Towards Coordinated Cascaded Approach To Effective Overvoltage Protection Of Home And Work AC Power Apparatus System

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***Abstract*-Diverse research have revealed that one of the features of global climate change is that there will be an upsurge in the occurrence of lightning strikes. This does not just relate to regions that are not previously vulnerable to high risk of strikes but spreads to all regions on the globe. The assurance of well-fortified residential electrical installation against surge voltages is therefore required now more than ever before. Previously, many designers of surge preventive device (SPD) approach the issue with a one-shot arrestor located at the upstream part of the power system to tackle the impinging transient surge. This method is not exhaustive because other internally generated surge voltages within the facility are left unattended to. The object of this paper is to present a reliable mode of design that guarantees a relatively error- free surge voltage protection which takes care of both the upstream and the downstream parts of the installation, that is, the externally and internally engendered surge voltages for residential and work AC power systems.**

Keywords—Cascade, arrestor, suppressor, lightning strike, transient overvoltages

I. INTRODUCTION

Owing to the demand of the modern day activities at homes and at work almost every undertaking now relies on electrical/ electronic equipment. Computers, printers, flat screen television, microwaves, electric cookers washing machines etc. are generic. Hence, significant anticipatory precautionary measures must be put in place to protect these valuables from transient overvoltages with its attendant degradation of equipment and or eventual damage of them.

In power systems, various types of surge voltages occur sometimes. They are primarily differentiated by the magnitude of their power and duration. Some can last for hundreds of microseconds, while others can exist for few hours or days. When surge voltages happen, it leaves behind it some deleterious trails on the electrical/electronic system of which the severity depends on the level of the power of the surge voltage pulse. The amplitude of surge voltages can vary between a few millivolts to some ten thousand volts [1].

One major source of surge overvoltages is *lightning strikes* which can produce surge currents of amplitude of up to some ten thousand amperes. This is usually transient- of relatively short interval. Typically, the effects of the surge voltage on any electrical system shows up when its level surpasses the dielectric strength of the electrical system. Therefore, one of the primary purposes of any surge voltages protection systems is to forestall the collapse of the dielectric strength and insulation breakdown of the system, hence, outages or damage to equipment and installations.

Uncontrolled surge voltages therefore impinges on the reliability of the power system with its consequent negative economic implications [2]. A reliable surge voltage protection depends, among others, on proper design and component selection [3]. Improper and inadequate connections is counterproductive, and defeats the objective of the whole exercise and yet provides a false sense of protection on the system. Regrettably, misrepresentation regarding surge voltages protection devices, and techniques result in wrong decision about what to do. Consequently, avoidable damages to electrical installations, costly outages, replacements and costly maintenance ensue. As a result of these intricacies associated with surge voltages, it is important that a good grasp of matters connected to it obtained.

Previously, many designers of SPD approach the issue with a one-shot arrestor located at the upstream part of the power system to tackle the impinging transient surge. This method is not exhaustive because other internally generated surge voltages within the facility are left unattended to. The object of this paper is to present a reliable mode of design that guarantees a relatively error- free surge voltage protection which takes care of both the upstream and the downstream parts of the installation, that is, the externally and internally engendered surge voltages for residential and work AC power systems.

II. SOURCES OF SURGE VOLTAGES

Transient surge voltages in power systems arise broadly from three sources namely *power frequency overvoltage, switching overvoltage* and *lightning overvoltage.* There is no doubt however, that the most ruthless cause of overvoltage is lightning strokes.

III. POWER FREQUENCY OVERVOLTAGES

In comparison with switching and lightning overvoltages, power frequency overvoltages weilds the lowest in magnitude. [4] observed that for most causes of power frequency overvoltages, the magnitude may fall within the range of a few percent to 50% above the nominal operating voltage. In spite of this seemingly trifling proportion, however, their influence in overvoltages protection devices cannot be disregarded. This arises from the fact that it exhibits high level of energy which most contemporary surge voltage protection apparatuses are unable to discharge. Therefore, it is necessary that the ratings of protective device be chosen so as not to function under probable power frequency overvoltages. The major causes of power frequency overvoltages are: electrical fault and sudden changes; and its magnitude is determined by the various circuit parameters.

