ENEA Infrastructure Simulation and Analysis Center

Architecture and available tools

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Index

1 - Introduction

ENEA (Italian National Agency for New Technologies, Energy and the Environment), in the framework of the Strategic Project on Management, Safety and Security of Technological and Energy Networks, is implementing a National Infrastructure Simulation and Analysis Center, open to contributions from other subjects involved in the area. It will develop technical and technological solutions to be used for the purpose of interdependences analysis based on "what if" approach.

The main objectives of the center are:

- The evaluation of vulnerabilities, reliability and operational safety with regard to large technological networks;
- The study of the different types of interdependences among different networks, particularly energy, telecommunication and transportation networks;
- The evaluation of the consequences of natural events on the main infrastructural networks, and the identification of the countermeasures in order to keep such consequences within acceptable levels;
- The training of people involved in the management of crisis situations, helping to evaluate correctly the consequences of their reactions on different infrastructures.

The accomplishment of such tasks is very complex, and therefore, also taking into account the large number of involved subjects, the reasonable approach is to use a federative methodology, so that each subject can develop “in house” its own products, which will then be cast in a broader architecture. For the same reason it is not feasible to impose a standardization of the software and of the operating systems, but it is necessary to integrate different kinds of products, some of which will be developed for specific purposes, and others will be purchased, choosing them among the best available alternatives, or will be taken from the public domain.

Such an approach implies that heterogeneous simulators of different domains must communicate, and it can also require a large computing power. Both requirements can be fulfilled by the ENEA-GRID computing facility, which is based on the AFS file system, and includes a very large computing power available in the Portici ENEA center.

Taking into account the European dimension of the problem, the center could be a node of the pan-european network of such centers, EISAC (European Infrastructure Simulation and Analysis Center), whose accomplishment has been proposed by the Project in the framework of the European Roadmap ESFRI (European Strategy Forum on Research Infrastructures), and of the Italian Roadmap on Large Research Infrastructures.

2 - Description of the architecture

The software architecture of the test bed is shown in Figure 1. There are three layers:

1. Simulators layer

   This layer encompasses in turn two sub layers, “Domain Simulators” and “Orchestrator”. The domain simulators are necessary to model the physical networks (electrical, telecommunication, transportation etc), while in the Orchestrator level the interactions among the different networks are modelled. The Orchestrator level is particularly relevant, and its tasks can be performed by one of the four software products currently under development, i.e. Diesis Middleware, Cisia, Ciab and Simcip. The choice about the Orchestrator to be used will be based on the spatial scale to simulate, and on the functions to be performed. A brief description of such modules is available later in this document.

   Cisia and Ciab Orchestrator modules activate and communicate with the domain simulators through a software module, “Interoperable Simulation Middleware”, which has been developed for this purpose.

   The Diesis Middleware Orchestrator will make use of a Knowledge Base to store its models, which will be based on ontologies

   Simcip is a tool that has its own graphical editor, in which in particular it is possible to specify interdependencies rules specifying the mutual interaction between power and telecommunication networks.

   Most of the tools described here are already currently available.

2. Scenarios Setup layer

   This intermediate layer provides a clean interface to be used by the expert people who will define the scenarios. It will also make available the results of the underlying level, which often consist of simple numerical output, in a friendlier way.

   It will include two graphical editor, the “Scenarios Deployment and Design Interface”, trough which it will be possible to define the scenarios making use of icons and drag and drop techniques, and the “Simulator Output Results”, which as said above will show the results of the underlying simulators, and will probably be used to activate and control them as well. The outputs of these editors could be used also in public demos to show the way experts implement their knowledge.

   To perform the functions planned in this layer, the scenario experts will also be supported by some additional tools, which are currently under development, and include a high level simulator which makes use of a “Leontief methodology”, a tool for network topology analysis, and a tool for studying the impact of natural events on critical infrastructures.

   The tools belonging to this level are currently under development.

3. Presentation layer

   This layer includes the interface aimed to the final users, who consist both of people who will attend the demonstrations, and the Decision Makers, who will perform them and, interacting with such interface, will have access to a series of scenarios and will be able to select the one to investigate. The interface will allow the Decision Maker to change some

parameters of the scenario (“Scenario Configuration”), for example to simulate faults, malfunctionings and/or natural events, and to verify the consequences (“Results Presentation”). Such interface will be implemented using GIS technology.

