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An architecture for integrating an Expert System with NEPLAN in a DMS/EMS operational environment

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***Abstract* — During 2006-2008, the Electrical Research Institute in México developed an On-Line Simulator of the Electric Distribution System (Distribution Network) for Comisión Federal de Electricidad, the main electric utility in México. The Simulator was installed in a Regional Distribution Control Center in Tampico, Tamaulipas, México.**

In the functional specification stage, a requirement was detected, consisting of an "intelligent" module that is inside the On-Line Simulator in charge of emitting on-line recommendations as to reconnection strategies, in case disturbs are found in the Distribution Network. Therefore, analyzing, designing, validating and integrating an expert module or Expert System was necessary, in order to assure that it meets the customer's expectations.

As part of the whole project, a search was carried out, in order to define which of the commercially-available Network Analysis Tools was the best option for the particular project. Using a formal and recursive strategy, NEPLAN by BCP was selected because it is the one which best complies with the functional requirement evaluation.

In this context, one of the most important challenges of the project was to define and to validate the system architecture that allows all the software components to work in an integral and collaborative way, capable of exchanging messages with relevant information related to the Distribution Network in DMS/EMS operational environment, considering and including the integration of the real-time information, a connectivity to a SCADA system in order to continuously update the real operational status.

This writing shows the result of the system architecture for integrating NEPLAN and the Expert System in a DMS/EMS operational environment in a Distribution Control Center in CFE.

***Keywords* — On-Line Simulator, Distribution Network, NEPLAN, DMS, EMS, Expert System.**

I. INTRODUCTION

The On-Line Simulator (**SimSED**) is defined as a software tool for decision support in the Regional Distribution Control Center (**CORD**) of Comisión Federal de Electricidad (**CFE**) in México; allowing functions such as: current network analysis (On-line, gathering real-time data from SCADA), network planning, developing "normal" and "in contingence" operation plans, training of the network operators and analysis of current operation in order to make improvements, based on the current operational state.

The SimSED software tool integrates many components, the most important being: a commercial platform for Distribution Network analysis and planning that includes Distribution Functions and that allows them to be programmatically controlled (using API's or libraries); an Expert System for a continuous analysis, generating recommendations about reconnection strategies in case disturbs are detected in the Distribution Network; a Manager for Transactions control; as well as a Graphical User Interface (**GUI**) for operators in the Control Centers (CORD).

Additionally, the SimSED includes some interfaces for data from CFE's legacy systems:

- GIS interface: Off-line obtains geographical, topological and electrical information of the Distribution Network. It includes an electrical library to complete the NEPLAN's electrical model.
- DMS interface: It allows obtaining on-line historical information related to fails detected in the Distribution Network, this information allows operators a deep analysis of the presented contingence.
- SCADA interface: It gets (in real-time) the whole SCADA data, then applies it in an updated algorithm to analyze the current situation and it evaluates if is necessary the Expert System execution. Additionally, it stores the real-time data in an historical database for off-line analysis.

In this way, the SimSED is operating in a DMS/EMS operational environment into the CORD, which is a new concept for Distribution Control Centers in México.

This configuration allows the identification of the architecture's main elements and functional requirements for

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an integration system, in order to obtain a final seamless product operating in a collaborative and integral way.

II. Functional Requirements

The most important detected requirements for the systems integration architecture are:

a) The architecture must be functionally independent of any software tool or operative platform. This means that it must allow using and interacting with any third-part software that uses similar data interfaces, and it must be well defined and documented.

b) It must allow concurrent access of multiple applications.

c) It must include a Transactions Manager and a message queue using a scheme for priorities.

d) For the data interchange, a standard format as XML must be considered.

e) It must be distributed, meaning that it must accept requests from third-part software tools executing in any other computers distributed in the DMS/EMS operational environment.

f) Multiplatform, it means that it must accept requests from third-part software tools, executing in different operational systems (UNIX, LINUX, Windows, etc.)

III. NEPLAN Integration Description

While using internal/external programming ability, this writing shows a proposal for integrating NEPLAN with other information systems, specifically interconnect the NEPLAN results with an Expert System in charge of evaluating and emitting operative recommendations in case of events that leave, out of service, some circuits in the Distribution Network.

NEPLAN by *BCP-Switzerland* is a commercial software tool for the planning, optimization and simulation of electrical, water and gas networks. For electrical systems, such as distribution, generation and transmission networks, in their different voltage levels and topologies, can be also analyzed.

