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Integration GIS–SCADA Power Systems to Enclosure Air Dispersion Model

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***Abstract*—**This paper will explore integration model between GIS–SCADA system and enclosure quantification model to approach the impact of failure-safe event. There are real demands to identify spatial objects and improve control system performance. Nevertheless, the employed methodology is predicting electro-mechanic operations and corresponding time to environmental incident variations. Open processing, as object systems technology, is presented for integration enclosure database with minimal memory size and computation time via connectivity drivers such as ODBC:JDBC during main stages of GIS–SCADA connection. The function of Geographic Information System is manipulating power distribution in contrast to developing issues. In other ward, GIS-SCADA systems integration will require numerical objects of process to enable system model calibration and estimation demands, determine of past events for analysis and prediction of emergency situations for response training.

***Keywords*—**Air dispersion model, integration power system, SCADA systems, GIS system, environmental management.

I. Introduction

OPEN systems as innovation technology are developed to upgrade traditional control process in recent power system. The mean application such as integrating GIS–SCADA is no longer considered a stand–alone system. It is the key function of integration different objects for improvement interoperability and independences in applicable forms. These interfaces communicate in systematic standards to exchange between layers and perform query based structure and operations, depending on service—oriented architecture [1]. In traditional integration, the geographical data with other electrical elements, attributes and parameters are kept in GIS spatial database [2]. The analysis will require multiple data structures and software that support a wide range of spatial queries and promote statistical and deterministic modeling. Spatial data structure forms refer to geo-referenced data as represented and stored in computer. Frank and Barrera [3] list four major elements that spatial data structures are formed in layers as:

1. Type of geometrical data (point versus region)
2. Object handling (non-fragmenting versus fragmenting)
3. Retrieval (direct versus hierarchical)
4. Subdivision of space (regular versus data determined)

A modeling system must provide a generalized data structure for the simulation distribution as in Fig. 1 [4]. Landscape, wind direction and cooling tower systems are described parameters that influence transport processes. These processes are modeled easily using matrices or "grid": A matrix with *n* rows and *m* columns of quadratic cells with an equal cell-length size. In GIS systems, data structure is represented in either raster (region, fragmenting, direct, and regular) or vector (region, non-fragmenting, direct, data determined) as acquired from Satellite Monitoring Stations. The component, such as line, is stored in a sequence of points with end edge defines nodes with geometric coordinate (χ, y, Z) and polygon name (ID). However, solutions of geometrical problems are employed to use the mathematical formulation of Euclidean geometry. Euclidean geometry is based on a continuous space consisting of an infinite number of points. Analytical geometry is convenient mapping to the coordinate space and relies on real numbers where between any two numbers another one exists. This is necessary to represent the property of Euclidean geometry in which between any two points, another one can be inserted [5].

II. Object Oriented Database Features

Main merits of OODBSs are the modeling of power systems, because objects reflect a "natural" view of the world that are reflected in software model, the reusability and extensibility of object components influence application as a result of data abstraction, inheritance, and polymorphism capabilities. The possibility of merging most application into database schema refers to data encapsulation procedure. The graphical structure is associated to objects as explored in Fig. 2 [6], [7].

At the intentional (schema) level, a database is defined by a collection of inter-related object classes and is represented by an interrelated object graph (i.e., university dataset). The main classes are grouped into two general categories as follows:

1. The non-primitive-class which represents a set of objects of interest in an application world, each of which is assigned a system-wide unique object identifier (OID) and its data are explicitly entered in database by the user,
2. The primitive-class which represents a class of self-named objects serving as a domain for defining other object classes, such as a class of symbols or numerical values.

