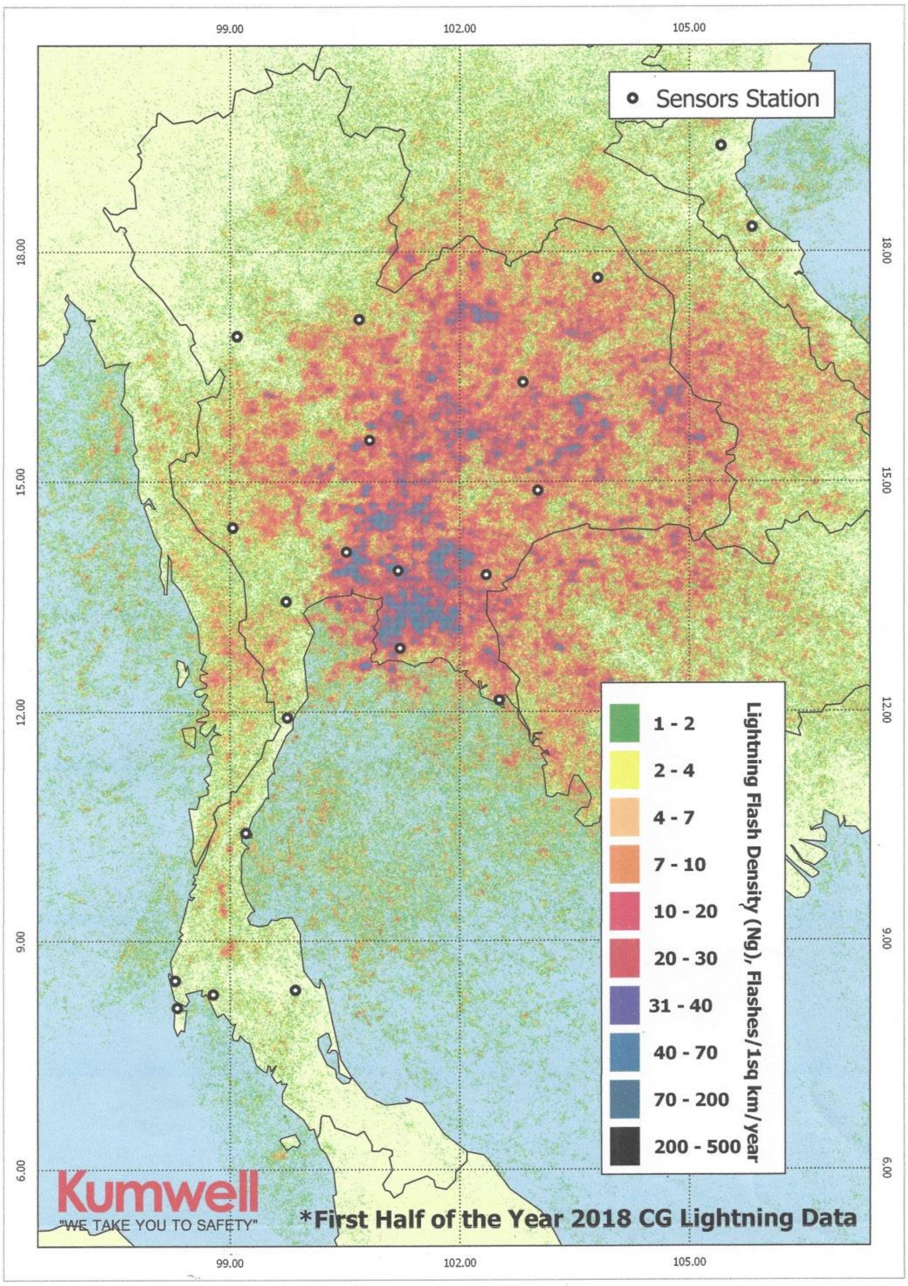

Fig. 1 CG lightning data for first half of the year 2018 (Kumwell).