The interface at the moment is still at a specification definition stage, and the actual choice of the tools to be used has not yet been carried out.

Besides the software products implementing the layers, there are other significant products that must be mentioned:

- The add-on tools, already mentioned above, are currently thought as a support in defining the scenarios, but it is possible to hypothesize in the future enhancements to use them in the simulation stage as well;

- The repositories will consist of collection of data and models of the different networks and scenarios, and will be used at the scenario definition stage, as well as during the configuration for the demonstration. The methodologies pertaining to this aspect are being defined.

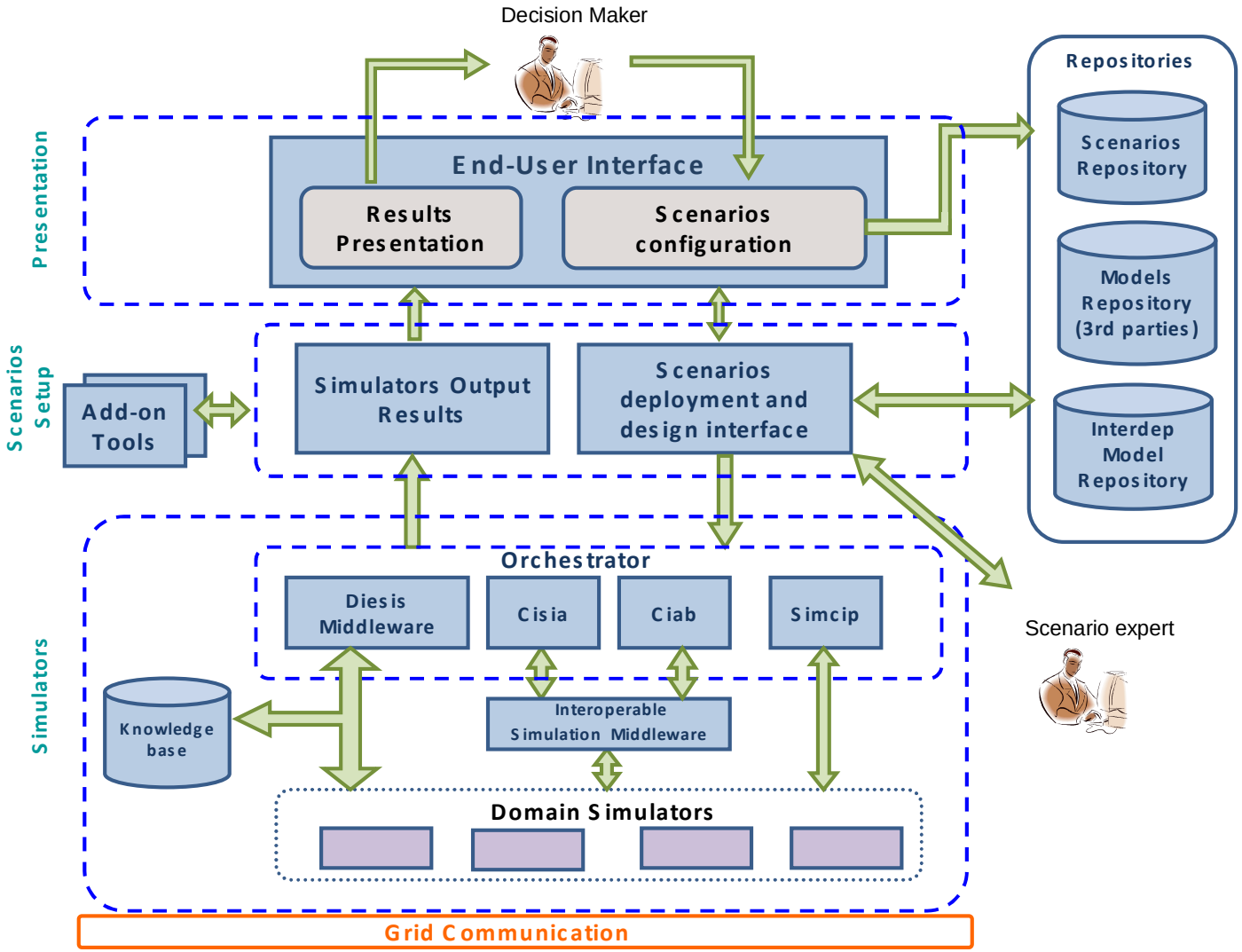

Fig. 1 – Architecture of ENEA Simulation and Analysis Platform

3 – Available products

Here follows a list of currently available products. Some of them have been developed specifically for the test bed, while others have been purchased or they are freely available. At first the Orchestrator simulators are being shown, and then the domain simulators and other additional tools follow.

