



Critical Energy Infrastructure Protection. Assessment Results Communication.

CEIPSec. A GIS-Centric Web-Based Application for results communication and visual assessment of the impact of failures on the European electrical power transport system

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EUR 24764 EN - 2011

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JRC 64106

EUR 24764 EN
ISBN 978-92-79-19756-7
ISSN 1018-5593
doi:10.2788/71469

Luxembourg: Publications Office of the European Union

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1. Introduction

1.1. What is CEIPSec

CEIPSec is a web based GIS¹ centric application developed for results communication and visual assessment of the impact of failures on the European electrical power transport system. It was developed within the context of the Administrative Arrangement *Critical Energy Infrastructure Protection* between DG ENERGY and the JRC (2008-2010).

CEIPSec is designed as backend of NEPLAN^{®2} electrical transmission module. The application offers various visualization ways of the results of NEPLAN[®] simulations, crafted from an impact assessment oriented perspective. The results are provided in both *quantitative* and *qualitative* fashion through a user interface that follows (at a high level) the generic guidelines in *visual analytics* realm: intuitive and interactive interfaces for facilitating the *visual reasoning*³ techniques [ref].

1.2. Justification

Computer simulation of real systems is most of the time a complex task, both in terms of the analytical models describing the process and the usage of the tools that implement the models themselves. The simulation tools addressing different processes (e.g. NEPLAN[®] for power systems, AERMOD for atmospheric dispersion modelling, etc.) are consequently extremely powerful sector-specific applications, yet oriented towards professionals.

Naturally, the results of such tools are also mainly professional oriented. Depending on the addressee and the goal of the assessment, communicating the results in an ‘out-of-the-business’ manner is sometimes required. Likewise, from the perspective brought in by visual analytics and visual reasoning fields, the analyst should be provided with various ways of representing and visualizing the results (data), accompanied by intuitive and interactive user-interfaces.

Some of the simulation platforms offer (up to some extent) the capabilities mentioned before. Relying only on them leads however to at least a couple of drawbacks in the specific case when the results target several addressees: first, if *interactivity* is required, *all* the addressees must have access to the simulation platform and also must have knowledge about the usage of the specific software. Second, if the results are required to be consumed (accessible) by virtually anybody, most probably they are in the form of a report (usually in *pdf* file), i.e. a *static* manner.

Another aspect of complex systems simulation is the effective *simulation time*. This depends on the complexity of the models describing the process on the one hand, and the complexity of the system under consideration on the other. There are cases in which a trial (simulation run) may take several hours. In these circumstances designing an assessment platform that accommodates scenario-building, simulation running and results assessment in a contiguous workflow is not feasible. Splitting up and addressing separately the assessment phases is a more convenient way to deal with this issue.

¹ Geographical Information System - GIS

² NEPLAN. Planning and information system software for electrical transmission, distribution and industrial networks. http://www.neplan.ch/html/e/e_home.htm

³ Visual analytics - the science of analytical reasoning facilitated by visual interactive interfaces (acc. to James J. Thomas and Kristin A. Cook (Ed.) (2005). *Illuminating the Path: The R&D Agenda for Visual Analytics* National Visualization and Analytics Center.)

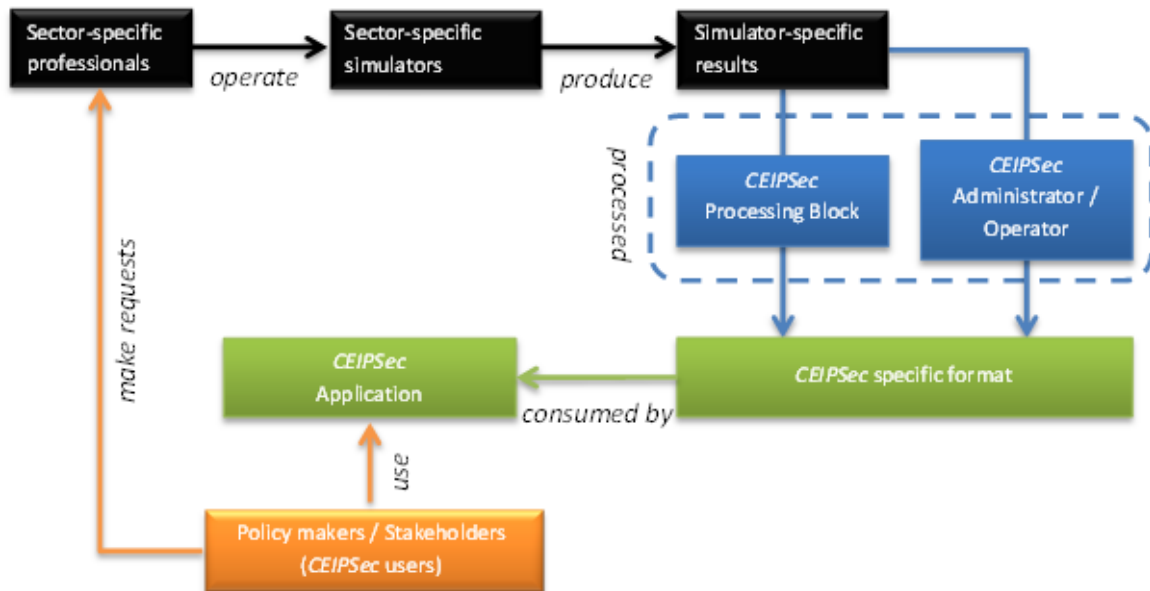


Figure 1. Assessment framework for Critical Energy Infrastructure Protection

A last topic regarding *CEIPSec* is the issue of *common visualization platform for representation and assessment* of the results. As it is developed now, *CEIPSec* only deals with the impact of failures in the electrical transport networks. However, the power grid is not the one-and-only networked critical infrastructure in Europe. As its immediate ‘relative’ is the gas network. Despite the intrinsic differences between the two systems (in respect with operational aspects – *immediate consumption* vs. *storage and consumption*, or with internal, physical processes describing the systems) from the security of European energy supply viewpoint both systems share a set of common characteristics. The differences are reflected in the different simulators used for physical process assessment. The common characteristics are reflected in the overall system behaviour. Thus, one or more nodes failure propagates throughout the system; the initial failure may have trans-border characteristics; the network flows are affected, etc. A *common visualization and assessment platform* ensures in this case the delivery to the stakeholder the assessment results of different systems in a common fashion. After all, *how many countries are affected by a failure* can be communicated the same way regardless whether initial failure is on a power substation or a gas processing plant.

1.3. The Framework

CEIPSec was developed as part of an assessment framework that takes into account the considerations in the previous section. The framework is depicted in Figure 1. The assessment is seen as a complex process involving the joint efforts of different *actors*, each of them with different responsibilities: the *Policy makers*, *Sector-specific professionals* and *CEIPSec administrators*.

The *policy maker* is the start and endpoint of the whole enterprise. On the one hand he/she is the one making requests to the sector-specific professionals. On the other hand he/she is the *user* of the visualization application. Different visualization options are the means for supporting scenario results analysis which may lead to drawing conclusions or make additional requests to sector-specific professionals.

Sector-specific professionals are in charge of operating the sector-specific simulators and provide the results of the assessment to the *CEIPSec Administrators*.

In turn, *CEIPSec Administrators* are in charge of the management of the visualization application resources. By visual application resources we understand the data consumed by the visualization application. Management of the resources is two-folded: on the one hand it implies ensuring (either thorough automatic tools or manually) the ‘translation’ of the simulation-specific output into the format understood by the visualization application; and on the other hand, tracking any changes that occur in the application resources (e.g. add/edit/update cases, cleaning-up obsolete services, etc.). A good understanding of the visualization application functionality and data architecture is required.

The rest of this document presents the *CEIPSec* application. The document targets both the users and the administrators of the system. Focus is mainly given to the application operation. Architectural, design and more technical details will also be provided, mainly for application administrators.

2. *CEIPSec*. The Application

CEIPSec is a visual analysis application developed for supporting policy making in the realm of European Critical Energy Infrastructure Protection. As in the version developed within the aforementioned Administrative Arrangement, *CEIPSec* only accommodates the European Power Transmission System facet of the more comprehensive Energy Protection field. Therefore, *CEIPSec* should be seen as (and is) a proof of concept intended to test the feasibility of such an approach for a common visualization and security assessment platform.

CEIPSec targets both *policy-makers* and *sector-specific professionals*. This is reflected in communicating the results in various forms and at different levels of detail. The information is provided in *numerical*, *graphical* (i.e. as charts) and *geographical* (i.e. on maps) form. The information given is either *bare data* (the actual values in the simulation output, e.g. P_{Loss}) or *aggregated* (statistics based on simulation results).

From a *visual analytics* viewpoint it was the developer's intention to provide *CEIPSec* the capability of communicating the information by addressing different cognitive and perception levels of the analyst. Thus, one may get relevant information in a *direct* form (e.g. a number), on a *stimulus-based* basis (e.g. 'red' is bad) or based on his own previous experience (expert judgment, e.g. 'I've seen this before').

2.1. Challenges and Design Considerations

CEIPSec is designed for having basic DSS characteristics, i.e. to provide relevant information for decision (policy) making and answer to (simple, in this case) questions. However, *CEIPSec* is primarily a *Data and GIS-centric* application. Consequently, the main guideline when designing the application was 'the user is not a specialist' in either databases or GIS. Hence, from the user-perspective, the following design consideration were followed:

- The application must be *intuitive* to use; and
- The application should be *accessible* in terms of the software required to use / access the application.

From the *operational* perspective *CEIPSec* is built on the attitude 'what would the user want to know'. From the *technical* viewpoint, the application is constructed on the 'drain-out as much (relevant) information given the available data' philosophy.

The application is designed considering both the *users* and the *administrators*. This is reflected in specialized administrator-oriented modules intended for helping with the application resources management.

Flexibility is another *CEIPSec* design characteristic. Flexibility here refers to (i) the capability of accommodating new simulation cases; and (ii) the flexibility (to some extent) in the structure of the initial data sources.

Summing up, the following lists some of *CEIPSec* design consideration and implementation specifications⁴, seen from the user-oriented and technical viewpoints.

- User-oriented
 - Accessibility – user requirements: WEB Browser with Internet access

⁴ The development and deployment (production) server configurations are different. The application was tested on development server configuration. *CEIPSec* is available on production server, having however some known non-critical functionality issues. When the case, this will be mentioned in the document.