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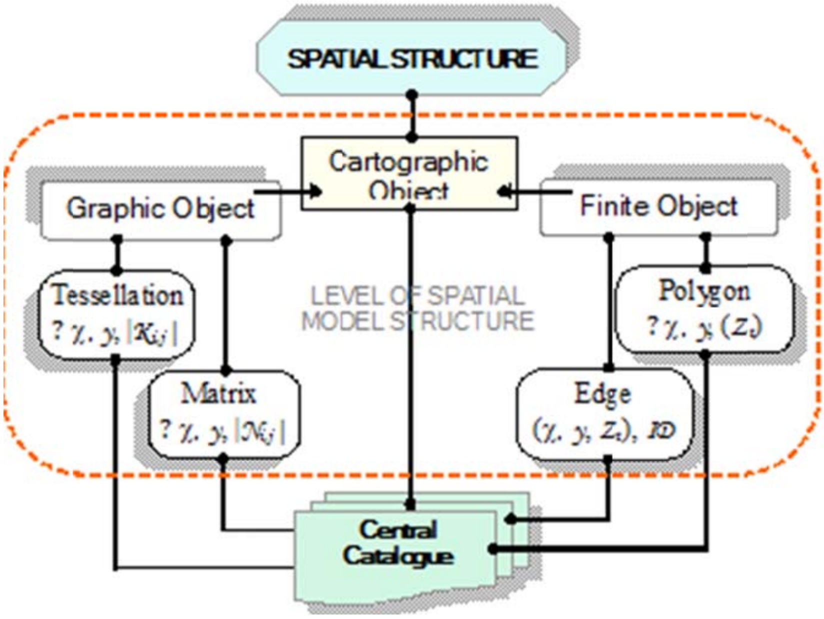

Fig. 1 Conceptual objects design of spatial model structure

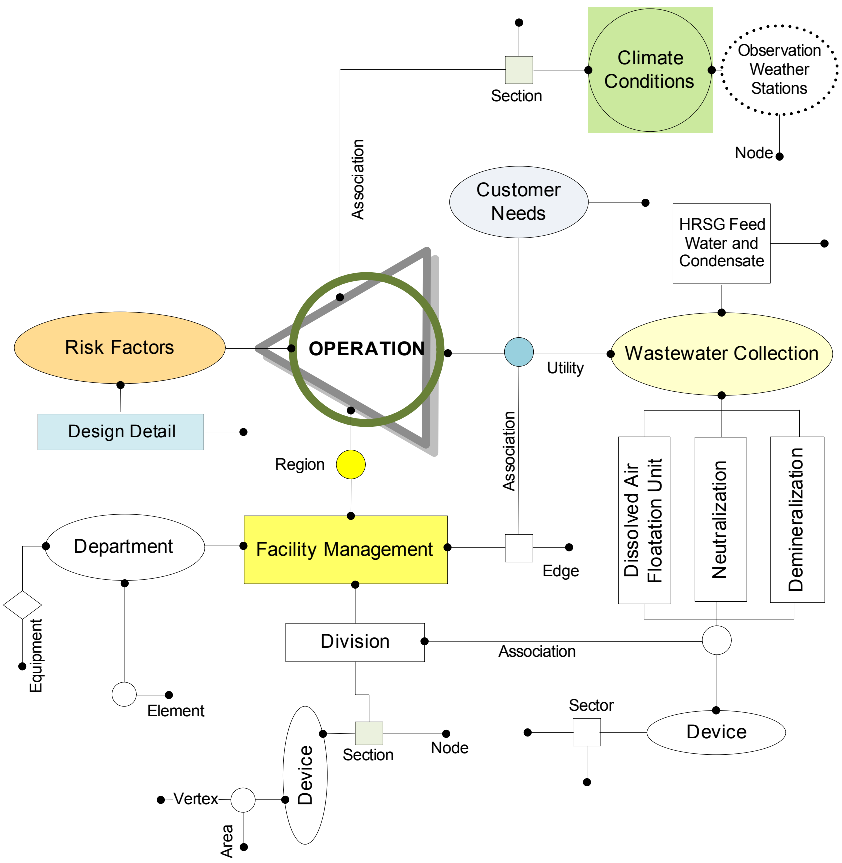

Fig. 2 Principals graph of power system objects Schema

The properties of an object class are described in terms of logic gate of system–defined or user–defined operations (e.g., retrieve, display, delete, insert, rotate a design object, etc.), which can meaningfully operate on its objects using their corresponding programs (or methods). The properties of an object class have its structure and, thus, its objects consist of two types of data:

1. Descriptive data (or instance variables), which define the states of objects, and
2. Association data which specify the relationships between its objects and the objects of some related classes.