2.5. The lightning current impulse characteristic.

The characteristic of a lightning current that is caused by lightning strikes can be shown by a lightning waveform. The most worrisome type of lightning flash is the lightning flash from cloud-to ground (CG). Understanding of the CG lightning waveform is needed l to design the protection system. CG Lightning flashes have two types; downward and upward flashes [16]. Downward flashes start by downward leader from cloud to ground and upward flashes by an upward leader from a ground structure to cloud. More downward flashes occur compared to upward flashes.

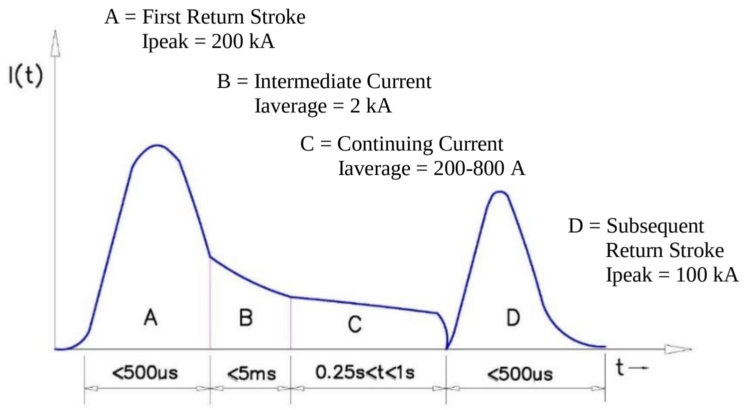

Fig. 2 Lightning current waveform (MIL-STD-464C).

The lightning waveform [17] as shown on Figure 2 consists of four parts (A to D). Part A is the most essential to our study. It is a high amplitude current impulse and also the direct current transient which can reach up to 200 x 10^3 amperes and has duration time less than 2 milliseconds. This part is called the first return stroke. Part B is an intermediate current from part A with approximate thousand amperes. Part C is another type of lightning strike which is long stroke with duration longer than 2 milliseconds and its current about 300-800 amperes. Part D is subsequent return stroke. It normally occur 3 or 4 restrikes in one lightning event. All restrikes have one half current magnitude of the first return stroke.

The IEC committee related to the standards for protection against lightning has determined the characteristics of lightning waveform for standardized testing as shown on Figure 3; the surge current waveform of direct lightning strike is 10/350 µs which is used for SPD class I, the surge current waveform of indirect effect of lightning strike is 8/20 µs which is used for SPD class II; and the voltage surge waveform is 1.2/50 µs which is the effect of the lightning strike current induction through the conductor, which then makes the voltage rise, is used for SPD class III.

Table 2 Standardized testing impulse waveform.

Type of lightning strike	Type of impulse waveform	Front time = T1	Time to half value = T2	Class of SPD
Direct lightning strike	Current	10 µs (10%-90%)	350 µs (10%-50%)	I
Indirect lightning strike	Current	8 µs (10%-90%)	20 µs (10%-50%)	II
Voltage surge	Voltage	1.2 µs (30%-90%)	50 µs (30%-50%)	III

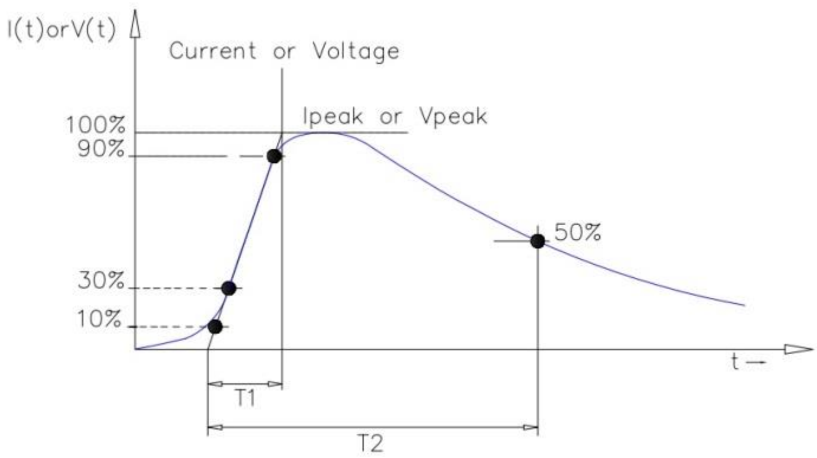

Fig. 3 Impulse waveform (IEC 62305-1).

