FINITE ELEMENT ANALYSIS OF ELECTROMAGNETIC COMPATIBILITY IN DISTRIBUTION SYSTEM BASED ON GIS

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ABSTRACT

One major consideration with the design and use of distribution system, connectors and accompanying equipments assemblies in modern electronic systems is the Electromagnetic fields. One of the best ways to analyze of Electromagnetic Compatibility (EMC) is use of a software system with precise location that 3D or 2D position of equipment of a distribution system. In this article, a two-dimensional finite element model for both the EMC and EMI solutions inside a power distribution system by Geographic information systems (GIS) has been presented. Also, this paper stimulates an actual distribution system in GIS to have a real model based on Alborz power utility company in Iran. After modelling the network in GIS the network equipment and urban objects are simulated finite element method (FEM) software to analyze the EMI against the operational reliability of both the system and subsystems. Moreover, an experimental test in utility is conducted to compare the real field and simulation result.

INTRODUCTION

The electrical power system in a spacecraft more or less determines the payload, spacecraft size, cost, operating life, and mission efficiency. One major consideration with the design and use of distribution system, connectors and accompanying equipments assemblies in modern electronic systems is the amount of radio frequency (RF) or microwave leakage coupling into both systems and subsystems via the connecting cables or overhead lines. To facilitate system and subsystem designs, it is necessary to determine both the coupling performance and shielding effectiveness (SE) characteristics of equipments and connectors that interconnect various components, subassemblies, equipment, and subsystems. The methodologies measuring the coupling and SE of lines and connectors have been the subject of a great deal of research and development during recent years. To reduce the electromagnetic disturbances, changing the type of equipment is suitable method. To decide on having a first overview of the distribution network is required. The shielding industry in the area of connectors has proposed a myriad of measurement techniques and procedures, hardware and software designs, literature descriptions, test standards and guidelines, and practices. One of the best ways to analyze of electromagnetic compatibility (EMC) is use of a software system with precise positioning of 3D or 2D equipment of a distribution system. As a result of rapid development of computer technology and decrease in costs, geospatial information systems (GIS) are now being used widely in the design and operation of electric distribution systems [1, 2]. These application systems provide an integrated hardware and software environment that is used to store, update, manipulate, analyze and display all forms of data and object relationship referenced by spatial or geographic coordinates. GIS integrates common database operations: such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and decision strategies. GIS provides adequate 3D or 2D platform for system representation and manipulation, since network models and databases can be accessed and modified to perform system analysis.

This Paper stimulates an actual distribution system in GIS to have a real model. The system provides platform for building a distribution network database which includes both the spatial and attribute information. The database can be used for facility management and distribution network analysis. Facility data or network model can be retrieved from the database. After modelling the network in GIS, we convert the network equipment and urban objects such as homes, trees, pipes and other in to a finite element method (FEM) software to analyze of the electromagnetic interference (EMI) against the operational reliability of both the system and subsystems. Dynamic information such as voltage, current, and grid stability in distribution lines, is collected by GIS. Information collected will be used for calculations. Also we have experimental test in utility to compare between real fields and simulation results

GIS BASED DISTRIBUTION NETWORK MODEL

Readability and aesthetics are two desired quantities for one-line diagrams. The main objective for automatic one-line diagram layout generation is in its ability to replace the labor-intensive task of manual diagram construction and produce visualizations of relational information that are easy to remember and understand aesthetically pleasing. There are four steps to draw one-line diagrams.

a. Obtain the topology of the distribution system elements (edges and junctions)

b. Add geospatial data that are related with the network elements to topology information

c. Generate an estimate of the positions of the buses on the basis of the geospatial data

d. Apply the intelligent routing algorithms to generate a crossing-free one-line diagram.

To modelling a network in GIS, modelling any groups of equipment based on the structure and action of it in to point, line or polygon model. Table I shows this modelling.

A network is a set of features that participate in a linear system such as a utility network, stream network, or road network. Networks are well suited for tracing analysis. A geometric network is associated with a logical network, which is a pure network graph consisting of edges and junction elements. Referencing the line-network-oriented thinking, expert experience is summarized as reasoning strategy which is described as routing rule. Using these rules, the diagram built in above section will become regular and readable [3].