The O—O models recognize different types of associations, the most commonly recognized associations are aggregation and generalization. Aggregation models the (a—part—of), (a—function—of), or (a—composition—of) relationship. For instance, a complex object can be modeled by an aggregation hierarchy (abstract data type) in which a complex object is defined in terms of its association with objects in other defined classes. In generalization models, the is—a function or the superclass—subclass relationship as an objects of a subclass inherits for both structure and behavior properties of its super –class(es). This practice example is declared as an association between the class equipment and the class department (i.e., an aggregation association); and an association between the class company and the class division (i.e., a generalization association). These actual paths set its relational in association algebra for expressing database processing. The logic gate is normally defined by default to construct object model in the same properties structure and behavior of objects as found in advanced applications such as CAD/CAM, CASE, and decision support [8]-[11]. Thus, from algebra point of view, an O—O database can be viewed as a collection of objects, grouped together in classes and interrelated through association. It can be represented by graphs at both intensional and the extensional levels as exemplified in [12] and [9].

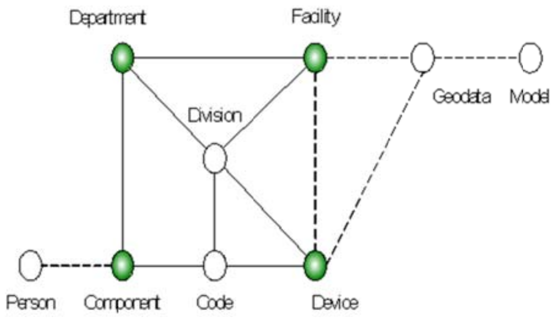

Fig. 3 Object graph represent interrelated in group classes

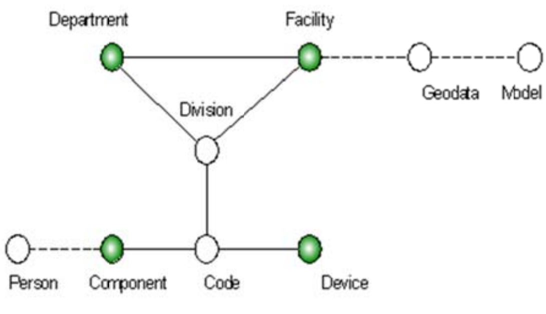

Fig. 4 Query by specification pattern

At the extensional (instance) level, a database can be viewed as a collection of objects, grouped together in classes and interrelated through some type-less associations; and as such, it can be represented by object graph as shown in Fig. 3.

The object is corresponding to a portion of universal set and based on the relational O—O database. The user can query the database by specifying different patterns of object association as search conditions. The query algebra is proposed based on the network of objects, objects type and their association as illustrated in Fig. 4. The mathematical property for this query is given by:

The domain of algebra is (facility∩ division) ∩ [R(division∩ department)](department ∩ section). These classes are denote, ***(A, B, C, D)*** *in associations sets of interrelation,*

$$\alpha \cap (R\ (A, B, C))\ \beta \;=\; \beta \cap (R\ (A, B, C))\ \alpha \qquad \textit{(commutatively)}$$
$$= \{\, \gamma \mid \gamma^k = (\alpha_\iota, \beta_\iota, a_n b_m) : a_n b_m \in (R\ (A, B, C)) \text{ and } a_n \in \alpha_\iota \wedge b_m \in \beta_\iota \text{ and } \gamma^k \,\} \qquad \textit{(associatively)} \tag{1}$$

where, (A, B, C, D, and V) denote classes; R = association between classes; α_ι, β_ι, γ^k = association sets for (i, k) pattern; a_n b_m = association inter-pattern or object instance.

III. Characterization Power System

The system components are characterized according to logic investigation, since no reliability data of existing system is available. The scenario of severity operation is assigned to possible fail—safe condition of accidental emission. These incidents have been quantified with a number of methodologies which help in evaluation of hazards, such as Fault Tree Analysis (FTA) [13], Hazard and Operability studies (HAZOP) [14], Functional Failure Analysis (FFA) or Failure Mode and Effect Analysis (FMEA) [15]. These methods are employed for inspection basic operations taking into consideration the structural, as well as, functional, interactive complexity to analysis the consequences of most severe accident in the power system.

