ON THE INSULATION CO-ORDINATION STUDIES USING (EMTP)

M. Aburaida (AMIEE)
Sceco-east, Secti,
Dammam, P. O. Box 5190
Dammam 31422, Saudi Arabia

ABSTRACT:

The reliability of supply provided by an electric power system, as judged by the frequency and duration of supply interruptions to its customers, depends to a great extent on the surge performance of the system. Although there are many other causes of interruptions, breakdown of insulation is one of the most frequent. In reality, the insulation has to withstand a variety of overvoltages with a large range of shapes, magnitudes and duration. These various parameters of overvoltages affect the ability of insulation to withstand them. So proper insulation levels are required for equipment as well as proper overvoltage protection.

The objective of this paper is to explain the different methodologies of insulation co-ordination studies and show how the EMTP can give an easy and reliable approach to insulation co-ordination problem. This will include modeling of the different elements of the power system and simulating their behavior under different types of surges (lightning, switching, fault clearing, …etc..). The insulation level of each equipment will be examined with reference to BIL as well as the selection, specification and location of arresters. Practical cases will be explained.

1. INTRODUCTION

Insulation co-ordination refers to the art of selecting appropriate insulation levels for equipment (e.g. transmission lines, transformers, generators..etc..) and the corresponding overvoltage protection system (arresters). For transmission lines, this means the design of the conductor-to-conductor and tower clearances, the selection and specification of insulator strings, the placement of ground (and in some cases shield and counterpoise) conductors and the specification of towers and tower footing resistance. For equipment such as transformers this means the specification of BIL (basic lightning impulse insulation level) and. Both conventional and statistical ways of specifying these insulation levels are recognized in the standards. For equipment such as breakers, additional specification parameters include the TRV (transient recovery voltage) characteristics [1].

Selection of insulation levels for equipment and selection and location of overvoltage protection equipment are interrelated: the insulation level of a piece of equipment or line depends on the type of overvoltage protective equipment installed. Recent practice has been to attempt to reduce insulation levels by more liberal use of arresters, particularly zinc oxide arresters, and also the limiting of overvoltages by means of closing resistors.

A fundamental distinction must be made in the design process between self-restoring and non-self-restoring insulation. With solid insulation, such as in many cables systems and transformers, once it fail it must be replaced: this is non-self-restoring insulation. Open-air insulator strings, on the other hand, will usually fail by arcing around the string. Once the initial arc is extinguished, the insulation capability is restored. Statistical specification of a BIL is not appropriate to a non-self-restoring insulation, but is quite appropriate to a self-restoring insulation.

It is important to understand the meaning of BIL and BSL specifications. These specifications are intended to measure the ability of equipment to withstand representative overvoltages, intended to capture the general ability of the device with respect to a general kind of overvoltage condition. The BIL is specified with reference to a specific waveform: 1.2 microseconds rise time, 50 microseconds time to decay to half value. The BSL waveform has a 250 microseconds to peak, 2500 microseconds to decay to half value. The implication (not necessarily correct) is that typical lightning and switching waveforms have the same general characteristics and shape. While the expected characteristics of the overvoltage resulting from switching can usually be determined with good accuracy using the EMTP type programs (and consequently the designer can verify to what extent the standard test waveform is applicable), actual lightning waveforms can differ considerably from the assumed ones [2].

Insulation coordination also means the selection, specification and location of equipment intended to reduce overvoltages, such as lightning arresters and to some extent breakers, pre-insertion resistors and other such items. There are five parameters of interest in the selection of a lightning arrester:

[1] The lightning current discharge capability and its corresponding voltage.
[2] The switching current discharge and corresponding voltage.
[3] The energy dissipation characteristics of the arrester, or temporary overvoltage capability.
[4] The arrester rated voltage. Generally the maximum temporary overvoltage expected during operation before the arrester has a significant effect on the system.
[5] The continuous operating voltage. This determines the steady-state losses in the arrester.

Arrester location is always an important subject. In general, arresters should be located as close to the equipment as practical, with as short leads as possible. However, there are many reasons why sometimes arresters must be located at some distance from the protected equipment. For example, in gas Insulated Substations (GIS) arresters are often located outside the substation for economic reasons, but encapsulated arresters may also be required.

Thus, we see that insulation coordination is, as has been said of many other aspects of engineering design, as much as an art as it is an exact discipline, where the designer attempts to weight and consider many diverse factors and come up with a single answer. Insulation coordination methodologies are likely to vary with different companies and individuals.

2. INSULATION COORDINATION METHODOLOGIES

Methods for insulation coordination can be classified into four general categories:
[1] Rule of thumb methods.
[2] Precalculated deterministic studies.
[3] Deterministic methods and semi-statistical methods.
[4] Statistical methods.

Rule of thumb methods and precalculated studies are practical ways of designing insulation levels for most standard substations with simple configurations. Designs based on those methods are, generally, too conservative. For deterministic design most of the parameters needed for the design are to be selected before hand. This means that a lot of details are required for this method. For statistical design the values of those parameters are allowed to vary randomly within a known distribution.