Table I: Equipments model in GIS

Equipment	Line	Polygon	Point
Overhead line	●		
Underground line	●		
Transformer	●		
Pole			●
Substation		●	
Relay			●
Switches (Breaker, cat out or ...)	●		
Bus	●		
Fuse	●		

The following is the fundamental principle of routing:
a. Select the main feeder, *b*. Identification the laterals (branches), *c*. Assignment of directions, and *d*. Computation of co-ordinates. For electromagnetic analyze need to describe system with real line, for example for a subway with five line, need to have 5 line with geospatial position and real data that we have carefully studied on this issue.

ELECTROMAGNETIC COMPATIBILITY IN DISTRIBUTION SYSTEM

A Distribution System is exemplified in Fig.1. Applying the concept of fixed installation, there is principally no difference between electrical networks or connected equipment in terms of electromagnetic disturbances. Both networks and connected equipment can emit electromagnetic disturbances and immunity is similarly relevant in this context. A network may well be connected to other network(s) which may emit disturbances or be affected by disturbances in terms of imperfect voltage quality. Lack of immunity can also degrade the very basic function of the grid of energy transfer. One such case is where energy transfer is interrupted due to interference caused by geomagnetically induced currents. Disturbances can propagate from a network to connected equipment or vice versa as presented in Fig. 2 [4]. Disturbances may also propagate between networks as illustrated in Fig. 3 and emission from a network may be seen as a cumulative effect of emissions from a large number of connected equipment in terms of imperfect voltage quality at a specific site [5].

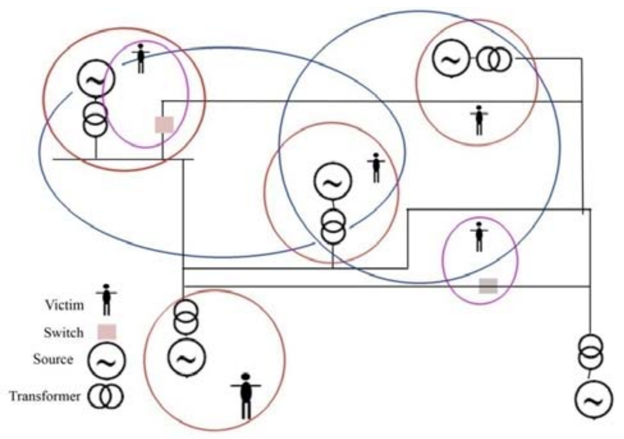

Fig. 1. Distribution system and electromagnetic interference

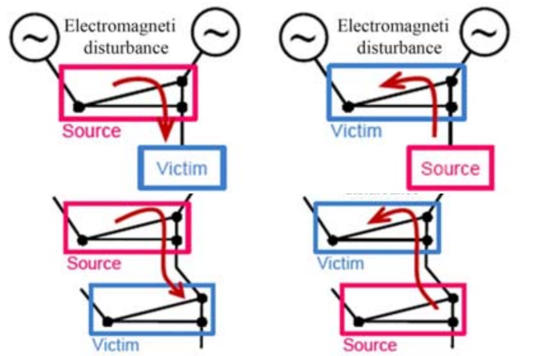

Fig. 2. Propagation of an electromagnetic disturbance between networks and disturbance between the network and equipment connected to the network

ELECTROMAGNETIC DISTURBANCES

Main character that we need to EMC is know that why electromagnetic distribution existence at distribution system.
In a power distribution system may have a lot of reason to the EMI. The IEC – International Electro technical Commission defines the following principal electromagnetic con-ducted phenomena [2]:
Conducted low-frequency phenomena:
Voltage fluctuations, harmonics and inter-harmonics, DC component in AC networks, signals superimposed on power lines, induced low frequency voltages, voltage dips and interruptions, voltage unbalance, and power frequency variations.
Conducted high-frequency phenomena:
Unidirectional transients, induced voltages or currents, and oscillatory transients.
Voltage dips is one type of disturbance phenomena emitted from grids which result in substantial economic costs [5, 6]. An individual voltage dip is, according to [7], characterized by two parameters; the residual voltage and the duration. In order to achieve electromagnetic compatibility, immunity of connected equipment is preferably such that a reasonably share of dips are within the immunity area.
An alternative representation of voltage dips is the use of contour maps [8, 9]. Also contour maps can be made for a specific site or as a representation of many sites in a geographic area
Naturally, in a three-phase electrical system there are a number of different types of voltage dips due to e.g. various combinations of faults and transformer connections between the fault and the observation point in the grid [6]. A classification of dips in three phase systems is used by CIGRE/CIRED/UIE working group C4.110 [10]. Voltage dips can be characterized to facilitate immunity requirements on equipment, individual or groups of equipment in industrial processes such as a paper machine [5, 10].