IV. SWITCHING OVERVOLTAGES

Power systems operations cannot successfully run without switching processes, and switching tasks are of diverse kinds, ranging from automatically controlled schemes to manually controlled ones from everyday regular operations. Example of operations involving switching are as follows: transformers, generators/motors, lines (transmission or distribution), shunt/series capacitor, shunt reactors etc. [2] noted that overvoltages occasioned by switching operations are characteristically proportional to the power frequency voltage; and that the frequency content of the switching transient depends on the system parameters. [5] remarked that there is a substantial probability for overvoltages higher than 5.0 pu in measured probability distribution curve of switching overvoltages. Two methods exist for the control of the degree of switching voltages. They include:

a. Employment of breakers with resistor pre-insertion, and

b. Employment of opening resistor or wound-type potential transformers to discharge trapped charges on lines.

V. LIGHTNING OVERVOLTAGES

When lightning strikes on the usually weather-exposed power system, overvoltages ensue. This could be direct or indirect. Direct lightning strikes happen when the power system apparatus is struck directly by the lightning while the indirect strikes nearby objects, from which subsequent overvoltage is transferred to the system through inductive, capacitive and conductive coupling.

It is pertinent to note that both the switching overvoltages and power frequency overvoltages are proportional to the voltage of the system; whereas lightning overvoltages are dependent on the system impedance and never dependent on the system voltage. For instance, some direct lightning incidences can produce an overvoltage proportionate to the magnitude of the lightning stroke and the specific impedance of the line. This level of overvoltages are typically very high that it is realistically and economically impossible to control its effect by mere insulation of the system. Hence, the need for more fortified and efficient system, which the subject of this paper is meant to address.

Lightning naturally occur in the atmosphere when there is a separation of electrically positive and electrically negative charges. When the separated charge increases to a particular extent, they are in between the dipole region breaks down in a giant spark (an intra-cloud stroke), or a charged region breaks down to ground (a cloud-ground stroke) [6]. This produces current which ionizes and increases the temperature of the air on its pathway to approximately 30,000 Kelvin. This ionized air shines brightly lasting for about 100µs (lightning), producing a current on the order of 10KA but can be as large as 200KA. This sudden rise in temperature enlarges the path and the surrounding air, resulting into serious pressure wave which rises to several millions Pascals causing a sound shock-thunder [7]. It was noted by [2] that the overvoltages arising from lightning is termed external surge; while those arising from switching are internally generated.

VI. DETERMINING FACTORS FOR CHOICE OF SURGE VOLTAGE PROTECTION APPARATUS

[8] noted that the choice of any overvoltage protection device depends on the following:

i. The exposure of the building to lightning transient

ii. The sensitivity and value of the equipment that requires protection

iii. The location, and hence, the exposure level of the installation

iv. The equipment used within the installation and if the equipment could generate switching transient.

VII. THE CONCEPT OF COORDINATED AND CASCADING OF SPD

Coordinated surge protective device (SPD) system is the concept whereby multilevel system of surge protective apparatus are synchronized at two different points of the entire power system network for better performance.

The more robust upstream apparatus, called the “arrestor” is designed to reroute the invading surge while the downstream apparatus referred to as the “suppressor” (located closer to the equipment to be protected), mops up the left over impinging surge including the internally generated ones. Figure 1 shows a block diagram of this concept. [9] observed that the essential factors to be considered for an effective synchronization of arrestor-suppressor cascade are the comparative voltage regulation/ clamping of the respective apparatuses, separating them from any form of electrical connection by means of wiring inductance and waveform of the invading surge.