2.6. Review of the relative protection against LEMP standard.

Radiated and conducted disturbances of lightning electromagnetic impulse (LEMP) from the external environment for smart homes and smart buildings can be prevented by the LEMP protection measures (SPM) which requires accurate and standard design.

Table 3 A relevance standards.

International Standard	Standard Description	Part Description
IEC 62305-1: 2012	Protection against lightning	General principles
IEC 62305-2: 2012	Protection against lightning	Risk management
IEC 62305-3: 2012	Protection against lightning	Physical damage to structures and life hazard
IEC 62305-4: 2012	Protection against lightning	Electrical and electronic systems within structures
IEC 60364-4-4-44: 2001	Electrical installations of building	Protection for safety-Protection against voltage disturbances and electromagnetic disturbances
IEC 60364-5-53: 2001	Electrical installations of building	Selection and erection of electrical equipment – Isolation, switching and control
IEC 60664-1: 2002	Installation coordination for equipment within low-voltage systems	Principles, requirements and tests
IEC 61000-4-5: 1995	Electromagnetic compatibility (EMC)	Testing and measurement techniques – Surge immunity test
IEC 61000-4-9: 1993	Electromagnetic compatibility (EMC)	Testing and measurement techniques – Pulse magnetic field immunity test
IEC 61000-4-10: 1993	Electromagnetic compatibility (EMC)	Testing and measurement techniques – Damped oscillatory magnetic field immunity test
IEC 61000-5-2: 1997	Electromagnetic compatibility (EMC)	Testing and measurement techniques – Installation and mitigation guidelines – Section 2: Earthing and cabling
IEC 61643-1: 1998	Surge protective devices connected to low-voltage power distribution systems	Performance requirements and testing methods
IEC 61643-12: 2002	Low-voltage surge devices	Surge protective devices connected to low-voltage power distribution systems – Selection and application principles
IEC 61643-21: 2000	Low-voltage surge devices	Surge protective devices connected to telecommunications and signaling network – Performance requirements and testing methods
IEC 61643-22: 2004	Low-voltage surge devices	Surge protective devices connected to telecommunications and signaling network - Selection and application principles

Table 3 shows the IEC standards relevant to the protection against lightning and electromagnetics. SPM depends on the lightning protection zone (LPZ) concept. This is explained in IEC 62305-4 ("Protection against Lightning–Part 4: Electrical and electronic systems within structures). The lightning protection zone concept describes the principle of classification of a lightning protection zones in various ways and this is used as the guideline in the LEMP protection measures system design. It consists of grounding and bonding, magnetic shielding and line routing, coordinated SPD system and isolating interfaces. Grounding and bonding are based on a complete grounding system where the grounding termination system disperses the lightning current into the soil and the bonding network minimizes the potential differences and reduces the magnetic field. Magnetic shielding and line routing are importance parts in reducing permanent failure of internal systems. Magnetic shielding can reduce the electromagnetic field and the magnitude of induced internal surges. Suitable internal line routing can help reduce the magnitude of induced internal surges. The coordinated SPD system can protect internal systems against surges. It requires a systematic approach consisting of coordinated SPDs for both power and signal lines. For the SPDs, testing is required to comply with IEC 61643-1 for power systems and IEC 61643-21 for telecommunication and signaling systems. The selection and installation of a coordinated SPD system should comply with IEC 61643-12 and IEC 60364-5-53 for the protection of power systems and IEC 61643-22 for the protection of telecommunications and signaling systems. Isolating interfaces can limit the effects of conducted surges from lines entering.