Simcip

SimCIP is a discrete-time deterministic simulation tool which aims at studying the interdependencies existing among certain classes of critical infrastructures. This product has been released by the Fraunhofer Institute for Intelligent Analysis and Information Systems (IAIS) which developed it in the framework of the European project IRRIIS.

SimCIP works in a distributed environment and it offers a set of functionalities useful to study interdependencies; among them we can mention:

- Visualization of an interactive map of the components of a particular scenario, which is real-time updated to show the functional state of each component.
- Insertion of failures scenarios chosen by experimenters in order to assess the effect of cascading failures between different infrastructures.
- Interface with the electrical simulator Siemens SINCAL and visualization of the nodes (e.g. bus bar, transformers, electrical lines) of a specific electrical network.
- Implementation of a routing algorithm to simulate the Telco communication.
- Interface with the MIT components (*Middleware Interoperable Technology*) which aims at performing a risk estimation measurement of a particular taking into account the state of different infrastructures providing services, and to share such information between the two infrastructures in order to suggest particular actions to the experimenters.

CISIA

The tool CISIA (Critical Infrastructure Simulation by Interdependent Agents) is a simulator that has been designed for analyzing the short term effects of a failure both in terms of faults propagation and with respect to performance degradations. CISIA defines an agent (implemented as class) for each type of macro component present into any infrastructure: e.g., electric power plant, transmission line, telecommunication channel, waste-water system, etc.. Each class defines the behavioural roles of the element and its input/output quantities in term of which resources the agent needs and supplies. Moreover, the class defines which type of failure can be propagated to (generated from) the agent.

During simulation, each agent communicates via messages. At every time instant an agent sends messages to its neighbourhoods in order to specify its needs (requirements), communicate its level of service (operative level) and/or propagate faults (physical-faults, geographical-faults and cyber-faults). CISIA implements an easy-linkage/black box philosophy: any model is obtained connecting together agents without any modification of their internal structure.

CISIA has been developed by University Campus Biomedico in cooperation with Università degli Studi Roma 3 in the framework of the ENEA CRESCO project.

CIAB

CIAB (Critical Infrastructure Agent Based) is a Java code developed using the free simulation framework REPAST, and it is based on a high level simulation model that describes a civic emergency situation where different agents (Java classes) interact by exchanging messages.

In particular the Service Requestor agent (that represents the human beings) manages the IS4CEM agent (Information System for Civic Emergency Management) in order to give other agents assistance. Different actor and infrastructure agents are involved in this scenario, such as:

- Health Care Center (HCC)
- Telecommunication Network
- Transportation Network
- Power Grid

This software is available in a version where the Power Grid Agent and the Telecommunication Agent are replaced with external domain simulators (in particular eAGORA and NS2 respectively).

CIAB was developed by the Università di Roma Tor Vergata in the framework of the ENEA CRESCO Project.

NS2

NS2 is an object oriented simulator for the analysis and design of telecommunications networks. It provides substantial support for the study and simulation of suite TCP / IP protocols for static and dynamic routing of unicast and multicast transmissions, both on wired networks LAN, MAN and WAN and wireless (local and satellite) networks.

An application in NS2 is a generator of traffic, as a source of a rate constant (CBR) or variable-rate (VBR) or a simulated application such as FTP, TELNET, SSH, HTTP, etc..

At transport layer, instead, you can enter the TCP agents (Transport Control Protocol) and UDP (User Datagram Protocol) for communications connection-oriented and connectionless-oriented or any other type of protocol defined by user . For each application and protocol you can specify the rate of transmission, the packet size and other parameters.

NS2, depending on what is specified in an input script, can produce different types of output trace file. The trace-files contain information regarding the nature of the network (nodes and links), the events of the simulation, packets that have travelled in the network.

NS2 is an open-source program.

EAGORA

The EAGORA simulator is a JAVA tool for the modelling and simulation of distribution/transmission power grid networks. In general, the tool can be used to monitor, plan and reconfigure distribution/transmission power grid networks.

The tool does not need an installation procedure and it is distributed as a folder that contains the jars files and the Windows bat file to lunch the simulator. The simulator, through the GUI, allows to model HV/MV/LV networks, to invoke the load flow and state estimator computation and to display the results.