This software has a special module that allows defining customized functions through a NEPLAN programming library (NPL);which includes functions to access NEPLAN data and calculation algorithms through a C/C++ user written program in Visual C++.NET.

The user program (NPL) is compiled into DLL files that can be locally or remotely invoked, using the provided communication interface and selecting the NPL routine.

When a NPL program is invoked, the internal routine takes the NEPLAN control and allows it to execute actions like a human user, as well as building predefined reports, considering any format programmed into the NPL.

The following figure shows the NPL programs in NEPLAN's operative scheme.

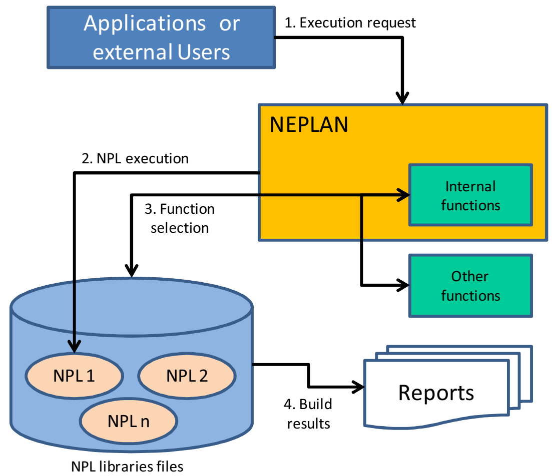

Figure 1. NPL programs execution scheme.

IV. Expert System: Functional Specification

The selected Expert System must execute the following main functions:

a) Real-time events monitoring, using the SCADA information.

b) Emitting operative recommendations, using NEPLAN results.

c) To identify plans for restablishing the service.

d) To procure support information from other DMS systems (CFE legacy systems), for decision making.

e) To support the plan execution (sequence).

f) To analyze fault events in order to refine reasoning algorithms.

g) To edit the knowledge used by the Expert System.

In the Expert System prototype (**ExSys**) for validation of the architecture, the Induce-It software tool was used. Induce-It allows defining a CBR expert system in an easy way, using Microsoft Excel.

V. Induce-It Description

Induce-It by *Inductive Solutions* is a commercial software tool; it implements the technique Case Based Reasoning (**CBR**) for Expert Systems development. The CBR is a similar method for decision making, used in medicine, law and business. [4]

In the Case Based Reasoning, problems and answers are represented as "cases". All the "cases" are typically stored in a "cases" database. When a new "case" is presented, the answer is interpolated or extrapolated, using the answers of the most similar "cases" stored in the "cases" database.

Induce-It integrates the versatility of the CBR and the usability of Microsoft Excel. Induce-It executes the evaluation and it emits a numeric result using the "cases" database stored and the numeric weighing of each one of the parameters in the current "case".

Induce-It was built using Microsoft Excel, so it inherits all the interoperability characteristics that Microsoft includes in its Office Suite products.

VI. Proposed Architecture

Using all the above described elements, it is possible to define and validate a software architecture that allows to integrate it in a collaborative and integral environment.

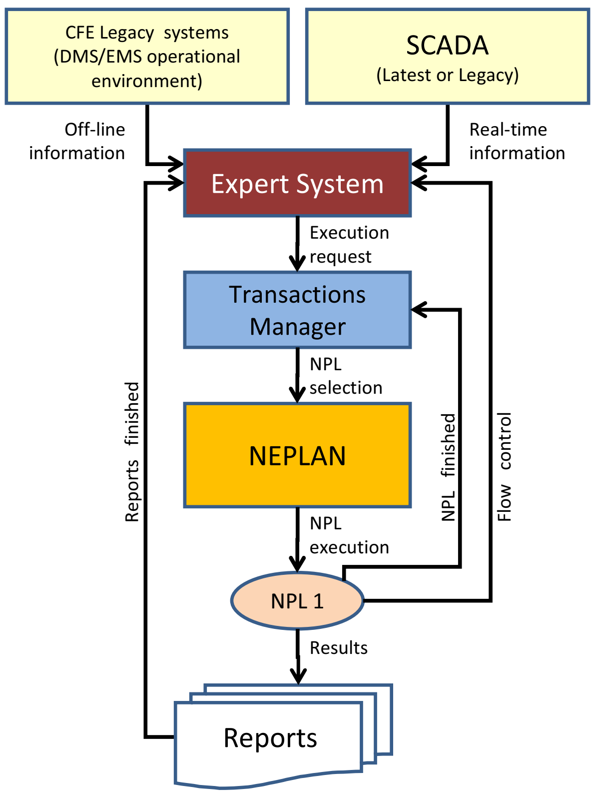

Figure 2 Proposed architecture for integrating NEPLAN and Expert System in a DMS/EMS operative environment.