ALGORITHM AND FORMULATION

EMI shielding is an important application when it comes to modelling power distribution systems. Thus, it is necessary to review the status of EMI modelling and shield design of the modelled power device thoroughly. Algorithm that we used for this study presented in Fig. 3.
The work of G. Vasilescu [11] is suitable in formulating SE

at distribution system. For a given external source, the shielding effectiveness is the ratio of electric or magnetic field strength at a point, before and after the placement of the shield in question. Denoted by SE, this figure of merit is calculated with the expression:

$$SE = 10\log\frac{P_i}{P_t}[dB] \quad (1)$$

Where Pi is the incident power density of the electromagnetic wave (measured at the point of observation, before shielding);
Pt is the transmitted power density of the electromagnetic wave (measured at the same point, after shield is in place).
Expression (1) holds for near- or far-field conditions, and can be used at distribution system.

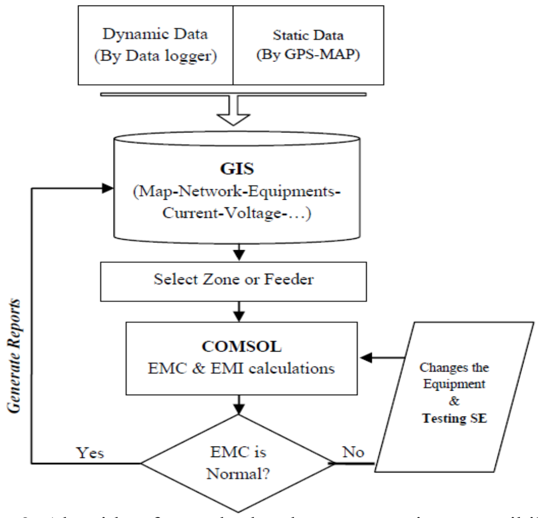

Fig. 3. Algorithm for study the electromagnetic compatibility

The total SE depends upon the absorption losses *A* and the reflection losses *R* in the following way:

$$SE = A + R + B \text{ [dB]} \quad (2)$$

B being is a term related to re-reflection (it is always negative). A, R, and B expressions exist on [11].

CASE STUDY:
PERFORMING MEASUREMENTS AND SIMULATIONS

In this article, a part of power distribution system form Alborz Company is used for study. Fig. 4 shows a geographical diagram of this system. Table II shows Specification of this network.

Table II: Case study details

Item	Unit	Quantity
Area	Km^2	150
Number of customers served	No	1109720
Length of 20 kV line	km	950
Length of LV line	km	3518
Number of distribution transformer	No	2590
Capacity of distribution transformer	MVA	886.226

At test system, medium voltage is 20 kV, which is reduced to 7% in some areas. Low voltage is 400 volts. Network frequency is 50 Hz. The peak current measured at the feeders are shown at table 3. Our measurement times are in peak time. The GIS helps us to have a full monitor on network and power quality can be controlled.
For numerical calculations, the FEM-tool COMSOL Multiphysics is used. This network has been studied in various electromagnetic modes. In the first case, the current state of the network is considered. The electromagnetic field calculations have been carried out in the first case. In the second case, the overhead line changed with wire shielded. In the third case, we use the underground line. Also we use gauss meter to measure the magnetic and electric fields in network and simulation results are also compared.

Fig. 4. Geographical diagram of this distribution system on case study

Table III: Max current of the 63kV substation's feeders

Substation 63kV	Feeders (Current, A) No 1	No 2	No 3	No 4	No 5	No 6	No 7
No 1	70	120	200	10	60	120	230
No 2	240	260	110	140	100	160	200
No 3	255	245	140	10	10	165	225
No 4	150	10	200	10	200	10	-
No 5	200	200	160	200	10	-	-
No 6	240	170	240	180	120	100	140
No 7	100	70	190	180	170	40	200
No 8	55	115	205	110	-	-	-