- Security – access by credentials
- Interactive interface
- Intuitive interface
- User-action synchronization: this refers to synchronizing the *active information entities*⁵ so that a user interaction⁶ on one of them to be reflected in the others. This may also be seen as a ‘get all information with one user action’ approach.
- Scalable interface.
- Technical
 - Modular architecture – to ensure scalability in terms of additional assessment modules

The following technologies and products have been in the development:

- ArcGIS 9.3 SP1⁷ – has been used as the core GIS solution;
- WEB ADF for ASP.NET – has been used for developing the GIS-web application engine (server-side);
- WEB ADF Javascript – used for client-side GIS interaction and manipulation;
- SQL Server 2008 Express – used for additional database engine;
- ASP.NET Web Application (Visual Basic);
- JavaScript for client-side interface features;
- AJAX Toolkit 1.1⁸

2.2. CEIPSec Security

CEIPSec is foreseen to consume highly sensitive data. Securing the application by allowing access to only a restrained number of users is in this case a natural requirement. Security is provided on two levels: *network* and *application*.

Security at the *network* level is guaranteed by placing the production server on a semi-closed network (i.e. access from Internet forbidden). In this particular case, *CEIPSec* production server is only accessible from the European Commission Scientific Network (NET1).

ASP.NET Forms Authentication⁹ system has been adopted for securing the *CEIPSec* at *application* level. In short, the Forms Authentication provides the framework for restricting the content of different parts of an application based on a set of *access rules* defined for a number of *users* belonging to different *user roles*.

There are two *roles* defined for *CEIPSec*: *Users* and *PowerUsers*. The members in *Users* have access granted to the visualization modules of the application. The *User* group is created for accommodating *Policy makers* and, in some cases, *Sector-specific professionals*. In addition, members of *PowerUsers* have access to the application resource management modules.

2.3. The User Interface

CEIPSec user interface has been designed following the guidelines:

- To be intuitive;
- To be interactive;

⁵ Any information representation user may interact with (e.g. chart bar or the row of a data table)

⁶ E.g. mouse click or mouse hovering.

⁷ Production server: ArcGIS 10

⁸ The AJAX version is given by the ArcGIS version. ArcGIS 10 uses AJAX 3.5

⁹ <http://msdn.microsoft.com/en-us/library/ff647070.aspx>

- To accommodate as much information as possible;
- The user should have *all information in-sight*.
- The user should be able to focus on part of the information, according to its needs.

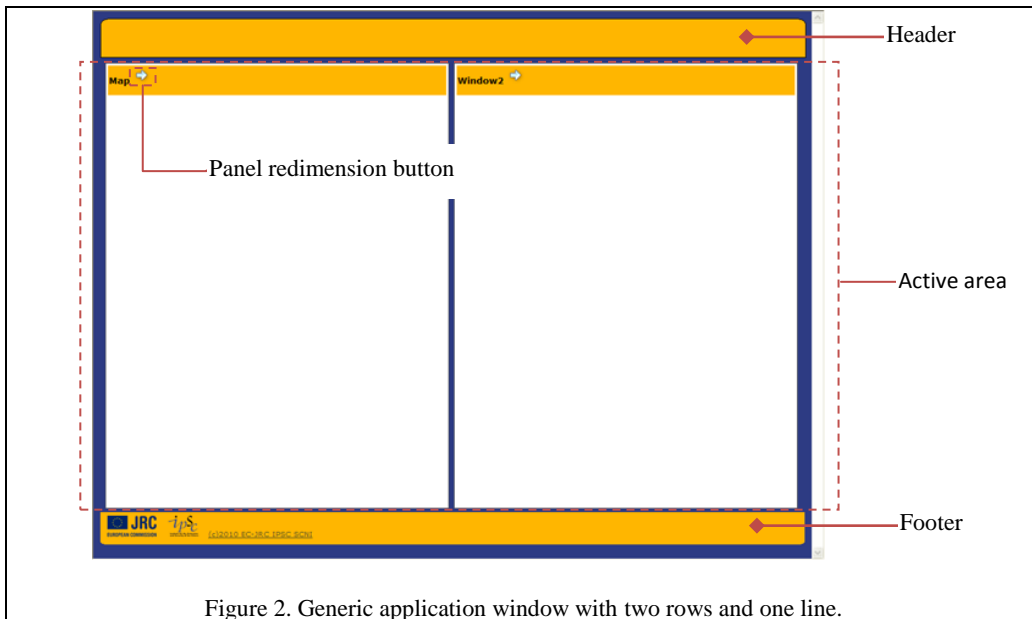


Figure 2. Generic application window with two rows and one line.

The solution adopted was to implement a set of *Javascript* functions to provide a *sizable, panel-based* interface (Fig. 2). *CEIPSec* interface dimensions as to cover the browser active window. The information is held in *resizable panels*.

The interface window is split in three sections (Fig. 2). The Header contains the Title of the current tool and the Toolbar. The Footer holds the copyright

note and useful links. The Active area is the area occupied by the panels. A panel has two states: *minimized* and *maximized*.

The active area is evenly split in a number of rows and columns. Each cell of the grid thus formed corresponds to a panel in *minimized* form. When a panel is maximized it occupies the whole Active area.

Resizable panels approach offers the user the capability of focusing on the information held by each of the panels. For instance, suppose the map is the focus point. The user may then maximize the map panel, read information, navigate, etc. Moreover, depending on the *user actions synchronization* settings, interacting with the map is reflected on other panels so that the user may get all the related information to particular information on map. More on this will be cover in the *Use Cases* section.

2.4. The site-map

The gateway of *CEIPSec* is *Critical Energy Infrastructure Protection* [Home] (Figure 3). [Home] is the only part of *CEIPSec* accessible to anybody (within the NET1 network). [Home]’s role in the application is double. On the one hand, it plays the role of the *log in* page. On the other hand, *once the user is authenticated*, and *in accordance with the user role*, [Home] is the starting point towards any of the available applications (tools).

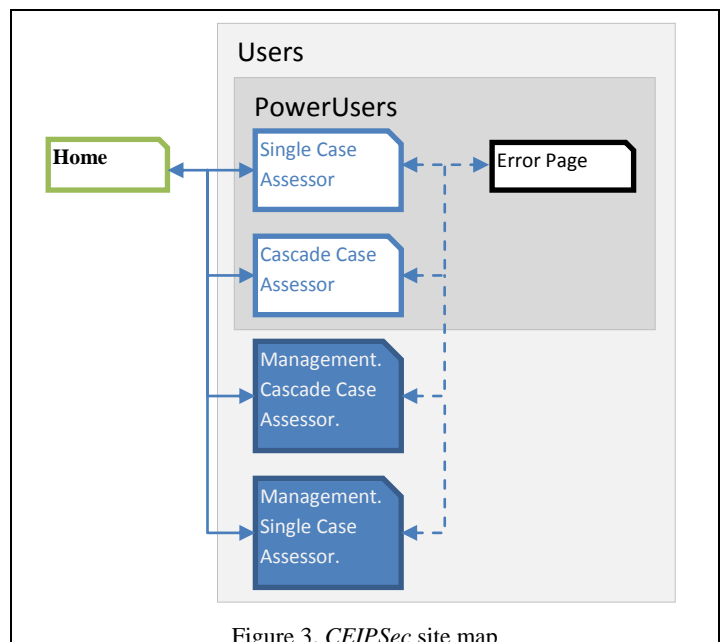
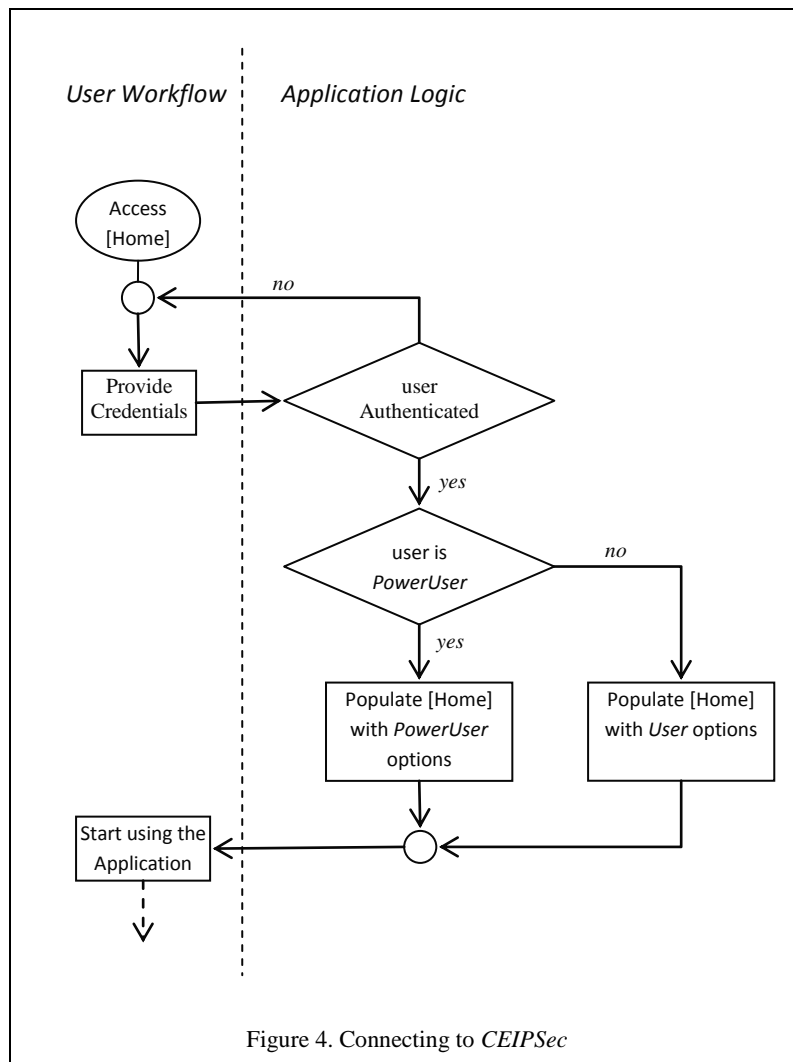


Figure 3. *CEIPSec* site map

Thus, belonging to *Users* grants access only to the visual analysis tools (Single Case Assessor [SCA] and Cascade Case Assessor [CCA]). Belonging to *PowerUsers* implies access granted to all the application tools (i.e. in addition to [SCA] and [CCA] the *user* may also access the management tools – *Management. Single Case Assessor* [MSCA] and *Management. Cascade Case Assessor* [MCCA]).