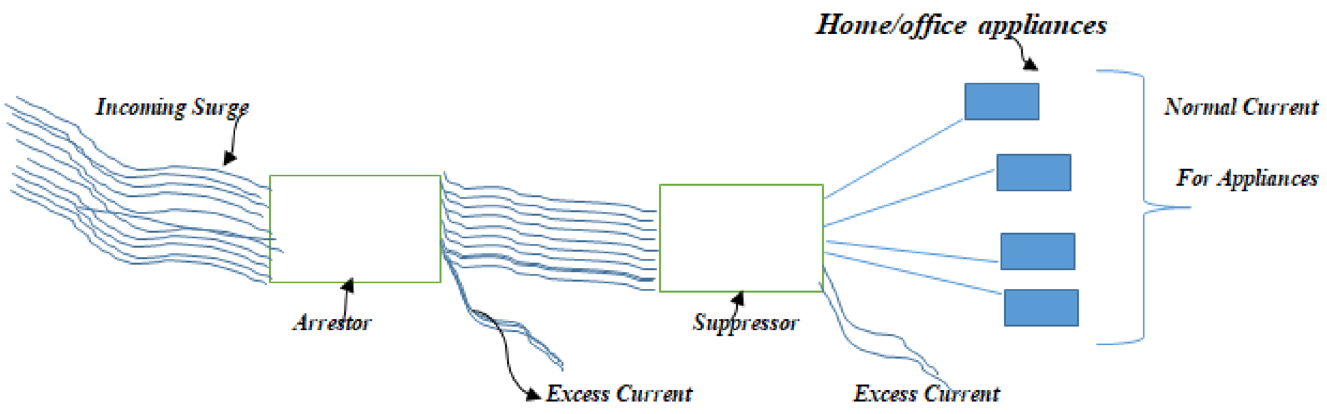

Figure 1: Block diagram of the coordinated cascaded SPD

VII. NEED FOR CASCADING AND COORDINATING SPD

The intent of the cascading and coordinating scheme are as follows:

i. To make the most of surge protection, at very low cost of materials
ii. To divert large surge currents at the upstream end of the installation so that they do not flow into the building, thereby avoiding side effects [10]
iii. It Increases the current diverting capacity of the SPD system while maintaining a low voltage to ensure maximum protection to valuable equipment.

VIII. MEASURES TOWARDS HIGH PERFORMANCE COORDINATED SPD SYSTEM

For a very efficient coordinated cascaded SPD system, the following steps should be put in place:

1. Separate the facility into lightning protection sections
2. Unite all connections traversing between different sections into a common connection with respect to their potentials, using the appropriate SPDs
3. The SPD apparatuses should be able to communicate exclusively with each other in order not to overwork any of the components
4. The supply links for parallel connections of the SPDs should be as short as feasible between active conductors and equipotential bonding
5. Protected and unprotected lines should be laid separately
6. All equipment should be ground through the respective SPDs
7. For a leak-proof result, smart monitoring system should be incorporated into the entire system. This is meant to monitor the different functions in the arrangement and immediately report results in a central control unit. This helps the system to react immediately to errors and thereby prevent consequential damages as well as costly downtime.

IX. CONCLUSIONS

Diverse research have revealed that one of the features of global climate change is that there will be an upsurge in the occurrence of lightning strikes. This does not just relate to regions that are previously vulnerable to high risk of strikes but spreads to all regions on the globe. The assurance of well-fortified residential electrical installation is therefore required now more than ever before. This is achievable with the coordinated cascaded SPD system rather than the one-shot arrestor placed at the service entrance of the installation which is common in many erstwhile installations.

The only attraction offered by this one-shot method is the low-cost nature, which on the long run cannot be compared with the copious benefits offered by the coordinated cascaded option especially when highly expensive and sensitive equipment are involved. In other words, with the available technology of the cascaded coordinated system, the one-short expended system is an avoidable risk with respect to the efficiency of overvoltage protection.

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