2.1 STEPS FOR AN INSULATION COORDINATION STUDY

The insulation coordination study can be done from three different perspectives:
[1] To select and size arresters for an existing system.
[2] To specify the BIL for new equipment added to an existing system.
[3] To select the insulation level for a new line.

The first step in any insulation coordination study is to determine which of these categories of studies is to be performed. Once the desired study has been classified, three slightly different methodologies can be adopted.

(1st) If the study is to select, size and locate arreters, then
- (a) Select an initial arrester operating voltage and rated voltage based on the system voltage and expected temporary overvoltage.
- (b) Define all important service configurations (equipment in and out of service possibilities).
- (c) Locate the arrester at the entrance of the substation and verify that for all service configurations and for different locations of lightning strokes that all substation equipment will be adequately protected.
- (d) Identify all probable switching operations and load rejections that may lead to arrester operation.
- (e) If the results are not within the specified limits, select new parameters for the arrester and check again.

(2nd) If the case is to select BIL for a new equipment,
- (a) Proceed as before with the exception of step (i)
- (b) Using an appropriate computer simulation program verify that tha addition of the new equipment will not affect the existing ones for all tested cases. Then using the results of this simulation the BIL of the new equipment can be determined.
- (c) Otherwise try to relocate the existing arresters or add new ones and perform the simulation once more.

(3rd) When the objective is to select the insulation level for a new line, then
- (a) Define all important service configurations.
- (b) Run simulations for all possible lightning and switching transient conditions.
- (c) Determine the overvoltages produced by all those simulations.
- (d) Using the worst conditions, specify the insulation level for the new line.

3. ELECTROMAGNETIC TRANSIENT PROGRAM

The Electromagnetic Transient Program (EMTP) is a computer program for simulating the Electromagnetic, Electromechanical and control system transients or transient Analysis of Control Systems (TACS) on multiphase electric power systems. It was first developed as a digital computer counterpart to the Analog Transient Network Analyzer (TNA). Many other capabilities have been added to the EMTP over the years and the program has become as a culture in the electric utility industry. The actual EMTP is the result of a cooperative development effort among many users [2].

3.1 EMTP APPLICATIONS

Studies involving use of EMTP can be put into two general categories. One in design which includes insulation coordination, equipment ratings, protective device specification, control system design, etc. The other is solving operating problems such as unexplained outages or system failures. A partial list of typical EMTP studies follows:

Switching surges, Lightning Surges, Insulation Coordination, Shaft Torsional Stresses, High Voltage DC (HVDC), Static VAR Compensation (SVC), Transient Stability Studies, Motor Starting.

This is only a partial list. One of the EMTP major advantages is its flexibility in modeling; an experienced user can apply the program to a wide variety of studies.

3.2 USING EMTP FOR INSULATION COORDINATION STUDIES

The EMTP provides the ability to perform insulation design. The questions that faces the designer when using the EMTP are:

[1] What runs should be performed
[2] What outputs are required?
[3] What models to be used?
[4] How are the results to be interpreted?

The systems in the following cases are modeled and simulated using the EMTP program [3].

4. CASES UNDER STUDY

4.1 CASE STUDY (1):

The system used in this study consists of a transmission line and a transformer as shown in Fig (1). The rated voltage of the system is 20kV. The transient is a lightning strike of 20kA and duration of 20us.

The objective of the study is to select an arrester with an appropriate operating voltage. The procedure followed is as outlined above.

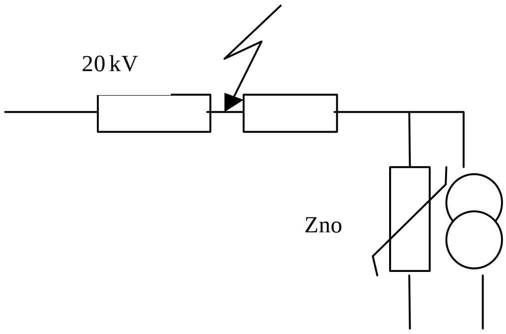

Fig (1) Transmission line model used in case study 1

4.2 CASE STUDY (2)

In this case the effect of using a piece of cable on the on the BIL of a connected transformer is investigated. The system under study is shown in Fig 2. The BIL for the transformer is 900kV. The transient is a lightning stroke of 20kA for 20us [4].

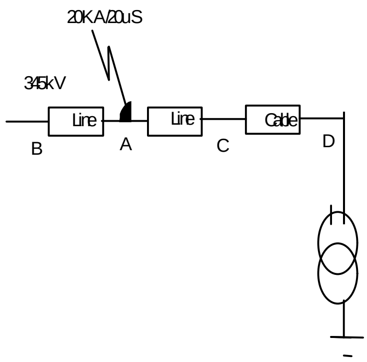

FIG2: Circuit used to investigate cable effect on system overvoltage

5. RESULTS AND DISCUSSION

Figures 3 and 4 show the resulting overvoltage in case study (1) with and without using the surge arrester.