Navigation through different tools can only be done through [Home].

The *ErrorPage* is used for displaying different error messages that may appear during the usage of the application.



3. *CEIPSec*. Usage Guidance

This section covers the usage aspects of the *CEIPSec* application. For each tool information on the typical workflow, data and results reading, and available capabilities is provided, all supported by application snapshots and use cases.

The first three sections target the *Users*. The following two are mainly oriented towards *PowerUsers*.

3.1. Accessing *CEIPSec*

The requirements for accessing *CEIPSec* are:

- The client computer being in the EC Scientific Network (NET1);

- Internet browser¹⁰ on the client computer.

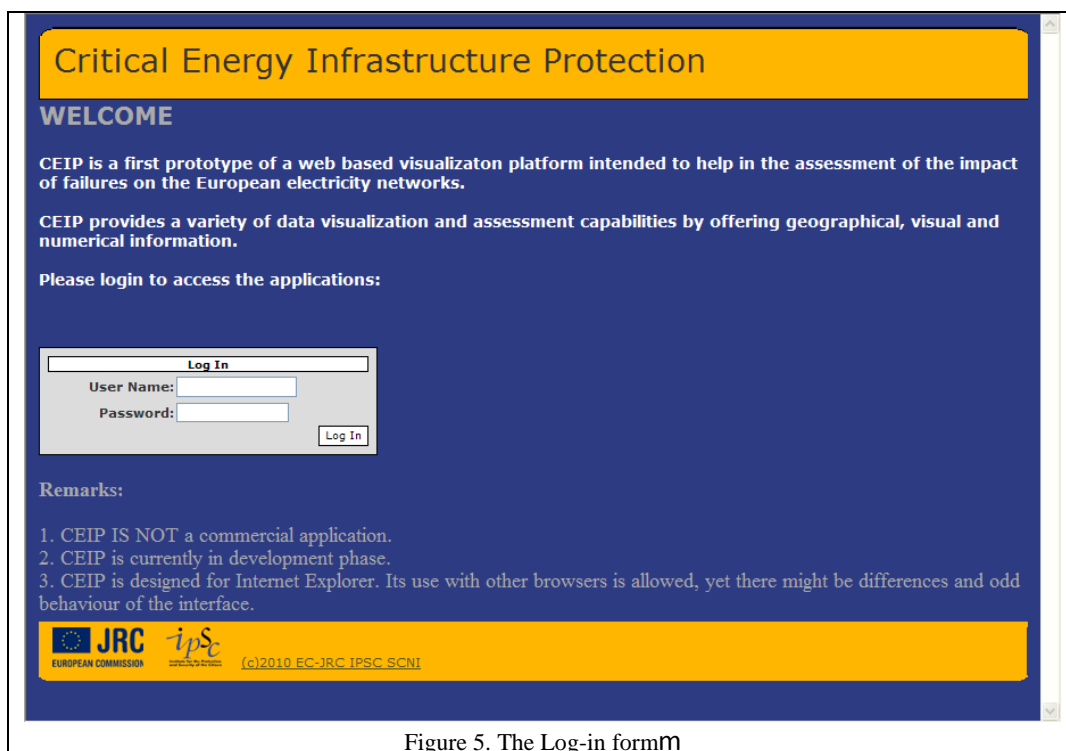


Figure 5. The Log-in form

Currently *CEIPSec* can be found

- Directly at <http://esu.jrc.nl/ceipsec10>; or
- Through the IES Electricity Portal at <http://esu.jrc.nl/>

Once the user is connected the *CEIPSec* [Home] window is displayed (Fig.5). Figure 4 depicts the user workflow together with the application logic. Figure [6(a)(b)(c)] shows [Home] in the *log-in*, *user* and *poweruser* modes respectively.

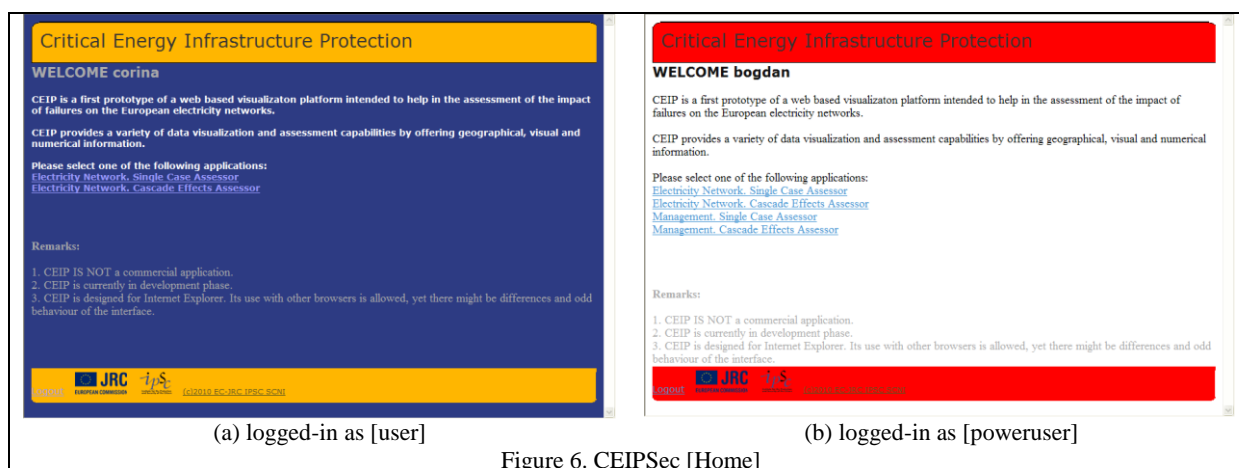


Figure 6. CEIPSec [Home]

The *User* and *PowerUser* mode in Figure 6 are in Blue and Red themes of *CEIPSec*. Moreover, the majority of *CEIPSec* snapshots will be with the application in Red Theme, due to printing considerations.

Once the user is authenticated he may proceed to any of the available tools.

¹⁰ Virtually any Internet browser may be used for accessing the application. However, *CEIPSec* is designed to work with Internet Explorer (later than 7). The use of other browsers is not thoroughly tested and may result in abnormal behavior of the application.

3.2. Electricity Model. Single Case Assessor.

Target: Users and PowerUsers

Role: Electricity Model. Single Case Assessor Tool (SCA) is a tool for visual assessment of the impact on the European electricity transport network of the failure of one or several infrastructure components (substations and/or lines).

Input Data: maps and numerical datasets pre-processed form NEPLAN[®] results file¹¹. Pre-processing the NEPLAN[®] file is done by using CEIPSec Management. Single Case Assessor tool and is a PowerUser responsibility.

Information communication means: geographical (by situational maps), numerical (by numerical tables) and graphical (by charts).

Assessment type: quantitative and qualitative

Communicated results: given in table below:

Result	Geographical	Numerical	Graphical	Quantitative	Qualitative
The impact of failure at the European level	X	X	X	X	X
The affected countries	X	X	X	X	X
The P_{Loss} transfer between the countries	X				X
The failure impact on each country	X	X	X	X	X
Loss propagation (country-to-country)	X				X
Most affected countries	X	X	X	X	X
Impact at country level	X	X	X	X	X

Some of the results in the previous table may be got in different ways. Further details on ‘how to get the results’ will be given in the Tool usage section.

The Interface

The initial view of SCA is given in Figure 7.

The SCA toolbar  holds:

- Open case button (first from left)
- Exit tool button (i.e. Go [Home]) (middle)
- Application theme button (last)

There are four panels available in SCA:

- The *Map* panel – used for visualizing and controlling the situational map.
- The *Charts* panel – holds the bar chart representation of the results.

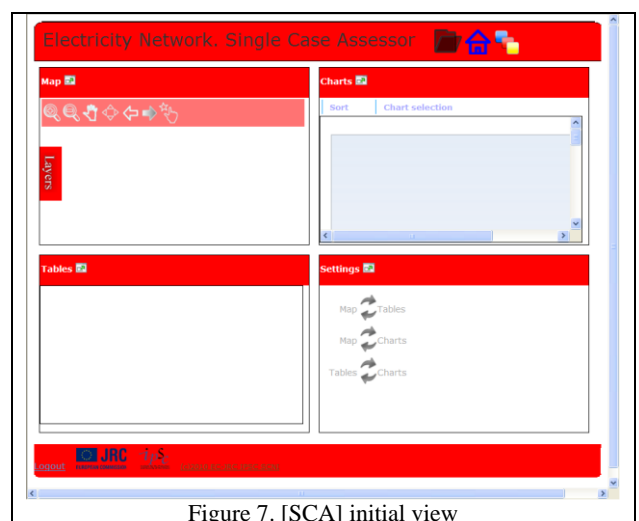


Figure 7. [SCA] initial view

¹¹ The format of the NEPLAN[®] results file must be Microsoft Excel Sheet (xls).

- The *Tables* panel – holds the numerical representation of the results.
- The *Settings* panel – used for user action synchronization settings.

The Workflow

[SCA] works with *cases*. A *case* is a snapshot of the power system after a failure of one or more components. The impact of the failure is given in a *case* by the power load loss (between different countries and at country level). There is no open case when [SCA] is initially accessed. Consistent with the *simplicity* objective, the typical workflow for [SCA] is:

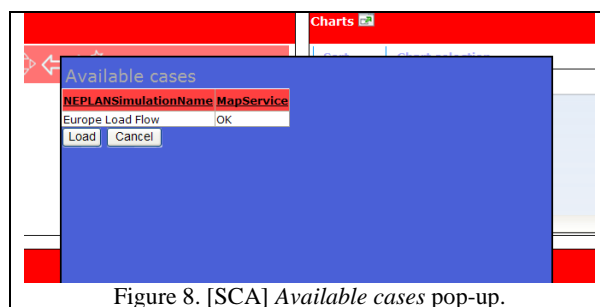


Figure 8. [SCA] Available cases pop-up.