Electrical simulation on network

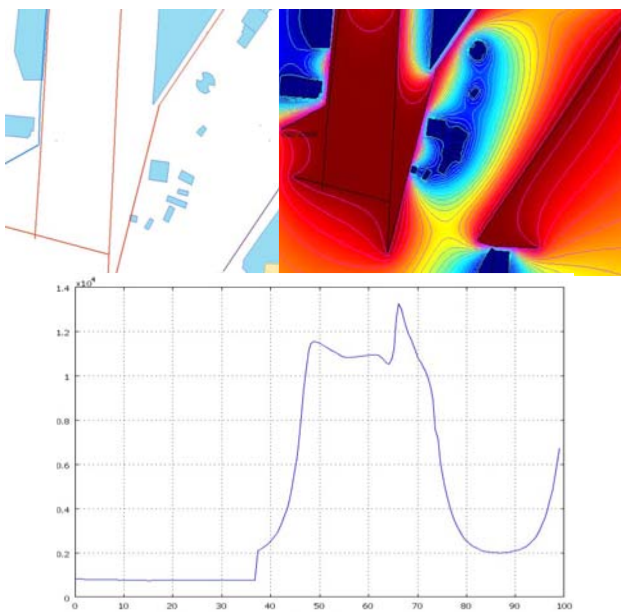

Fig. 5. Electric field at the first case
(Cross section of street is 100m)

Magnetic simulation on network

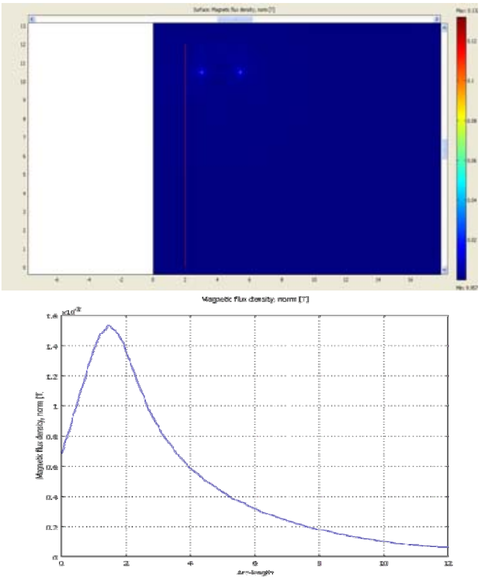

Fig. 6. Magnetic field at the first case
(Cross section of street is 12m)

Three points were selected for simulation and measurement. First point is under overhead line on ground. The second point has 6 meters distance from the first point. The third point has 12 meters distance from the first point a 6 meters distance from the second point.

Table IV: The results of the simulations and measurements at case study

		Case1	Case 2	Case 3
Electrical field Simulation (V/m)	Point 1	1.1×10^{3}	0.05×10^{1}	0.001
Magnetic field Simulation (T)		1.55×10^{-3}	0.4×10^{-4}	0.69×10^{-4}
Magnetic field Experimental (T)		1.82×10^{-3}	-	-
Electrical field Simulation (V/m)	Point 2	0.71×10^{3}	0.01×10^{1}	0
Magnetic field Simulation (T)		0.1×10^{-3}	0.12×10^{-5}	0.23×10^{-5}
Magnetic field Experimental (T)		0.13×10^{-3}	-	-
Electrical field Simulation (V/m)	Point 3	0.24×10^{3}	0.03	0
Magnetic field Simulation (T)		0.02×10^{-3}	1.2×10^{-7}	0.4×10^{-6}
Magnetic field Experimental (T)		0.34×10^{-4}	-	-

We use actual measurements to calibration the stimulants. The real conditions at the test site will be more effective computing. SE in all cases calculated and presented at table V.

Table V: SE at case study

point	Case 2	Case 3
No 1	39 dB	73 dB
No 2	67 dB	84 dB
No 3	69 dB	89 dB

CONCLUSIONS

In this article, a two-dimensional finite element model for both the EMC and EMI solutions inside a power distribution system has been presented. Also, application of GIS technology in power distribution network was introduced and communication between GIS and software in Power Company was defined. Static and dynamic data of distribution system by GPS and data logger are collected and stored in the GIS system. Dynamic data is updated online by the fast data loggers. All information stored will be transferred to the Comsol software. We have used various methods to reduce the effect of the electromagnetic interference. Use of underground cables and overhead lines with shield are methods that we use. The study also compared with standards. This way helps electrical engineering for have a correct derision about the EMC on their power system with minimum time and price. In the case study, we have experimental results for test the simulation analysis.

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