Protection against electromagnetics follow the standard series IEC 61000 Electromagnetic compatibility (EMC) as Part 5-6: Installation and mitigation guide lines – Mitigation of external EM influences [18]. The IEC 61000 is for mitigation of the external electromagnetic influences: lightning surges, RF transmitters, power-line and telecom transients, high-altitude electromagnetic pulse (HEMP) and other high-power electromagnetic transients on a facility. This standard ensures compliance with the electromagnetic compatibility (EMC) of electrical and electronic equipment or systems. For conducted disturbances, they can be intercepted by a combination of SPDs and filters or other decoupling devices as isolation transformers, and for radiated disturbances, they can be blocked by shielding, grounding and filtering.

3. LEMP protection measure technique for smart homes and buildings in smart grid systems

3.1. LEMP protection measure design architecture

Most standards mention that the protection against lightning electromagnetic impulse must define the concept of the protection system design as follows (see Figure 4); defining lightning protection zones (LPZ), assessing lightning protection levels (LPL), designing global grounding system, lightning protection system (LPS), shielding and equipotential bonding network, cable path and a combination of SPDs.

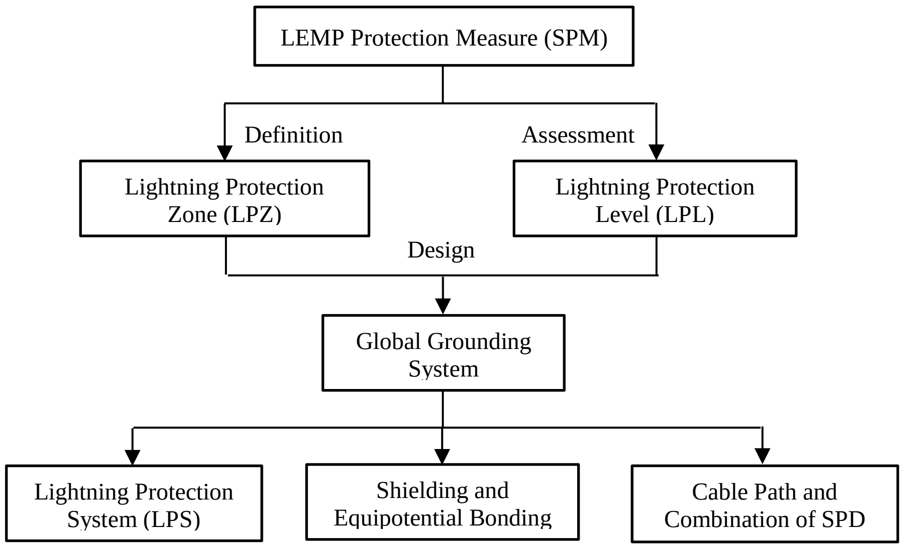

Fig. 4 LEMP Protection Measure (SPM) design architecture.

The definition of the lightning protection zone [19] is a process of area determination to examine the optimal protective methods and protective devices from the cause of damage, the intensity magnitude of lightning and type of lightning strike (such as direct strike or indirect strike), induction of lightning current and radiation of electromagnetic. LPZ is assigned for external building as LPZ0A and LPZ0B, for internal building as LPZ1, LPZ2 and LPZ3. The protection considers the boundary of zones and define the protective device between zones. The definition of lightning protection level is the result of risk assessment calculation [20] to assign the direction of the lightning protection system design. LPL helps save budget and select the right materials.