a) Expert System, by means of real-time SCADA information, detects an event (fault or disturb) and it requests an NPL execution to the Transactions Manager.

b) The Transactions Manager selects the next NPL to be executed, using the requests queue and the priority of each one.

c) The execution request is received in NEPLAN and the DLL file is selected to be executed.

d) The NPL executes the algorithms, it selects internal or external functions in order to complete results for the Expert System.

e) The NPL routine generates the result files for each selected function.

f) The NPL sends a message to the Expert System , notifying the finalization.

g) The Transactions Manager selects the next NPL to be executed, or it stays on hold.

h) Using its inference algorithm,The Expert System recovers the results, as well as the additional information from CFE legacy systems (DMS/EMS).

i) The Expert System emits an operative recommendation, in function of its internal analysis and internal knowledge database.

VII. Data Communication

For the proper operation of the proposed architecture, there must be a means of communicating information between applications and at the same time, they should be independent among them, so that it works effectively, regardless of the selected commercial tool or the operating system, being chosen.

In this way, the data communications scheme must allow "receive" and "process" requests from other applications running in different computers, and even in different operating systems.

In order to accomplish all the previous objectives, the multiplatform integration architecture, proposed in [6], was applied.

With this architecture, a defined area of memory is reserved for a specific purpose of system integration. This area can be accessed by various applications that require integration, even from remote computers connected to the local Operation Center LAN, as reported in [7] and [8].

VIII. Prototype

In order to validate the proposed architecture, a prototype was built to integrate all the elements described in figure 2, including NEPLAN, the Transactions Manager, the Expert System, CFE legacy systems, and the Shared Memory..

The prototype is composed by the following components:

- Transactions Manager (Visual Basic.NET application).
- Expert System (Induce-It) and the "cases" database (knowledge).
- Expert System controller (Visual Basic.NET application).
- NPL routines (DLL files compiled using Visual C++.NET).
- Shared Memory Manager (Visual C++.NET).
- NEPLAN and the reestablishment service module.
- XML files for reports.

IX. VALIDATION TESTS

The validation tests were applied in the following sequence:

a) The Expert System by means of monitoring the real-time SCADA, it detects the conditions for executing and evaluating reestablishment plans using NEPLAN. The execution request can be automatically or manually generated by the user.

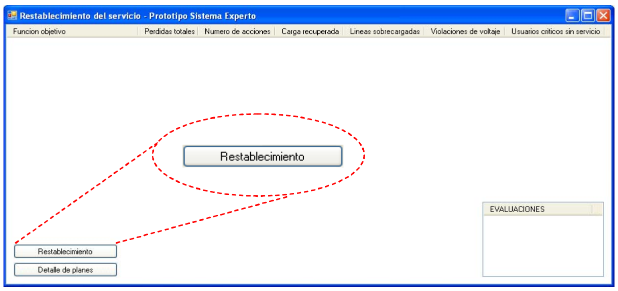

Figure 3 Expert System prototype GUI detecting a event in the Distribution Network.

b) The Transactions Manager receives the requested execution and puts it into the requests queue, waiting to be processed.

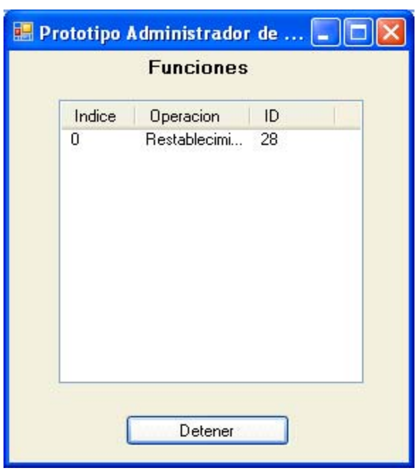

Figure 4 Transactions Manager queue viewer.

c) The Transactions Manager sends NEPLAN the execution order of the NPL, developed to use the reestablishment modules.

d) NEPLAN executes the defined NPL and generates a report in XML format including all the information about each one of the reestablishment plans. Additionally, NEPLAN shows a dialog and waits until the user manually selects the plan to execute.