The failure is considered potential, when a primary event of processes elements or components devices, causes complete or partial damage to stop the system or production. The system indicated failure when certain incidents exist as:

– Pathogens (viruses, bacteria, protozoa and helminths), or nutrients (nitrogen and phosphorus) in cooling water.
– Oxides exceed the emission limit (SO_x, NO_x, CO_x).
– Enforcement damage of critical components.

The critical operations of power system will rely on auxiliaries and fixtures to indicate emission or release failures. In filter/demineralizer unit, the influent is controlled with gate valve and bypass stop valve to reduce failure of the system. These control lines are simplified in Fig. 5 [16].

The water system is collecting facility wastewater form main units and extends connection to intake source to include:

– The primary filter before storage tanks
– Clarification discharge water within circular clarifier.
– Primary sand filters for backwashing system.
– Boiler backwash polishing filtered water.
– Demineralization plant.
– Heat Recovery Steam Generator (HRSG) system.

– Air Preheater wash waste.
– Neutralization basin.
– Oil/water separator collection system.

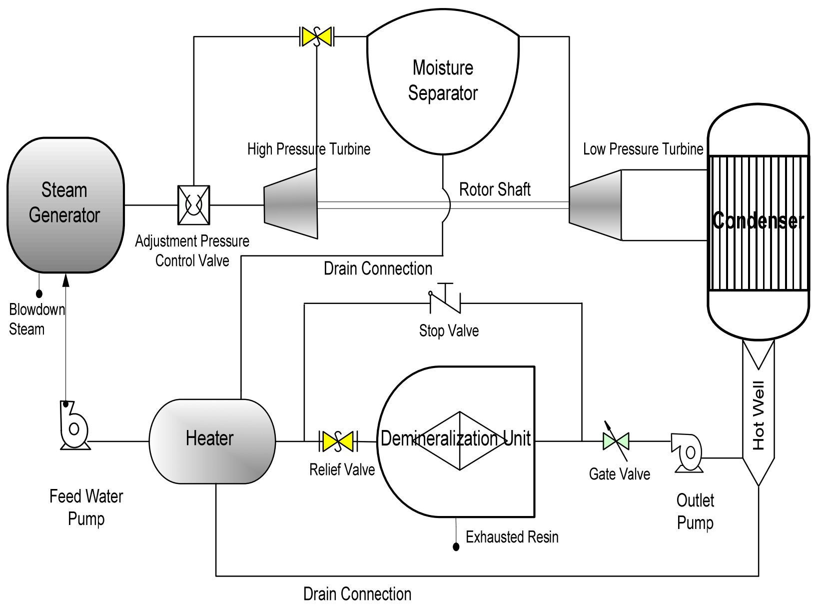

Fig. 5 System of Polish Resin Demineralizer

A. Criticality Analysis Approach

Weather analysis defines failure for safety as behavior that constitutes a hazard for safe continued operation, or for reliability as real-time response behavior, it can be measured in probabilistic terms. So, the most critical properties that an ideal emergency shutdown (ESD) system should have are:

- High availability is "1" when the system is always working (A= Uptime /Total time)
- High reliability means that systems may have to achieve failure less than, 10^{-3} to 10^{-6} failure per hour, while
- Safety critical system properties often require failure rates in the range of 10^{-7} to 10^{-12} failure per hour.
- Fail—safe operation means that in case of failure of ESD system, i.e. the system is no longer able to recognize a logic control to operate shutdown system, it will, through its control output, shut the system down for safety.

The above figures refer not to general system reliability, but to the incidence of critical failure [17].

The system design has to satisfy the safety—critical criterion with critical failure rate falling between 10^{-7} and 10^{-12} failure per hour. Failure rate of a system can be estimated directly in a test environment or calculated from reliability data of known failure rate of smaller components of the system. So, the system components that are most likely to cause malfunction are carried with failure rates assigned to possible bottom level causes using MS Excel® worksheet.

