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Electricity and Its Dangerous Sides

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Abstract: *Dangerous practice of electrical wiring systems and poor products must be thoroughly investigated if electrical fire incidents will be mitigated. Electricity can kill faster than any means and even destroy than tsunami. If anyone is seeking for the most dangerous energy means, they should trace it to electrical energy. Electrical fire does not just happen, it has propeller. From the man who designs it to the man who executes the design, and even the manufacturer of the electrical components, they all contribute to the outbreak of electrical fire. Electrical fires are fires which may involve electrical cables and equipments. This study examined the various dangerous sides of electrical wiring fault and its causes.*

Keywords: *Fire, cable, residential, wire*

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I. Introduction

Fires that are directly caused by the flow of electric current and or static electricity are called electrical fires. It is not necessarily mean that the origin of the fire is from the failed components but it may be as a result of close fault that is capable of producing enough heat to cause combustion (Babrauskas, 2008). Some electrical devices are not designed to produce heat at all, and if they become a source of heat, such device is said to produce electric fire.

Temperature differential in electrical components is the problem, whether cables, sockets, motors, switches, transformers, and many more. (Henry, 2010) wrote about the effect of high-resistance as the common cause of ignition. From the elementary study of power dissipation, it is learnt that power is equal to the product of the square of current and the resistance. If the resistance is increase as the current increases, definitely, the power loss due to the effect would increase. Again, Henry, 2010 furthered said that in loose connections, example, untightened screw in a terminal, may heat up, expand and energized when current flow through it. This would obviously results in high-resistance connection as the copper or aluminum conductor reacts with oxygen in the air. And a developed oxide can reach about 30-40 Watts on a 15-20 Ampere circuit (Henry 2010). From the investigation carried out by Henry, 2010, there was no mitigation means suggested for the effect.

Lilly & Vijayalakshmi 2014 discussed cases of fire accidents in buildings. The work presented reason for fire and ignition source, the spread of fire, how properties and lives are damage in the cause of the fire with relevant solutions. There are three things that must be noted while discussing ignition irrespective of the source; these include the heat (in this case, the current flowing through the electric cable produces the heat), the fuel (e.g. cable insulation and any flammable materials within the vicinity of the heat), and oxygen. Burning produces fire, and therefore fire can be said to be a chemical reaction erupted as a result of heat energy which combines with oxygen in the air. From(Lilly & Vijayalakshmi, 2014), two source of ignition were discussed which include human error type fire and appliances type fire. The human error type fire may occur when incompetent hands carry out electrical wiring installation, while the appliances fire type are due to faulty electrical appliances, e.t.c..

FEMA 2014 defined electrical fire as the fire that involve the flow of electric current or static electricity and are caused by electrical systems failures, appliance defects, incorrectly installed wiring, misuse, and poor maintenance of electrical appliances, and overloaded circuits and extension cords. From this definition, cogent issue that must be addressed in this research work is the incorrectly installed wiring and appliance defect or fake materials. When electrical fire occurs, it may not be easily noticed especially when the origin is in the wall or ceiling. Before intervention, properties worth millions dollars and irredeemable lives may be lost. This makes electrical fire very dangerous and prompt attention must be introduced to mitigate the problem.

Table 1: Factors contributing to residential **electrical fire** (FEMA, 2014)

Factors Contributing To Ignition Category	Percent Of Residential Building Electrical Fires
Electrical failure, malfunction	89.5
Mechanical failure, malfunction	6.1
Misuse of material or product	4.3
Operational deficiency	3.7
Design. Manufacture, installation deficiency	1.3
Natural condition	1.0
Other factors contributing to ignition	0.9
Fire spread or control	0.2

Table 2: Leading Items First Ignited in **Residential Building Electrical Fires**(FEMA, 2014)

Items first ignited	Percent Of Residential Building Electrical Fires
Electrical wire, cable insulation	29.8
Structural member or framing	18.5
Thermal, acoustical insulation within wall, partition, or floor/ceiling	7.3
Interior wall covering	6.3
Exterior sidewall covering, surface or finish	5.1
Other structural component, or finish	4.6