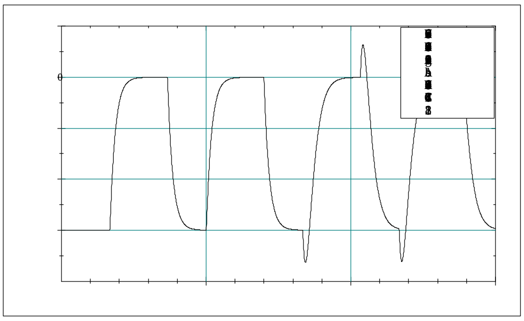

Fig (3) Voltage on transformer terminals during fault Without the use of a surge arrester

As seen from the figures, the arrester reduced the overvoltage from above 6MV to less than 200kV which is well below the BIL of the transformer. Figures 5 and 6 show the resulting overvoltage in case study (2) in the two conditions with without using a piece of cable to connect the terminating transformer.

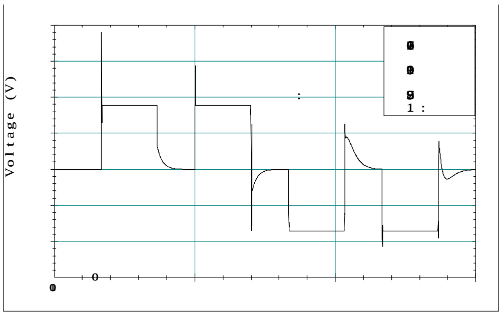

Fig (4) Voltage at the transformer terminals during fault withThe use of a surge arrester

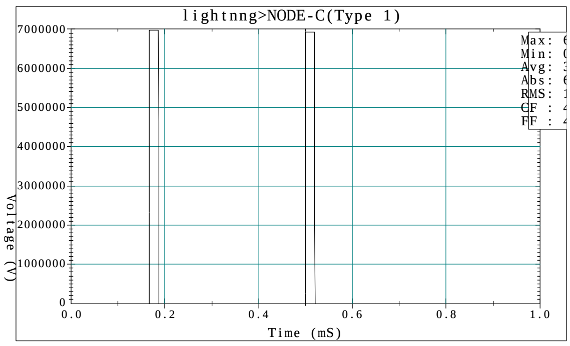

Fig 5 Overvoltage on transformer terminals Without the use of cable

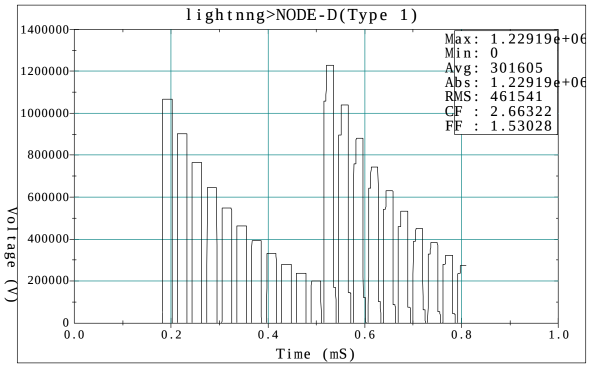

Fig. 6 Overvoltage on transformer terminals Using a piece of cable

As seen from the figures, the piece of cable reduced the overvoltage on the transformer terminals from about 7 MV to only 1.2 MV, which can easily be handled by any type of surge arrester.

6. CONCLUSION

A comperhensive explanation of the different methodologies of insulation co-ordination studies is presented. Two cases were simulated one with a lightning arrester and the other using only a piece of cable to study its effect on the determination on the transformer insulation level. It is shown that the EMTP allows the overvoltage transients and hence the required insulation level to be analyzed quickly and accurately.

7. ACKNOWLEDGMENT

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8. REFERENCES:

(1) Electromagnetic Transient Program (EMTP), Work book Volume 3, 1992.

(2) Electromagnetic Transient Program (EMTP) , Revised Rule Book Version 2.0 , Volume 1; Main Program , June 1989 .

(3) A. Greenwood, “ Electrical Transients in Power Systems “ . John Willey & Sons , 1991

(4) P.P. Barker, “Voltage Quadrupling on a UD cable .” IEEE Trans. PWRD vol. 5, No. 1 Jan. 1990 .

(5) W. Diesendorf, “Insulation co-ordination in high-voltage electric power systems”. Butterworth 1974.

9. BIOGRAPHY

M. Aburaida was born in Sudan. He received his B. Sc. in Electrical Engineering from University of Khartoum (Sudan) in 1980. He worked for National Electricity Corporation in Sudan and now with SCECO-EAST in Dammam, Saudi Arabia. He is currently working for an M. Sc. In Electrical Engineering in KFUPM in Dhahran. His present research interest includes power system modeling, transients and EMTP applications.