A global grounding is widely accepted as a requirement for electromagnetic compatibility (EMC). It may be the best approach to install the electromagnetic (EM) protection system for a smart homes and buildings in smart grid systems. The design of the global grounding system needs to consider the environment and the soil characteristics especially soil resistivity (ρ) of the ground installation area. The ground resistance (Rg) of a conductor can be derived from the soil resistivity as.

$$R_g = \frac{\rho}{2\pi L}[\ln(\frac{8L}{d}) - 1] \quad (1)$$

Where
$\rho =$ Soil Resistivity in Ohm × Meter
$L =$ Buried Length of the electrode in Meter
$d =$ Diameter of the electrode in Meter

A global grounding system is not just an earthing electrode system installation but includes an equipotential bonding conductor, shielding conductor, lightning protection system conductor and surge protective device installation. For electromagnetic field protection, earthing network, installation should include earthing grid with wire mesh size of 10 m × 10 m throughout the area of homes and buildings. The design of lightning protection system [21] starts with determining the lightning protection level which is calculated from the risk assessment. Normally most designer will use the rolling sphere method and protective angle concurrently. The shielding and equipotential bonding will be protection from the electromagnetic radiation and the reduction of the energy of the lightning current inducted through the internal conductor. The principle is as follows. The metal sheet roofing and the roof steel structure should be continuously connected to the reinforcement steel structure within the concrete. The electrical continuity at the connection should be less than 0.1 Ohm. It will be shielding at the level of the building and the room. The natural components of the shielding for a concrete building are the metal reinforcement in the ceiling, walls and floor, the metal framework, the metal roof and the metal facades. An effective shielding requires additional wire mesh size of 5 m × 5 m with a galvanized mild steel conductor or a reinforcing bar of minimum diameter 10 mm. The suitable cable routing can reduce the induced surges into the electrical and electronic system by the method of minimizing the induction loop area by using shielded cable and metallic cable ducts. The path of the power cable and signal cable should be separated or installed on each side. In the vertical direction of down conductor path, the cable routing should run in horizontal direction to avoid induction of the lightning current surges. If it cannot be avoided, the cable should run in the metal tray with complete cover and bonding to protect the magnetic field strength from down conductor. For the separated distance between down conductor and cable from the magnetic field strength can be computed using this equation:

$$H = \frac{I}{2\pi d} \quad (2)$$

Where
H = Magnetic field strength in A/m
I = Lightning current in Ampere
$d =$ Radius distance of magnetic field strength in Meter

For the protection the electrical and electronic systems from the lightning current [22], a coordinated SPD system should be designed to protect the cable crossing the different LPZs boundary. The selection of surge protective device (SPD) needs to be appropriate for the systems and magnitude of lightning current. At the zone boundary between LPZ0 and LPZ1, protective surge arrester should be installed with SPD class I which had been tested by lightning current I_{imp} (10/350 µs) and at the zone boundary between LPZ1 and LPZ2 SPD class II should be installed which had been tested by lightning impulse I_{max} (8/20 µs). For protection of important equipment at the zone boundary between LPZ2 and LPZ3, the protective surge arrester should be installed with SPD class III which had been tested by lightning voltage wave (1.2/50 µs). The configuration concept of LEMP protection measure for smart homes and buildings in smart grid systems are shown as figure 5.