Step1: Navigate to [SCA]

Step2: Open case

- 2.1. Click *Open Case* button in [SCA] toolbar. *Available cases* window (Fig 8) pops up.
- 2.2. Select one of the cases that have OK¹² in the *MapService* column.
- 2.3. Click *Load* button in the *Available cases* window. The [SCA] panels will populate with the case related information (Figure 9).

Step3: Start the assessment by analyzing [SCA] panels.

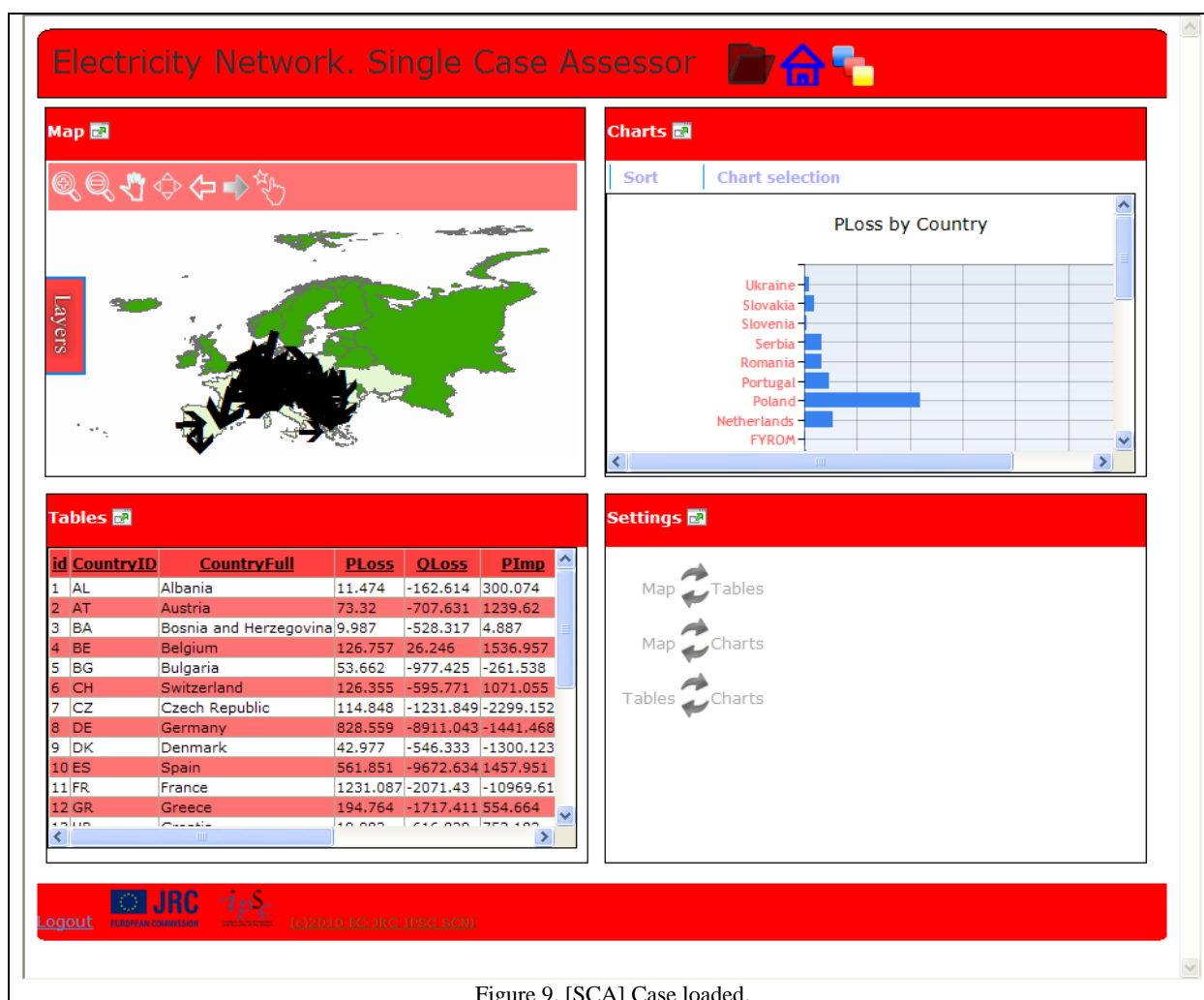
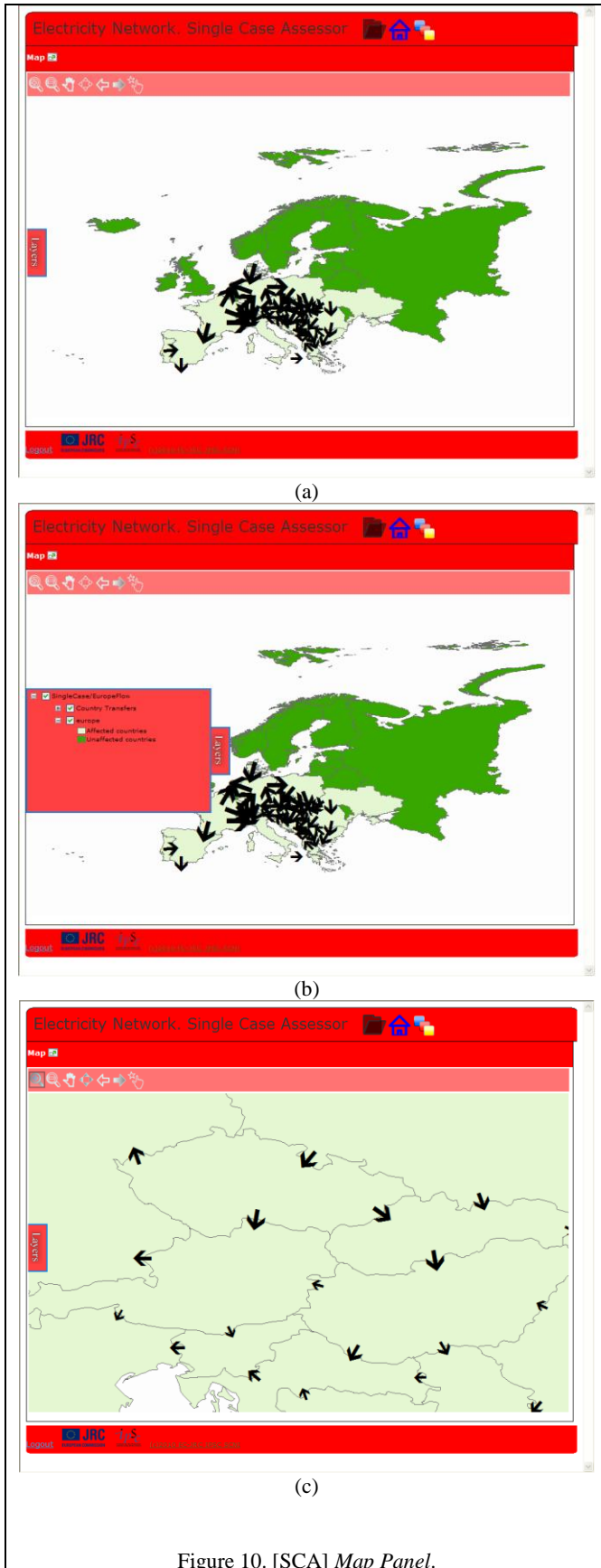


Figure 9. [SCA] Case loaded.

¹² Trying to load a case with [result unprocessed] in the *MapService* column would result in an error. Although an unprocessed result cannot be opened, it is listed in order to inform the analyst that there are cases pending for being processed.



Tool Usage

The Map Panel

The *Map* panel allows a *qualitative* and *partially quantitative* assessment of the failure. This panel holds the situational map. The situational map renders the impact of the failure at European level, described by the P_{Loss} transfer between countries. The map panel provides basic GIS interactivity; the following actions are available through the Map Toolbar:

- Zoom In / Out (click map and zoom or click and drag map to zoom to area)
- Pan (click and drag to move map around)
- Full Extent (zoom the map to accommodate the entire map)
- Map Back / Forward Extent (navigate through different map extents)
- Country Selection Tool (click a country to select it)

Country Selection Tool is a custom tool that allows selecting a country on map. Depending on the User Action Synchronization settings the country selection is reflected in other panels, thus providing the analyst additional information on the selected country.

Reading the map

By looking at the situational map one gets the following information:

- The P_{Loss} transfer between countries;
- The countries affected by the failure.

The P_{Loss} between countries is given by the arrows on the map. The loss *magnitude* is given by the *size* of the arrows. The *direction* of the loss (from country to country) is given by the *direction* of the arrows. The *partially quantitative* characteristic of the information is given by the fact that the size of the arrows is given by the membership of the correspondent P_{Loss} value to one of the pre-defined five intervals. To get the intervals one has to open the *Layers* panel (click on *Layers* in *Map* panel) and expand the *Country Transfers* node.

On the country layer, the countries that are affected by the failure are rendered in *pale green*, while the unaffected countries in *dark green*.