Homeland Securiy 2006 published a paper on the various causes of electrical fire and how it can be prevented through some precautional measure. Obviously, in a particular year in United States, about 67, 800 electrical fires occurred with approximately 485 deaths, and $868 million worth of property were loss in electrical fire (Homeland Securiy 2006). The period of this occurrence in US is frequent in December due to overloading of electrical cables. This period is winter month when more lighting, heating and use of appliances increases. Old wiring, and faulty electrical outlets, extension socket and many other may result in electrical fires. The most densely populated areas like urban centers may account for large percentage of electrical fire. Poor maintenance of electrical wiring system is so dangerous than not servicing a car. Therefore, Homeland Securiy 2006 suggested that worn out wires should be replaced promptly, extension socket must not be overloaded, standard materials should be patronize during installation, and proper protective devices should be install to mitigate the chances of electrical fires in home.

Patel 2005 defined two types of residential building electrical fires. Arc fires and fires due to heat from electrical equipments are the categories. Electrical arc occurs as a result of short-circuit due damage cable, loose, or worn insulation. But electrical fires due to heat from equipments normally occur by heat from equipments when overloaded or defective.

From Patel 2005 finding, it was discovered that as the rate of growth increased from 1986 to 2003, the total number of electrical fire also increased. The finding further revealed that short circuit arc electrical fires were caused by faulty, loose and or defective cables as a result of aged wiring.

A circuit that is originally designed to take a maximum load of 5 kW, this circuit should only power a device of actual rating.

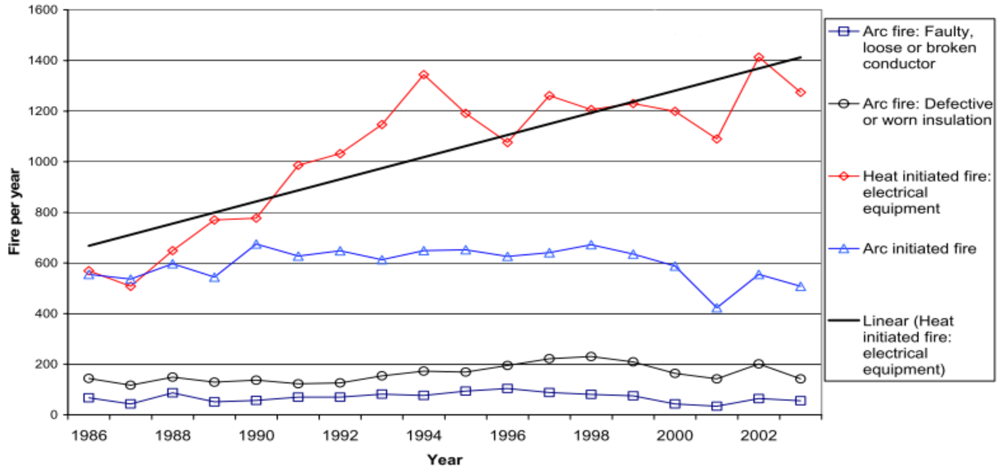

Figure 1: Cases of Electrical Fire in New Zealand (Patel 2005).

But most times, when users upgrade the device to a higher value, the sense of upgrading this electrical circuit might be absent. Overloading leads to excessive current flowing through the cable, short circuit are caused by cable insulation breakdown, damage cables, poor connections, aging, e.t.c., lack of standard electrical wiring materials usage; all these are the cause of electrical fire which must be addressed (IAPL, 2012). Thinking about corrective measure is inevitable. Electrical fires are in increasing order each year after year across the globe. Protection scheme that will mitigate this undesirable condition in order to save lives and properties is very essential.