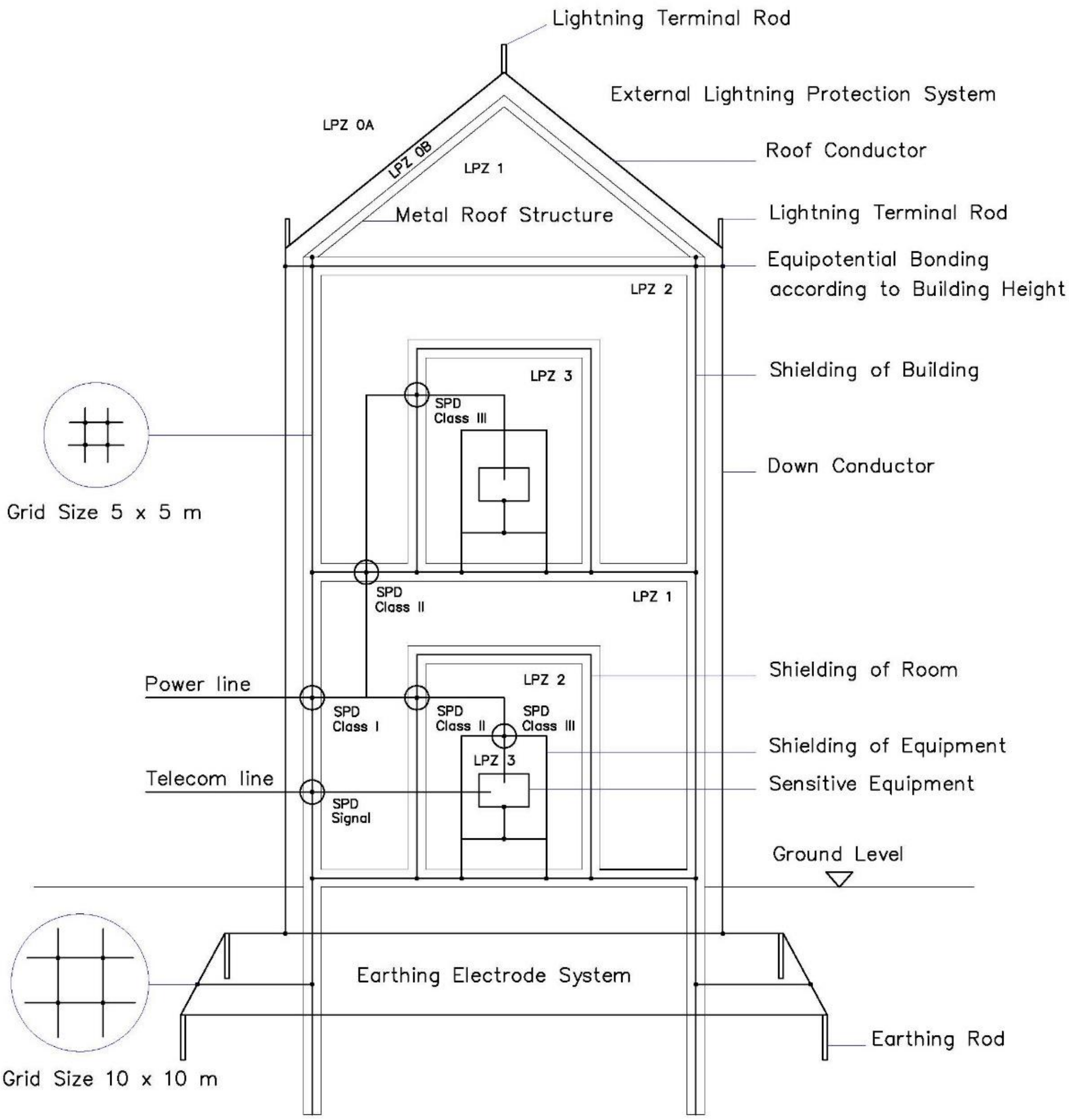

Fig. 5 Concept architecture of LEMP protection measure
for smart home and building in smart grid system.

4. Conclusion

Most of the operation control equipment of the energy management system for smart homes and buildings, them are made up of electronic devices which are sensitive to disturbances. The protection against the disturbances especially the lightning electromagnetic impulse (LEMP) which could make the system damage must be recognized as very important. The design of smart grid systems should not focus only on an energy management system, but must also pay attention to the protection system as well. If smart homes and buildings do not have protection system or are installed later, significant damage can occur. Installation late can be very complicated and may damage also the architectural design of the buildings.

At present, smart grid systems, face s more risks because of global climate change which causes more and more extreme weather events such as very strong thunderstorms accompanied with more frequent lightning strikes. In addition, smart grid systems also faces risks from possible criminal and terrorist attacks using high power microwave. Security of the systems should also not be overlooked.

LEMP (Lightning electromagnetic impulse) protection measure is the best approach for protection against the electromagnetic field as LEMP can provide protection from both wave propagation and induction through various conductors in the smart grid system. LEMP consists of the defining of lightning protection zone (LPZ) and lightning protection level (LPL), the design and installation of the earthing system, lightning protection system (LPS), shielding, equipotential bonding, cable path and a combination of surge protective devices (SPD).

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