Electricity Network. Single Case Assessor

Tables

ID	CountryID	CountryFull	P _{Loss}	Q _{Loss}	P _{Imp}	Q _{Imp}	P _{Gen}	Q _{Gen}	P _{Load}	Q _{Load}
11	FR	France	1231.087	-2071.43	-10969.613	-926.052	76006.5	12469.791	63005.8	13615.169
7	CZ	Czech Republic	114.848	-1231.849	-2299.132	80.544	7206.8	-278.981	4892.9	1007.413
8	DE	Germany	828.559	-891.043	-1441.468	-183.853	48703.228	5756.497	46433.2	14483.687
9	DK	Denmark	42.977	-546.333	-1300.123	133.508	2724.5	-207.65	1381.4	472.191
20	PL	Poland	439.011	95.578	-801.459	-203.96	15944.1	3451.512	14824.6	3191.974
22	RO	Romania	69.023	-2207.061	-708.077	-8.002	5204.3	32.046	4427.2	2231.184
24	SI	Slovenia	11.115	-185.392	17.115	134.53	905.1	48.277	911.1	368.2
14	HU	Hungary	49.606	-1227.646	-749.006	185.863	1815.3	-293.127	2515.7	1128.373
3	BA	Bosnia and Herzegovina	5.987	-528.317	4.887	-612.63	1004.7	316.056	999.6	231.743
24	SI	Slovenia	11.115	-185.392	17.115	134.53	905.1	48.277	911.1	368.2
13	HR	Croatia	19.082	-616.829	753.182	-201.794	423.4	-203.539	1157.5	211.496
25	SK	Slovakia	40.527	-678.281	329.727	-6.614	1753.9	-383.367	2043.1	288.3
16	MA	Morocco	0.236	-410.768	400.036	-326.668	0	0	399.8	84.1
12	GR	Greece	194.764	-1377.411	554.664	-416.375	7172.5	93.238	7532.4	1394.274
14	HU	Hungary	49.606	-1227.646	-749.006	185.863	1815.3	-293.127	2515.7	1128.373
13	HR	Croatia	19.082	-616.829	753.182	-201.794	423.4	-203.539	1157.5	211.496
8	CH	Switzerland	126.355	-595.771	1071.055	107.007	5001.7	819.422	5946.4	1522.2
8	AT	Austria	73.32	-707.631	1239.62	-465.434	1822.9	140.938	2989.2	383.135
10	ES	Spain	561.851	-9872.634	1487.951	-1758.127	30495.4	-2763.269	31355.5	5151.237
19	NL	Netherlands	111.298	-2563.838	2998.998	896.73	7154.2	455.983	10041.8	3916.551
15	IT	Italy	342.568	-3210.913	7177.768	409.763	22373.5	1769.853	29208.7	5390.538

(a)

Electricity Network. Single Case Assessor

Tables

ID	CountryID	CountryFull	P _{Loss}	Q _{Loss}	P _{Imp}	Q _{Imp}	P _{Gen}	Q _{Gen}	P _{Load}	Q _{Load}
16	MA	Morocco	0.236	-410.768	400.036	-326.668	0	0	399.8	84.1
17	ME	Montenegro	9.975	-150.855	-1.529	92.362	407.4	54.094	396.9	207.1
3	BA	Bosnia and Herzegovina	5.987	-528.317	4.887	-612.63	1004.7	316.056	999.6	231.743
24	SI	Slovenia	11.115	-185.392	17.115	134.53	905.1	48.277	911.1	368.2
13	HR	Croatia	19.082	-616.829	753.182	-201.794	423.4	-203.539	1157.5	211.496
25	SK	Slovakia	40.527	-678.281	329.727	-6.614	1753.9	-383.367	2043.1	288.3
9	DK	Denmark	42.977	-546.333	-1300.123	133.508	2724.5	-207.65	1381.4	472.191
14	HU	Hungary	49.606	-1227.646	-749.006	185.863	1815.3	-293.127	2515.7	1128.373
23	RS	Serbia	68.85	-304.799	418.55	895.351	3590.2	234.607	3939.9	1434.758
22	RO	Romania	69.023	-2207.061	-708.077	-8.002	5204.3	32.046	4427.2	2231.184
2	AT	Austria	73.32	-707.631	1239.62	-465.434	1822.9	140.938	2989.2	383.135
19	NL	Netherlands	111.298	-2563.838	2998.998	896.73	7154.2	455.983	10041.8	3916.551
7	CZ	Czech Republic	114.848	-1231.849	-2299.132	80.544	7206.8	-278.981	4892.9	1007.413
8	CH	Switzerland	126.355	-595.771	1071.055	107.007	5001.7	819.422	5946.4	1522.2
8	BE	Belgium	126.355	-26.346	1596.907	874.936	9877.8	2449.823	13297.8	3090.254
12	GR	Greece	194.764	-1377.411	554.664	-416.375	7172.5	93.238	7532.4	1394.274
15	IT	Italy	342.568	-3210.913	7177.768	409.763	22373.5	1769.853	29208.7	5390.538
20	PL	Poland	439.011	95.578	-801.459	-203.96	15944.1	3451.512	14824.6	3191.974
10	ES	Spain	561.851	-9872.634	1487.951	-1758.127	30495.4	-2763.269	31355.5	5151.237
18	DE	Germany	828.559	-891.043	-1441.468	-183.853	48703.228	5756.497	46433.2	14483.687
11	FR	France	1231.087	-2071.43	-10969.613	-926.052	76006.5	12469.791	63005.8	13615.169

(b)

Electricity Network. Single Case Assessor

Tables

ID	CountryID	CountryFull	P _{Loss}	Q _{Loss}	P _{Imp}	Q _{Imp}	P _{Gen}	Q _{Gen}	P _{Load}	Q _{Load}
1	AL	Albania	11.474	-162.614	300.074	-78.498	365.5	146.053	549.1	232.2
2	AT	Austria	73.32	-707.631	1239.62	-465.434	1822.9	140.938	2989.2	383.135
3	BA	Bosnia and Herzegovina	5.987	-528.317	4.887	-612.63	1004.7	316.056	999.6	231.743
5	BG	Bulgaria	53.662	-977.425	-261.538	-202.322	3460.3	425.218	3145.1	1200.321
6	CH	Switzerland	126.355	-595.771	1071.055	107.007	5001.7	819.422	5946.4	1522.2
7	CZ	Czech Republic	114.848	-1231.849	-2299.132	80.544	7206.8	-278.981	4892.9	1007.413
8	DE	Germany	828.559	-891.043	-1441.468	-183.853	48703.228	5756.497	46433.2	14483.687
9	DK	Denmark	42.977	-546.333	-1300.123	133.508	2724.5	-207.65	1381.4	472.191
11	FR	France	1231.087	-2071.43	-10969.613	-926.052	76006.5	12469.791	63005.8	13615.169
12	GR	Greece	194.764	-1377.411	554.664	-416.375	7172.5	93.238	7532.4	1394.274
13	HR	Croatia	19.082	-616.829	753.182	-201.794	423.4	-203.539	1157.5	211.496
14	HU	Hungary	49.606	-1227.646	-749.006	185.863	1815.3	-293.127	2515.7	1128.373
15	IT	Italy	342.568	-3210.913	7177.768	409.763	22373.5	1769.853	29208.7	5390.538
16	MA	Morocco	0.236	-410.768	400.036	-326.668	0	0	399.8	84.1
17	ME	Montenegro	9.975	-150.855	-1.529	92.362	407.4	54.094	396.9	207.1
18	DE	Germany	828.559	-891.043	-1441.468	-183.853	48703.228	5756.497	46433.2	14483.687
19	NL	Netherlands	111.298	-2563.838	2998.998	896.73	7154.2	455.983	10041.8	3916.551
20	PL	Poland	439.011	95.578	-801.459	-203.96	15944.1	3451.512	14824.6	3191.974
21	PT	Portugal	84.605	-329.778	2609.098	184.869	8794.1	1444.781	6300.5	1530.044
22	RO	Romania	69.023	-2207.061	-708.077	-8.002	5204.3	32.046	4427.2	2231.184
23	RS	Serbia	68.85	-304.799	418.55	895.351	3590.2	234.607	3939.9	1434.758
24	SI	Slovenia	11.115	-185.392	17.115	134.53	905.1	48.277	911.1	368.2
25	SK	Slovakia	40.527	-678.281	329.727	-6.614	1753.9	-383.367	2043.1	288.3
26	UA	Ukraine	18.183	-690.224	-500.097	-369.055	542.3	139.03	624.1	526.2

(c)

Figure 11. [SCA] Tables Panel.

Q & A.

In a question – answer format, the Map panel may be used for:

Q1. Which are the affected countries?

A1. The ones in light-green.

Q2. Which is the impact of the failure at European level?

A2. Given by the ‘spread’ of the light-green countries.

Q3. Which is the P_{Loss} transfer between countries?

A3. Given by the arrows.

Q4. Which is the impact at country level?

A4. Given by the size and number of the incoming arrows.

Q1. How a given country affects its neighbors?

A1. Given by the size and number of the outgoing arrows of the given country.

Q1. How does the failure ‘travels’?

A1. Given by the orientation of the arrows.

The Tables Panel

The Tables panel (Fig. 11) holds the failure impact quantification values¹³ in a tabular format. The information is country specific. The main role of the Tables panel is to provide a quantitative assessment tool.

The table only contains the countries that are affected in the current case. This is per se a way of communicating the failure impact level in terms of number of affected countries. From the user-oriented perspective the Tables panel provides:

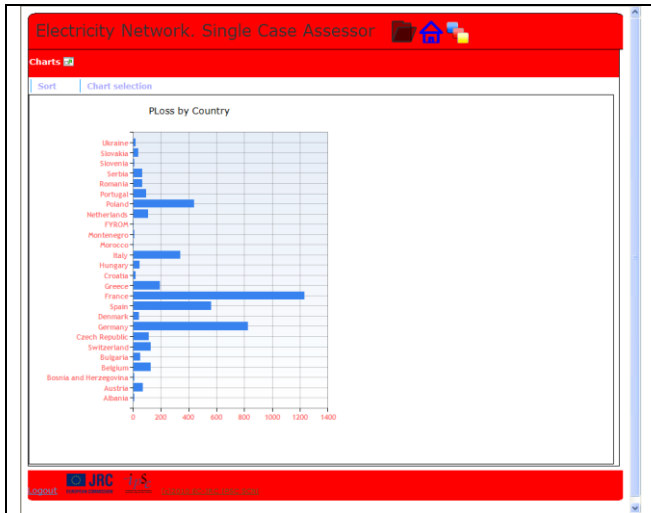
- Record selection – by clicking a row. When used in conjunction with user action synchronization this action is also reflected in other panels.

- Sorting capabilities – the data may be sorted by column. To do this, click on the column header. The sorting order is ascending.