II. The Electrical Cables and Wires

Cables and wires are used interchangeably by Electrician and even Engineers. But there is a difference between the two. Wire is a single length of conductor of any size while cable is a collection of two or more wires. Cables and wires make electrical wiring possible. Cable may consist of conductor and or insulator. The ability of any cable and wire to resist heat determines its ampacity.(FEIC, 2015), described some heat resistant wires and cables which include halogen free, flame retardant, flexible, cross-linked polyethylene insulated wire. This wire has heat resistant temperature of 110^0C with applied voltage of 600 V-6600 V. Another examples of such wire are silicon rubber insulated lead wire (this wire has heat resistant temperature of 180^0C, 600 V, 3300 V, 6600 V), silicon rubber insulated, glass braided wire (this wire has heat resistant temperature of 180^0C, 600 V, 3300 V, 6600 V), silicon rubber insulated, reinforced silicon rubber sheathed cab tire cable (180^0C, 600 V), Fluorine rubber insulated lead wire (200^0C, 600 V), e.tc.. The various requirement of any cable could be size, strength, electrical properties, mechanical damage, flexibility, chemical resistance, moisture resistance, and radiation resistance. These various requirements of wires and cables must be tested before they are eventually used for electrical wiring.

According to British Standard Code 7671, the current capacity and associated voltage for Polyvinyl Chloride (thermoplastic) insulated cable, is presented in Table 2.3. These cables could possess an operating temperature of 70^0C, and ambient temperature of 30^0C(AEI-Cables, 2008).

Table 3: Current for PVC cable according to BS 7671

Conductor	Reference method 100 (above a plasterboard ceiling covered by thermal insulation not exceeding 100mm in thickness)	Reference method 101 (above a plasterboard ceiling covered by thermal insulation exceeding 100mm in thickness)	Reference method 102 (in a stud wall with thermal insulation with cable touching the inner surface wall)	Reference method 103 (in a stud wall with thermal insulation with cable not touching the inner surface wall)	Reference method C (clipped direct)	Reference method A (enclosed in conduit in an insulated wall)	Voltage drop
mm^2	A	A	A	A	A	A	mV/A/m
1	13	10.5	13	8	16	11.5	44
1.5	16	13	16	10	20	14.5	29
2.5	21	17	21	13.5	27	20	18
4	27	22	27	17.5	37	26	11
6	34	27	35	23.5	47	32	7.3
10	45	36	47	32	64	44	4.4
16	57	46	63	42.5	85	57	2.8

The size of fuse that can be used to provide semi-protection for the conductor is given in Table 4.

Table 4: Size of fuse to provide semi-protection for conductors (AEI-Cables, 2008)

Nominal current of fuse element	Nominal diameter of wire
A	mm
3	0.15
5	0.20
10	0.35
15	0.50
20	0.60
25	0.75
30	0.85
45	1.25
60	1.53
80	1.80
100	2.00

Gulf-Cable 2011 state that for short circuit conductor, the equation 2.1 and 2.2 holds.

$I_{sc} = 0.115 \frac{A}{\sqrt{t}}$………………………2.1

The equation 2.1 is for PVC 70^{0}C insulated cable.

$I_{sc} = 0.104 \frac{A}{\sqrt{t}}$ ………………………2.2

The equation 2.2 is for PVC 70^{0}C insulated cable.

Where I_{sc} = short circuit in kA, A = conductor size in mm^2, and t = short-circuit time in Sec.

The maximum permissible temperature for the conductors is 160^{0}C.

Cables performance generally may be determined by environmental condition and handling during installation. Radiation, heat exposure, stress, and many others may constitute to shortening of life span and inability of the cable to work as manufactured (Anchor, n.d.).

Vigya 2012carried out investigation on the cables insulations. Insulation being a veritable part of any cable, the decision onits type to be used in any installation cannot be overemphasized. Power cables are categorized may be categorized as cross-linked polyethylene, polyvinyl chloride (PVC), elastomer insulated cable and rubber insulated cable. The cross-linked polyethylene like any other cables can be aluminum or copper. They are generally used for under water cable, underground burial, and ducts, e.t.c. The polyvinyl chloride is the most popular and most widely used cable across the globe. The biological and chemical resistance of this cable makes it flexible for use in different domestic applications. Elastomer cables are used for installation with not more 90^{0}C (load temperature plus ambient for normal operating condition), and 250^{0}C (load temperature plus ambient for short-circuit condition). They are majorly manufactured extension sockets as flexible cords. Vigya 2012 concluded by saying that the type and size of cable used in electrical wiring should be properly selected. They should be capable of delivering the optimally with conformity to its ampacity. The factors such as short-circuit current rating, voltage drop and resistive volume are important parameters to be considered while selecting cables for electrical wiring.