The basic figure of entire system is reflecting possible failure rate components have been estimated from elementary process using FMEA [18]. The sequence of dependent fail-safe condition is described failure mechanism from physical entities of device components (e.g., small elements and measurement test). These failures and their causes are made visible by surveying the most critical element of the system according to FTA; however, FMEA method can apply the failure rate and significant effect from archived detection of failure rate records and significant effects for management power system.

The criticality value of failure mode is a number calculated using pervious parameters to interpret component reliability at operation conditions as given in equation [18]:

$$C_m = \beta . \alpha . \lambda p . t \quad (2)$$

where, C_m = Criticality number for failure mode; β = Conditional probability; α = Failure mode ratio; λp = Part failure rate; t = Duration of time expressed in hours or in number of operation cycle or inspection period.

The total system failure rate is found to be 76.19 failures in 10^6 hour (in 114 year). This figure shows all system failures, but it should be stressed that they are not critical. Several scenarios have been applied to the system and the most severe condition is found 8.84 fail at 10^{-7} hour at turbine system with other components as determined from FMEA results.

B. Composite Relation Model

The consequence has been estimated by performing composite calculation for cross applications of Gaussian plume model [19]. The meteorological data (i.e., air temperature, and wind speed), is collected from observation stations to estimate the rate of deposition according to a particular point source emission. Based on the coefficients received from [20] and [21], Gaussian is specified parametric

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equation of dispersion model to describe the concentration levels of oxides surround the facility from:

$$C_{(x,y,z)} = \frac{Q_{R2}}{2\pi\, u\, \sigma_z \sigma_y}\, exp\left\{-\frac{1}{2}\left(\frac{y}{\sigma_y}+\frac{z}{\sigma_z}\right)^2\right\} \tag{3}$$

where: **C** is concentration of gas in mass per volume (ppm); $\mathbf{Q_{R2}}$ is rate of emission in mass per unit time (kg/s); **u** is the average wind speed; **y, z** are distance in crosswind direction and elevated source; $\boldsymbol{\sigma_y}$ $\boldsymbol{\sigma_{z}}$ are standard deviation of lateral and vertical concentration distribution in diffusion direction (dispersion coefficients*)*

Gaussian plume model employed Sutton's theory [22] to specify diffusion of gases in lower atmosphere and suite dispersion variation in cross and downwind distance with vertical dispersion coefficients (y). Other dispersion coefficients and deposition of airborne material is determined on the basis of [23]:

$$\frac{\sigma}{x}\alpha\, C_{(x,y,z,t)} \tag{4}$$

Hosker graphs are used to determine the dispersion of most severe accidental emissions to atmosphere for analysis both rural and urban areas as well.

The downwind concentration is depends on distances (χ) to approach areas according to wind speed, temperature and atmospheric stability classes in both open area as rural and urban terrain.

IV. Geospatial Virtual Interpretation

A GIS system has the ability to combine layers of information about a place for a better understanding of environmental damage. Several database drivers are connected via JDBC-ODBC for interpretation results in a virtual map such as the one shown in Fig. 6. The integration between drivers requires interfaces for measurement-based information which is necessary for estimation loads of other environmental variables. The drivers' connection is supporting object relations for interpreting potential fail—safe modes of power system and monitoring network topology for removing violations constraint in case of emergency. The layers are depending on meteorological information of weather stations, SCADA real-time data and GIS to provide a powerful tool in automation control system. The described concentration-contours are a parabolic shape cover a large area vicinity to the plant. These dispersion curves are predicting emission of power plant using PC software system known "SURFER".