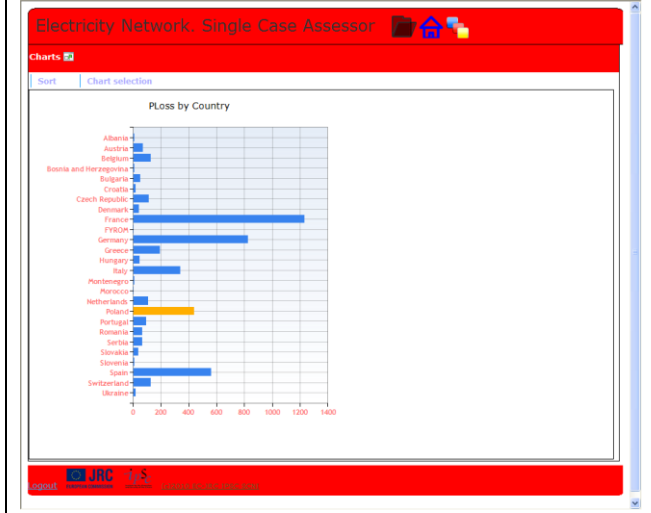
Q & A

The Table panel may be used for answering to:

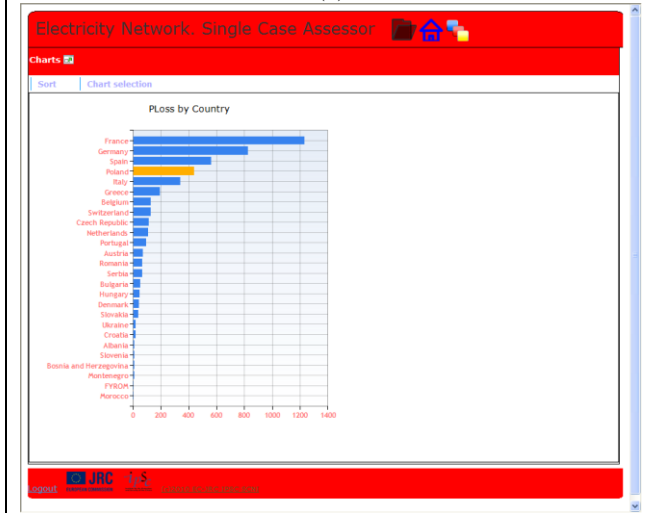
¹³ Impact quantification values: P_{Loss} , Q_{Loss} , P_{Gen} , Q_{Gen} , P_{Imp} , Q_{Imp} , P_{Load} , Q_{Load}



(a)



(b)



(c)

Figure 12. [SCA] The Charts panel.

Q1. Which is the most affected¹⁴ country in terms of [value]?

A1. Sort by [value] and check the last row.

Q2. Which is country X's ranking in terms of [value] loss?

A2. Sort by [value] and check the position of country X.

Q3. Which is the impact at European level (in terms of number of affected countries)?

A3. Check the number of records (or sort by ID and get the ID value of the last row).

Q4. Which is the impact on each country?

A4. Check the figures.

The Chart Panel

The *Charts* panel (Fig. 12) contains the bar chart representation of the data in the *Tables* panel. At a given moment, only one impact quantification value is rendered as a chart. The information is country-specific.

The *Charts* panel may be used in both quantitative and qualitative assessment. The qualitative aspect is intrinsic, being given by the actual image of the chart. The quantitative aspect is conferred by the built-in capability of providing the underlining numerical value when hovering the mouse over a chart bar.

Same as the *Table Panel*'s table, the chart only contains the records corresponding to the affected countries.

The *Charts* panel provides the following display options:

- *Sort*. Sorts the chart. There are two sorting possibilities:
 - *Sort by Country* – sorts the records of the chart in alphabetical order;
 - *Sort by Value* – sorts the records by value in descending order.
- *Chart Selection*. Select the impact quantifier to display the chart for.

Each of the chart bars is 'selectable by click'. Depending on the synchronization settings, selecting a chart bar might be reflected in the other panels.

¹⁴ When using the 'sorting' capabilities one should pay attention to the sign of the value. If the values are both positive and negative, sorting may be seen as more as reordering the data. Thus, in this case, one should check the absolute values of the first and last rows of the table.

Q & A

Examples of what the *Charts Panel* may be used for are:

- Q1. Which is the most affected¹⁵ country in terms of [value]?
A1. Use *Chart Selection* to display the chart for [value].
Use *Sort by value*.
- Q2. Which is country X ranking in terms of [value] loss?
A2. Sort by [value] and check the position of country X.
- Q3. Which is the impact at European level (in terms of number of affected countries)?
A3. Count the number of bars.
- Q4. Which is the impact on each country?
A4. Hover the mouse over the bar correspondent to the desired country.
- Q5. How is country X affected compared with country Y?
A5. Check the relationship between the bar lengths of the corresponding countries.

The Settings Panel

The *Settings Panel* (Fig. 13) holds the user actions synchronization settings. The synchronization is set by pairing up the available panels. To synchronize the Panel A with Panel B click the arrow A->B. The arrows have two states: On / Off. An On arrow between A and B means that A and B panels are synchronized.

For a synchronization setting as in Figure 13 one gets:

- Selecting a country on map (using *Country selection tool*) results in the selection of the row in the *Table panel* corresponding to the selected country.
- Selecting a bar in the chart (by mouse click) results in:
 - The selection of the correspondent country on map. An automatic pan and zoom is also performed on the map to bring the selected country in the middle of the map.
 - The country correspondent row is selected in the Tables.
- Selecting a row in the Tables panel results in:
 - The selection of the correspondent chart bar (due to the Tables->Chart direct link);
 - The selection of the country on map (cascade selection due to the Charts->Map setting).
- Synchronization of actions permits the application to behave accordingly to the user preferences. One possible benefit of user actions synchronization may be found in the sequel.

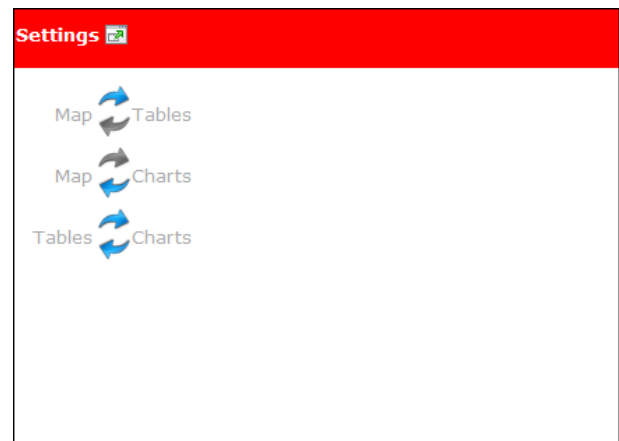


Figure 13. [SCA] Settings panel

Use Case Example

The following is an example of how *Single Case Assessor* may come into supporting the assessment of a failure in the Power Transmission System. The results are purely fictions.

¹⁵ The sign of the value should also be taken into account



Figure 14. [SCA] Use case

Suppose the analyst focus is on the situational map. From the map his attention is drawn by the number of arrows of ‘significant’ size coming and going from Germany. Which are the actual values of the impact quantification values in case of Germany? Where Germany ranks among the affected countries? To answer to this the analyst may follow the steps:

- Step 1: set user action synchronization as in Fig. 14 (b).
- Step 2: activate *Country Selection Tool* in the *Map Panel*.
- Step 3: click Germany on map.

Step 4: select *Sort Chart by Value* in the *Charts Panel*. After Step 3 the user would have selected Germany on map, the correspondent row in table and the correspondent bar in chart. The numerical values are given in the selected row. The Germany rank is obtained from looking at the chart (after Step 4).

3.3. Electricity Model. Cascade Case Assessor.

Target: *Users and PowerUsers*

Role: *Electricity Model. Cascade Case Assessor (CCA)* is a tool for supporting the visual assessment of cascade effect scenarios (an initial failure of one or several infrastructure components, i.e. substations and/or lines has onto the European Power Transport System). The assessment is done on a step-by-step basis.

Input Data: CCA consumes cascade-effects maps¹⁶ provided through ArcGIS Map Services. The cascade-effects maps are ArcGIS map documents having a pre-defined structure of the data; the cascade-effects maps are understood and processed by the CCA.

A cascade-effect map is basically a map having a set of base layers (e.g. country borders) and a set of *active layers* corresponding to each step of the cascade effect. Creating the cascade-effect maps and map services is a separate process from *CEIPSec* and should be done manually, according to given specifications. The management of the cascade effects cases (i.e. connecting the previously created map services to *CEIPSec*) is done by using *CEIPSec Management. Cascade Effects Assessor* tool and is a *PowerUser* responsibility.

Information communication means: geographical (by Maps), numerical and graphical (by charts).

Assessment type: quantitative and qualitative

Communicated results: given in table below.

Result	Geographical	Numerical	Graphical	Quantitative	Qualitative
The impact of failure at the European level	x	x	x	x	x
The system components (lines and power substations) affected in the current step	x	x	x	x	x
The system components already disabled (already affected in previous steps)	x		x	x	x
The failure ‘spreading’ throughout the system	x		x	x	x
The share of substations affected in the current and previous steps	x				x
The share of transmission lines in the current and previous steps	x	x	x	x	x
The share of each class¹⁷ of substations affected in the current step	x	x	x	x	x
The share of each class¹⁸ of transmission lines affected in the current step	x	x	x	x	x
The ‘worst’ step (in terms of number of components affected)	x	x	x	x	x

The Interface

The initial view of CCA is given in Figure 15.

The CCA toolbar  holds:

- Open case button (first from left)
- Exit tool button (i.e. Go [Home]) (middle)
- Application theme button (last)

¹⁶ The cascade-effect ArcGIS maps have been developed by IES-ESU.

¹⁷ There are three classes of substations taken into account: 400kV, 225kV and 150kV.

¹⁸ There are three classes of transmission lines considered: 380kV - 499kV, 220kV-299kV and *Other*.

There are two panels available in CCA:

- The *Map* panel – used for visualizing and controlling the situational map. The *Map* panel also holds the *Case Navigator Control* and the *Cascade Case Chart* control.
- The *Case report* panel – holds the cascade case report.

The Workflow

[CCA] works with *cases*. There is no open case when [SCA] is initially accessed. The typical workflow for [CCA] is:

Step1: Navigate to [CCA]

Step2: Open case

- 2.1. Click *Open Case* button in [CCA] toolbar. *Available cases* window (Fig 16) pops up.
- 2.2. Select one of the cases.
- 2.3. Click *Load* button in the *Available cases* window. The [CCA] panels will populate with the case related information (Figure 17).

Step3: Start the cascade-effects assessment.

Tool Usage

Once a case is loaded the user has access to:

- The situational map – renders the case information on map;
- The *Cascade Case Navigator* – allows the navigation between the cascade effect steps;
- The *Cascade Case Chart* – renders the current case and step information in graphical form;
- The *Cascade Case Report* – a report compiled on the fly from the information provided by the map server.