NOTE: in the latest commercially-available NEPLAN version, the GUI was improved and the dialog for manually selection was changed and consistently improved.

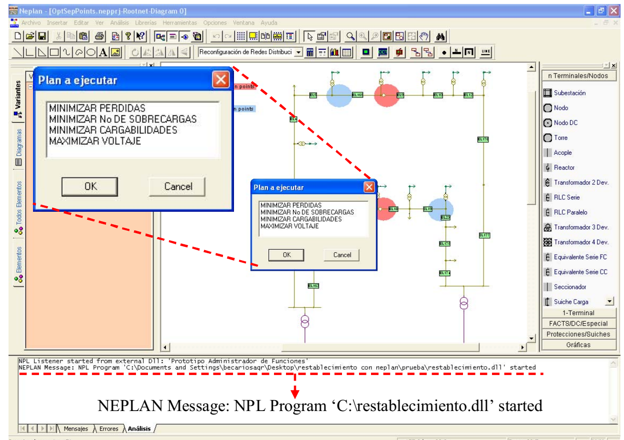

Figure 5 Dialog prototype for manual plan selection.

e) At the same time, the Expert System analyzes the information into the report generated by the NPL program and creates the message to be used by the inference engine (CBR).

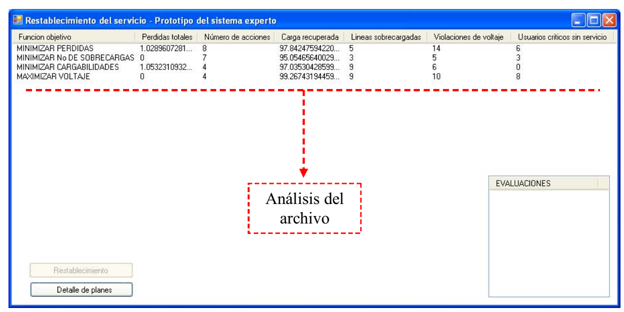

Figure 6 Expert System prototype GUI showing the NPL results.

f) The inference engine evaluates each one of the plans and the results are returned to the Expert System controller in order to emit the final recommendation in function of the "cases" database and of the knowledge database, previously introduced.

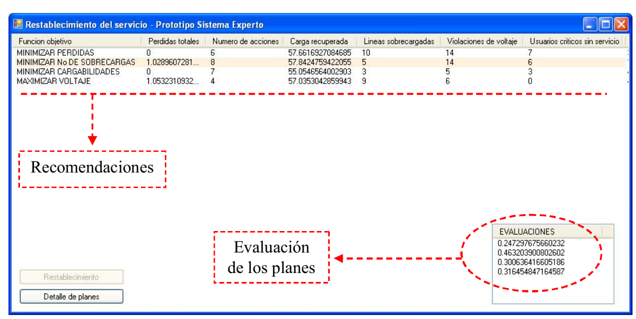

Figure 7 Expert System prototype GUI showing the evaluation results.

g) Based on the emitted recommendation, the user selects the reestablishment plan to be executed in NEPLAN.

h) The user follows the reestablishment plan, selected in NEPLAN.

i) When the reestablishment plan is finished and the Distribution Network is normalized, the cycle can be repeated.

X. TESTING RESULTS

a) The software architecture to integrate NEPLAN and an Expert System was validated. The validation considered a commercial software tool for the Expert System. For the Expert System another commercial software tool can be used or an application developed, the restriction is the use of the Shared Memory (using DLL libraries).

b) The functional prototype allows using all the software components identified in the SimSED system.

c) The prototype was validated using the real DMS/EMS operative environment in a Distribution Control Center in CFE.

d) The Transactions Manager was tested using multiple requests in a concurrent way.

e) All the concurrent requests are enqueue and the Transactions Manager is in charge of dispatching each one using the selected .priority.

f) The proposed architecture takes advantage of standard technology for data interchange.

g) All the requirements established for the SimSED were accomplished.

h) The technology for data exchange operates properly in multiplatform and it has been successfully validated in UNIX, VMS, Windows and LINUX [6] and [7].

i) The performance of the Shared Memory in Win32 environment is adequate for real-time systems [6] y [7].

j) In the integration architecture it showed that the commercial software tools (NEPLAN and Induce-It) can be easily replaced. The main requirement is that the new software tool considers similar data interfaces, standardized, well defined and completely documented.

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