An important feature of EAGORA is the possibility to remotely control and manage the simulator. Indeed, EAGORA listens TCP/IP messages on a predefined port. In the client/server configuration it is possible to: load a particular network model, run the load flow and state estimator computation, modify the network model, to get the results (in a XML format).

The tool has been acquired within the SAFGUARD project and it has been developed by the EleQuant company.

SINCAL

The SINCAL (**Si**emens **N**etwork **Cal**culation) program for system analysis and planning has been created by Siemens to simulate, display and evaluate utility and industrial power supply systems. Typical user groups include municipal power companies, regional and national utilities, industrial plants, power stations and engineering consulting firms.

SINCAL offers a wide range of procedures for the complex field of protecting or examining electrical transmission and distribution networks, and provides the following procedures:

- Distance Protection Setting
- Protection Simulation for DI and OC Protection devices
- Protection Route Diagrams
- Protection Documentation
- Fault Location

SINCAL is a commercial tool distributed by SIEMENS.

PSAT

PSAT is a Matlab toolbox for static and dynamic analysis and control of electric power systems. The command line version is also compliant with the UNIX OS GNU Octave tool. The main features of the PSAT tool are: Power Flow, Continuation Power Flow, Optimal Power Flow, Small Signal Stability Analysis, Time Domain Simulation, Phasor Measurement Unit (PMU) Placement, Graphical User Interface, User Defined Models, FACTS Models, Wind Turbine Models, Data Conversion Files. Moreover, PSAT allows to expert the results using different formats EPS, plain text, MS Excel e LaTeX files.

Once the PSAT tool has been downloaded and the Matlab path has been updated it is possible to launch the simulator typing on the Matlab prompt *psat.* Then the main user interface window will be showed. Through this interface it is possible to load network model data, run the different computation procedures and the display the results.

PSAT is an open source code.

ASSOCIA Core

ASSOCIA Core (**A**pplication **S**erver for **S**imulation **O**f **C**ritical **I**nfrastructures and data **A**daptation) is the *management middleware* that manages the interactions between some domain simulators and some orchestrator simulators. It is a component of the software platform ASSOCIA, based on a distributed architecture that runs over the ENEA GRID. It has the following features:

- The information exchange among simulators by wrapper and mapping protocols
- The run time execution requests of a particular simulator.

The ASSOCIA software was developed by CRIAI (Consorzio Campano di Ricerca per l'Informatica e l'Automazione Industriale) in the framework of the ENEA CRESCO Project.

Associa Web

This software is a web application that was made up for submitting different simulation models by a generic user with an AFS account using the computational power of the ENEA GRID. At the moment, Associa Web supports only the two orchestrators CISIA and CIAB.

This software is the *request middleware* that lets the communication between the generic user and the specific orchestrator happen, and it allows the setting up of all the changeable parameters that describes the scenarios represented in the orchestrator.

Associa Web was developed by CRIAI (Consorzio Campano di Ricerca per l'Informatica e l'Automazione Industriale) in the framework of ENEA CRESCO Project

MIMESIS

MIMESIS (Multi Infrastructure Map for the Evaluation of the Impact of Crisis Scenarios) is a Decision Support System realized to evaluate the risk to which Critical Infrastructures (CIs) present on a given area are exposed, and to study physical interdependencies among different networks.

The region is firstly characterized in terms of its Critical Infrastructure content; then the system evaluates the vulnerability of these sites based on static and dynamic land data.

The system includes a database containing the following data:

- GIS data of the major Critical Infrastructures of a given area;
- Land data, collected from different proprietary sources (geological, hydrographical, seismic etc.).

Besides static and historical data, MIMESIS can be also connected to sources for the acquisition of dynamic data, such as:

- Real-time sensor networks ;
- Simulation models for weather forecasting;
- Simulation model for flood predictions.

After the critical exposition of specific CI sites have been defined, the Decision Support System evaluates the impact that specific faults (induced by land-induced crisis on CI components) produce on the CI themselves through the use of "Federated Simulators".

MIMESIS is under development by ENEA, and a new improved version is going to be released shortly.

PowerWorld

PowerWorld Simulator is an interactive power systems simulation package designed to simulate high voltage power systems operation on a time frame ranging from several minutes to several days. The software contains a highly effective power flow analysis package capable of efficiently solving systems with up to 100,000 buses.