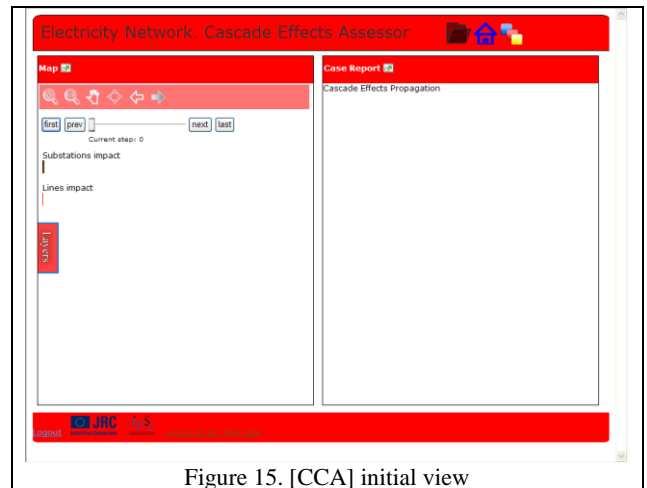


Figure 15. [CCA] initial view

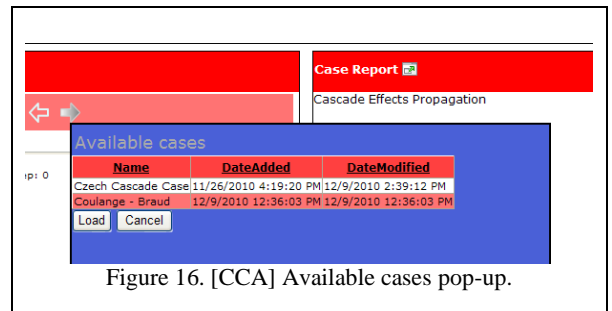


Figure 16. [CCA] Available cases pop-up.

The Map Panel

The *Map* panel allows a *qualitative* assessment of the failure at each step of the cascade effect. This panel holds the situational map (i.e. cascade-effect map), the *Case Navigator* and the *Cascade Case Chart*.

Basic GIS interactivity is provided; the following actions are available through the Map Toolbar:

- Zoom In / Out (click map and zoom or click and drag map to zoom to area)
- Pan (click and drag to move map around)
- Full Extent (zoom the map to accommodate the entire map)
- Map Back / Forward Extent (navigate through different map extents)

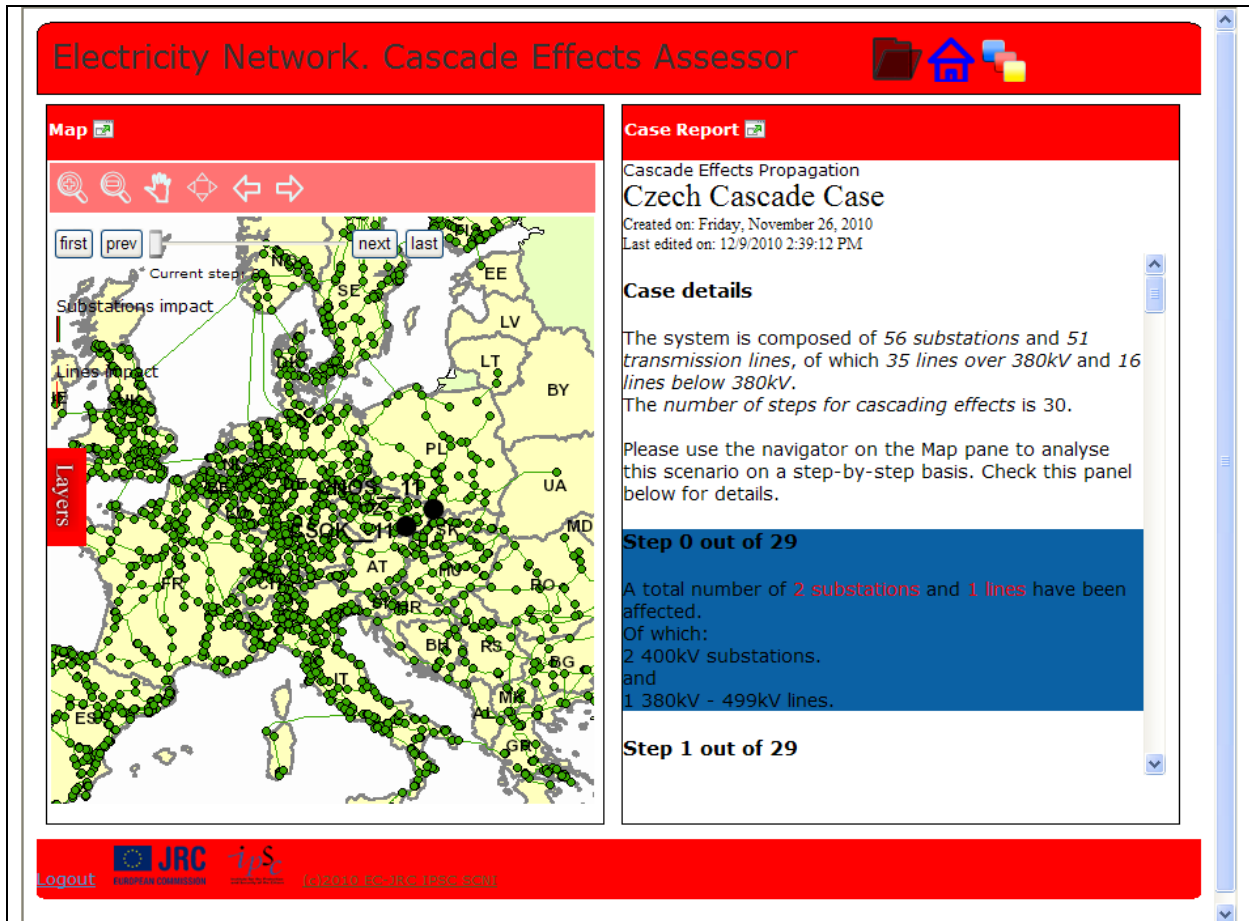


Figure 17. [CCA] Case loaded.

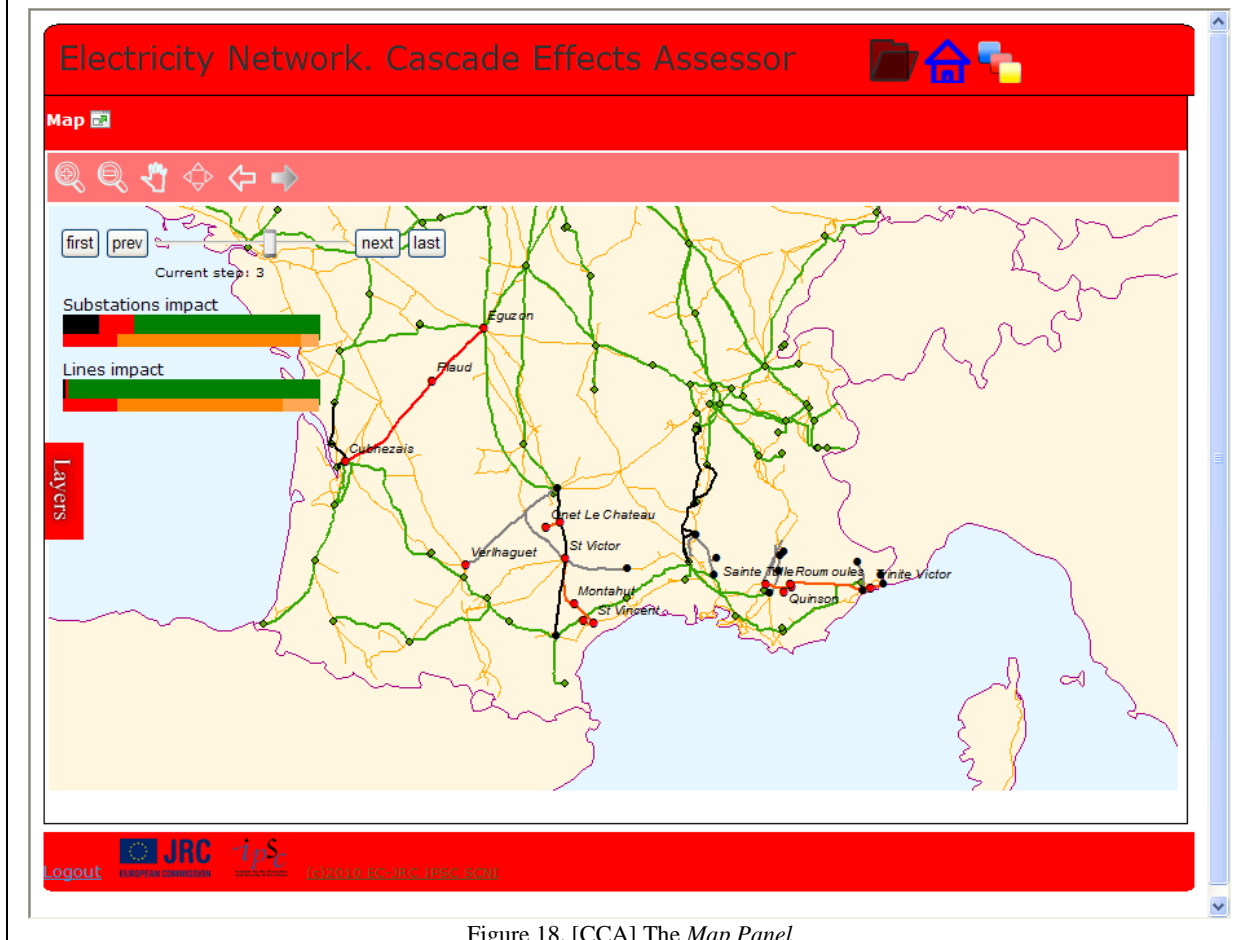


Figure 18. [CCA] The Map Panel

Reading the Map

A typical cascade case map is given in Fig. 18; the map has as *base layers* the country borders and as *active layers* the substations and the power lines layers.

Each of the system components may be in three states: *unaffected*, *affected in the current step* and *affected in previous steps*. The color coding the component states is *green*, *red* and *black* respectively. Different shades of red and black (grey) may be encountered to differentiate between the components sub-classes.

The cascade Case Navigator

The navigation through the cascade effect steps can be done in two ways: by using the *Cascade Case Navigator* (Fig. 19) or through the *Case Report* (explained later).