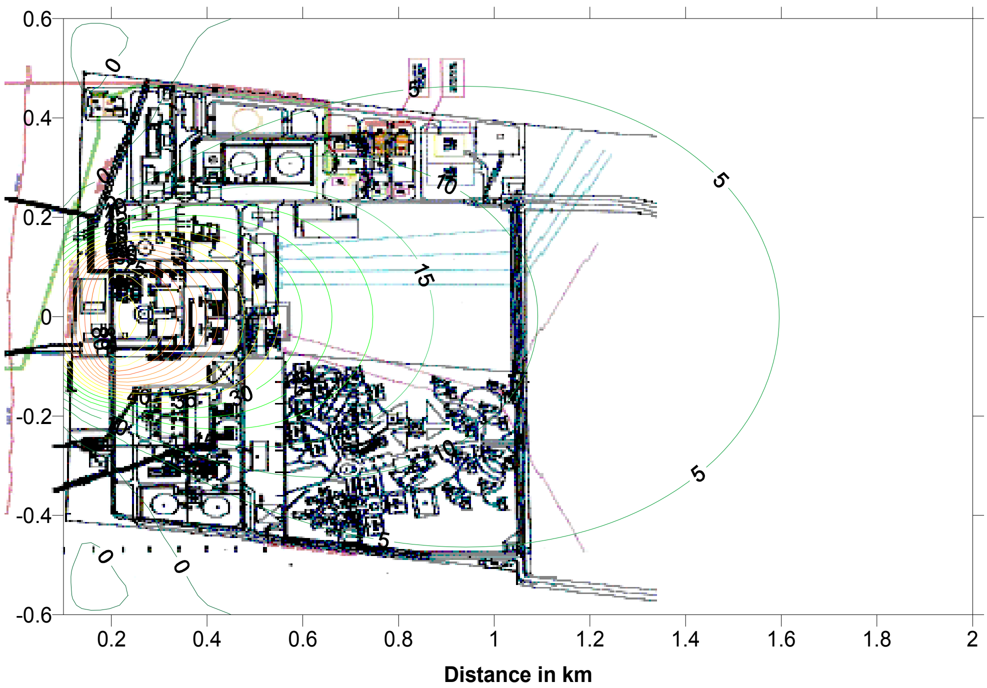

Fig. 6 Dispersion in concentration levels at power plant

V. Elevation Effects

The model evaluates the effect of topographic features in critical—safety operations of power system. The solar radiation is warming surface to influence dispersion and hence, linear variation of coefficients as determined in Gaussian plume model. The elevation diffusion over plume dispersion in Fig. 7 is comparing concentration contours which are higher in urban area, five times as evaluated in analysis methods. At higher concentration levels, the density of air increases within wider areas to slow down dispersion and expand plume to the elevation effects. The dispersion in crosswind varies with vertical variations along downwind distance *x*, in both rural and urban terrain as well. In rural areas: Open community nearby plant and solar radiation has smaller effect on ground to prompts diffusion in air. In urban side, the elevated building, with other surfaces reflect thermal radiation for warming ambient air temperature as obstacle pollutant dispersion into atmospheric layers. The topographic feature affects the plume dispersion and blocking radiant heat in inversion of vertical gradient temperature. This result of plume diffusions over dominant lands is confirming greenhouse effect in urban area with other meteorology parameters.

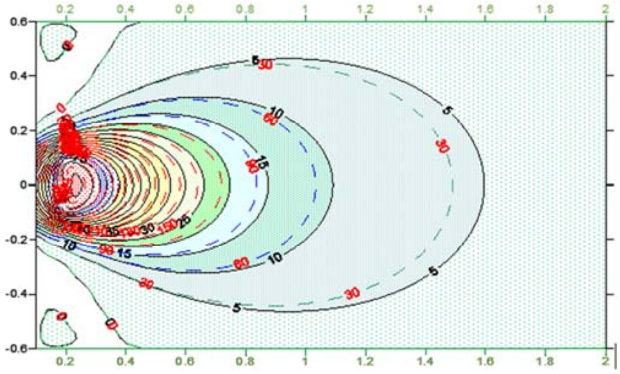

Fig. 7 The concentration levels comparing urban and rural effects

VI. Conclusion

Profiling scenarios of industrial incidents are encouraged for characterization complex control system situations where safe–state environment cannot embrace abnormal conditions. The environmental model has been extended to area exposure types (i.e., urban and rural terrain) to express virtual impact of emissions surround the facility. Under conditions of low wind and absence of downdraft, this theory predicts that the larger dissemination will be in urban area which reflects the elevation effects and illustrates the behavior of plume dispersion in urban side, in contrast to open areas. These tools serve to define acceptable standards in design and operation practices which in turn enhance the long-term maintainability of a facility [24], [25].

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dispersion pollution with integration to GIS. These experiences provide a dynamic stability to switch work between objectives in different environment conditions and improve synthetic operations in system technology