PowerWorld gives the ability to specify operating conditions and obtain power flow solutions for a series of points in time. Besides, using Simulator's Time Step Simulation, it is possible to develop timed exercises to improve operators' knowledge of the system and response to unexpected events.

PowerWorld licence has been recently acquired by ENEA, and this tool is currently under examination, in order to check its possible uses inside the simulation platform.

Stochastic Chains

Stochastic Chains activity aims at providing the simplest model to describe networks inter-dependence while predicting the basic macroscopic evolution of events, including cascades. Simple linear models to describe network interactions are commonly recognize as I/O (Input/Output) models.

ENEA has applied the former class of models to network inter-dependence describing each net (or eventually its components) by means of an "inoperability" index. Moving from that original simple approach, extensions of such I/O models have been positively explored by introducing three basic new features: time evolution, Stochasticity and Inner structure of networks.

As a variation from Leontief models, the I/O relation has been seen as an evolution law for interdependencies. External disturbances of different shapes and duration can be applied and released Such disturbances, as well as inter-dependence coefficients do acquire a stochastic nature in our models. Finally the geographic or logical organization of the different nets has been dealt with, thus leading to further improvements of the model.

A software tool that applies such concepts has been developed by ENEA, and a simple web interface for it has also been deployed. In the next future, the tool will undergo further improvements, and a better graphical interface is also planned.

NAT Package

NAT is a package for the analysis of topological parameters of a graph. It has been conceived and realized to apply ideas and methods of Complexity Science in the area of the analysis of Large Complex Critical Infrastructures (LCCI). Each LCCI can be ultimately represented by a network containing the logical position of its different constitutive elements, connected through (logical or physical) links. Networks can be subsequently mapped onto graphs which constitute the ultimate, and more abstract, layout of a technological infrastructure, where only the mathematical structure of its constitutive elements and their connections are kept. Graphs can be thus analyzed by methods typical of the Graph's Theory; the final goal is to estimate relevant network's properties from the analysis of the associated graph and thus to gain insights on the effective properties of the "real" technological network represented by the graph.

Further functionalities have been added to the NAT tool.

The first concerns with the possibility of simulating a specific graph as representing a communication network. A simplified version of a data traffic simulator has been introduced, aimed at allowing the user to simulate the efficiency of a given network in allowing the flow of data among the nodes.

The second concerns the simulation of the effects which network's interdependency introduces into infrastructures behaviour. As technological infrastructures are mutually interdependent, a linear Leontief model for evaluating the effects on network operability induced by the presence of an "interdependency matrix" has been provided. This matrix quantifies the extent of the perturbation which a network produces on the others when its operability is reduced.

NAT contains different tools to solve different problem associated with the analysis of LCCIs:

1. A DataBase containing the graphs of several LCCIs
2. A graph generator
3. A Topological analysis of unweighted graphs

4. A Topological analysis of weighted graphs
5. A simplified Simulator of a communication network
6. A Vulnerability analysis of unweighted graphs
7. Interdependency Simulator (Leontief approach)

NAT package has been realized by ENEA in the framework of the EU-funded project "IRRIIS" - Integrated Risk Reduction of Information-based Infrastructure, and the EU-funded coordinated action "GIACS" - General Integration of the Applications of Complexity in Science.

Other tools

Within the ENEA activities in the context of CI simulation and interdependencies analysis, a series of tools have been developed that, eventually, could play a role in the final architecture. In particular, a genetic algorithm based tool for the reconfiguration of distribution networks has been developed in cooperation with the Department of Computer Science Engineer of University of Palermo. The final parallel version of the tool will be deployed and made available on ENEA-GRID.

Furthermore, a tool for the modelling and simulation of TCP/IP traffic based on the fluid dynamic theory has been developed. The final version of the tool will be deployed and made available on ENEA-GRID.

Networks data

A series of networks data has been collected to be used in the modelling and simulation activities carried on over the platform. Here follows a list of such data, and it should be taken into account that other item will be added in the future, since we are constantly seeking them.

- Electrical power network (380-120kV) - Lazio
- Railway network – Rome area
- Highway and road network - Lazio
- Rivers, hydrological basins - Italy
- Gas pipeline - Italy
- Water supply - Italy
- Seismology map - Italy
- Landslide liability – Italy
- Telecommunication network – Rome area
- Internet worldwide network
- Different scenarios to be used in the “what if” activities