Ogherowo et al., 2012 conducted research work analysis of copper cable types commonly used in Nigeria for Electrical Wiring and power Distribution. Copper being a conductor with excellent conductivity, and low resistance also has density advantage. When conductors are subjected to load, they fail even at rated capacity while others of the same gauge do not. There are reasons responsible for cable anomaly operating which may include the resistance of the cable (this is mean that a lower resistance value cable would produce little voltage drop across it and therefore, less heating and vice versa), the insulation on the cable and the environment of the cable. A cable on the surface of wall cannot produce the same heat as that in duct. Copper cables are mechanical strong and durable. The manufacturer of this cable can alter the chemical composition of the conductor by adding impurities to it. Impurities affect the mobility of electron and conductivity of conductor. This effect makes cables of the same rating differs.

Ambient temperature, presence of water or moisture, dust, corrosive or polluting substances, mechanical stresses, damage and solar radiation were identified by (Jenkins, 1981) were conditions to be considered while planning to install and erect electrical wiring. In order to satisfy all these conditions, the use of computer based software would be very necessary (Laughton et al., 2001).

For example, the outer-casing of some electrical equipments or components such as insulator, when dropped suddenly to the floor may break resulting in defect of such device or poor connections. When a careless user continues using such device, there is evidence of electrical fire outbreak. Therefore, the material used in the making of insulation constitutes a lot to standard electrical wiring systems.

Electrical, physical, thermal, mechanical and chemical properties of cable are very essentials for the determination of the ampacity of any cable type. The expected current flowing through a cable to the consumption point is supposed to be 100% if loss is absent along the line. But the unfortunate scenario is that there is always a voltage drop in the conductor due to the resistance of the conductor (Bowen & Inst, 2010). The voltage drop can be calculated from equation 2.3 and equation 2.4.

$R = \frac{\rho l}{A}$ ………………………………..2.3

where ρ called resistivity for materials differs, l is called length and A is called cross-sectional area of the conductor.

$v = IR = \frac{I\rho l}{A}$ ……………………….2.4

Equation 2.4 gives reason why a short length conductor has minimum power loss when compared to conductor of same cross-sectional area with longer length.

Shea 2007 buttressed conditions for series arcing phenomena in PVC wiring. The research work stated clearly how glowing contacts and surface arcing can cause degradation of PVC insulation, form ignitable gases which if the arcing continues; it would ignite and burn insulation.An overheated connection can be created when there is glowing contact and or chemical incomplete combustion of conductors. A series and parallel are two combinations of circuit connections in homes. Consequently, a series or parallel fault could occurs in the wiring connections due to external heating, damage insulation, over-current, over-voltage, loose connection, e.t.c., and any of this can initiate fire. Glowing contact and arcing over surface under certain conditions, could heat-up PVC wire insulation which invariably, leads to potential fire as a result of decomposition of the PVC wire insulation.

III. Cases of Electrical Fires across the Globe

According to Korean Electrical Safety Corporation report, in 2011, 43 875 fires leading to direct loss of about 234 million dollars, 263 deaths, and 1599 injuries occurred in Korea. An approximate of 21.3% fires was as a result of electrical current. The analysis further noted that the cause of this electrical fire were due to insulation breakdown which accounted for 24.5% of the fire as a result of electricity, short-circuit caused about 24%, 7.7% were caused by 7.1% and lastly, 73.2% were due to electrical arc **(**Moon et. al., 2015**).**

Lai 1993categorized electrical wiring fault into equipment or component defect and design negligence, installation defect, and negligence in maintenance. This four (4) classification cause of electrical wiring fault by Lai 1993 can be avoided by carrying out proper electrical installation design which conforms to IEE Wiring Regulations, selection of proper equipment for a particular environment, and routine maintenance. Engel, 2012 reported that the cord of an electric crock pot became crimpled between the outside metal pan and the interior ceramic crock of the unit in a residential building in Bethlehem. This scenario resulted into serious electric with no loss of lives but a damage of properties worth $150, 000. This case can be seen as short circuiting when the cord became excessively hot, insulation breaks and conductor-to-conductor with the metal pot caused the fire.

Gao & Liu, 2016 gave the report of 1993 to 2007 cases of electrical fire in China. The conclusively said that from 1997 to 2007, about 373700 cases of electrical fires occurred in China which amount to 24.5% of the total fires in the country. Also, from 1997 to 2007, catastrophic electrical fires occurred in the same country. The properties lost in this electrical fire incidents amount to 1.56 billion (whether in Dollars or Yuan, the author did not mention). And therefore, investigating the causes of electrical fire and how to prevent it so as to be able to protect lives and properties should be upheld.

The risk associated with electrical wiring is more severe in older wiring than today's electrical wiring. Factor responsible for this is just due to today increasing electrical demand. And therefore, attention is needed to be shifted on this issue for more protection scheme (Patel, 2005). Electrical shock and fire are two dangerous hazards that electricity can cause, and these need urgent attention in the world today. Patel 2005 stated categorically that according to Zealand Fire Service, around 59, 000 electrical fire incidents occurred between 1986 and 2003 in New Zealand. About 30, 000 out of 59, 000 fire occurred in residential buildings. From the cause of electrical fire, electrical arc was said to be about one-third contributor to electrical arc, and two-third by heat from electrical equipment.

Saharul & Abdul 2015investigated current trends and challenging situations of fire incident statistics. From the article, it was reported that the case of electrical fire increased with a percentage of 6.8% in Malaysia between 2012 and 2013. This category of fire is said to be structured fire. In 2014, the causes of fire in shopping complexes, offices, hotel, residential building, e.t.c., in Singapore were attributed to electrical fire.

According to a research survey conducted by Khan 2011 in Bangladesh, it was discovered that the incessant occurring of electrical fire outbreak in the country especially in garment industries were as a result of improper use of fuse wires or cutout. Despite the discouragement of the populace to use this device, its popularity is still on the high side due to its low cost without considering the dangers that is liable to vent out as a result of its use. This improper fuse wire reported to be common in Bangladesh as the cause of electrical fire is rampant in Africa. Therefore, inappropriate electrical protection may be a cause of electrical fire. Also, Khan 2011 further identified electricians low education knowledge as a cause of electrical fires in the country. This issues boils down to poor government regulations on who to practice and carry out electrical installations. Faulty fuse leads to fire of non-electrical origin as it spread through electrical cables to other parts of the building.

In Shea 2007 research, it was noted that CPSC reports 163 000 total residential electrical fires in the United States of America. About 40 000 of this total fire incidents were as a result of electrical distribution in the year 1997. Properties lost only to electrical fire worth $678 million in that year. The two source of this electrical fire were summarized as glowing contact and arcing over char.When a loose connection undergoes make and break in the presence of load, a series arcing of the conductors occurs which forms a Cu_2O (semi-conductive copper oxide). This oxide can lead to overheating of the resistive joint to a temperature of about 1235 ^{0}C. This temperature is high enough to melt the PVC wire insulation and therefore ignite any fuel within its vicinity.

IV. Conclusion

The physical mechanisms responsible for electrical fires do not just consist of short circuiting or overloading. It consist a quite number of factors like poor connections, arcing across a carbonized paths, arcing in air, excessive thermal insulation, ejection of hot particles, dielectric breakdown or liquid insulations, and some miscellaneous phenomena. This paper has x-rayed the various causes of residential electrical fire with a note on electrical wire insulation as a contributing factor.

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