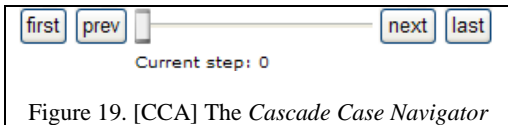


Figure 19. [CCA] The Cascade Case Navigator step.

Using the *Navigator* is self-explanatory. The user may go step-by-step by using the <prev><next> buttons, get to the initial or last step by using the <first><last> buttons or going to a particular step by dragging the slider and checking the information given by Current step.

The Cascade Case Chart

The *Cascade Case Chart* is a qualitative assessment helper that provides information on the share of the affected components at the current and previous steps. When used in conjunction with the *Cascade Case Report* the *Cascade Case Chart* also qualifies as a quantitative information locator.

The chart contains two sub-charts characterizing the impact at the substation and lines respectively. Each of the sub-charts is composed of the *main chart* (thicker chart) and *details chart* (thin chart). Since the interpretation of the charts is identical in the substations and lines cases, we describe the use of the charts taking as example the Substations impact.

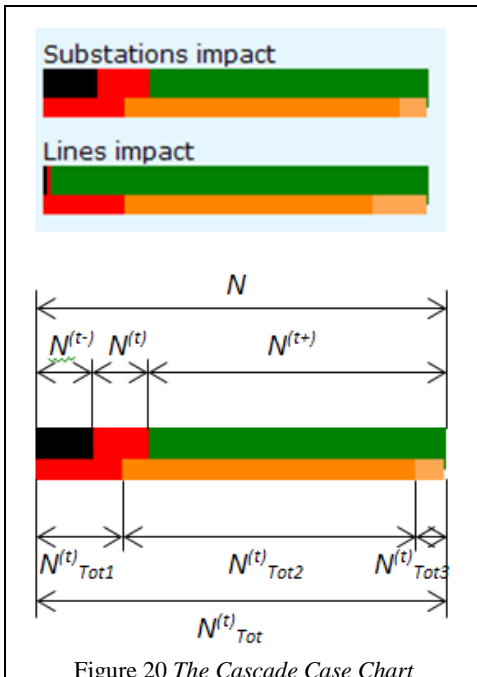


Figure 20 The Cascade Case Chart

Let denote (Fig. 20):

N - the total number of substations defining the system;

$N^{(t)}$ - the number of substations affected at step t ;

$N^{(t-)}$ - the number of substations already affected in the previous steps

$$N^{(t-)} = \sum_{i=0}^{t-1} N^{(i)}, t > 0$$

$N^{(t+)}$ - the number of unaffected substations

$$N^{(t+)} = N - (N^{(t-)} + N^{(t)})$$

The *black*, *red* and *green* segments length corresponds to the $N^{(t-)}, N^{(t)}, N^{(t+)}$ values, given the total length of the main chart corresponding to N .

The *details chart* renders the shares of each of the component classes in the total number of the system components affected in the current step. The *details chart* should be read as: 'from the substations affected in step t the most numerous are the 225kV, followed by 400kV and 150kV'. The relationship between the numbers of substations in each class is given by the length of each of the segments. The actual number of the substations may be found in the *Case Report* (details in Action Synchronization section).

The Cascade Case Report Panel

A report characterizing the scenario is generated on the fly by *CEIPSec* while opening a case. The report contains a basic description of the system and statistics on each of the cascade effects case. The statistics of each step are presented in a *step cartouche*. The report is accommodated in the *Cascade Case Report Panel* (Fig. 21).

The report is presented in a narrative form, thus facilitating readability.

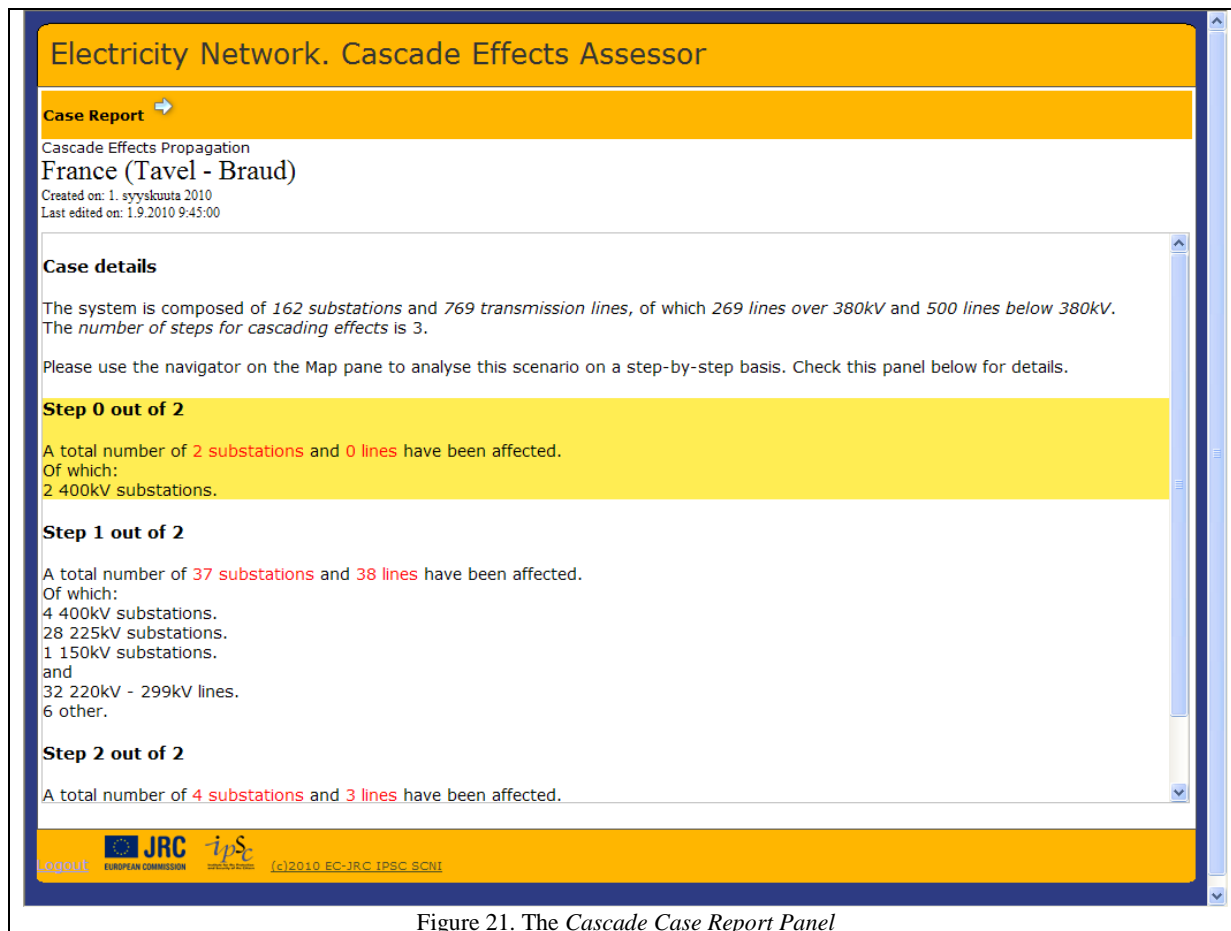


Figure 21. The *Cascade Case Report Panel*

The Case details section offers system related information (the *number of substations and transmission lines* of the system). A *step cartouche* has the format:

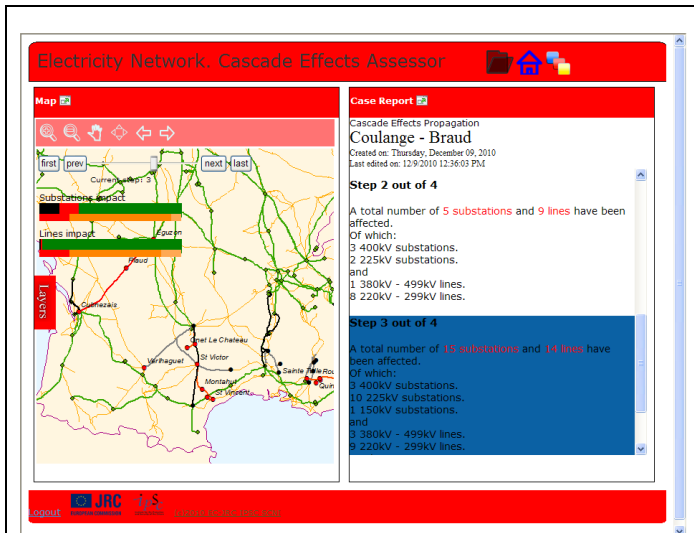
Step 1 out of 3

A total number of X substations and Y lines have been affected.
 Of which:
 X1 400kV substations
 X2 225kV substations.
 X3 150kV substations.
 and
 Y1 380kV - 499kV lines.
 Y2 220kV - 299kV lines.
 Y3 other.

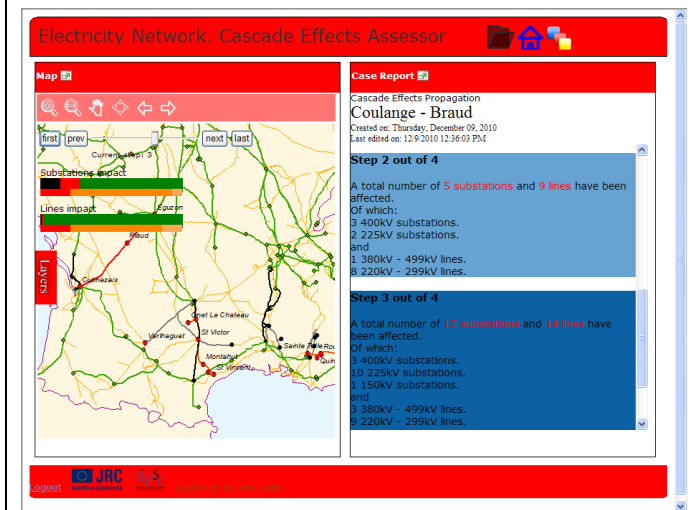
The *Cascade Case Report* is interactive. The user may interact with the report by:

- Placing the mouse over a *step cartouche*, case in which the paragraph gets highlighted (Fig.22(b))
- Clicking on a *step cartouche* which leads to setting the current step the one addressed by the cartouche.

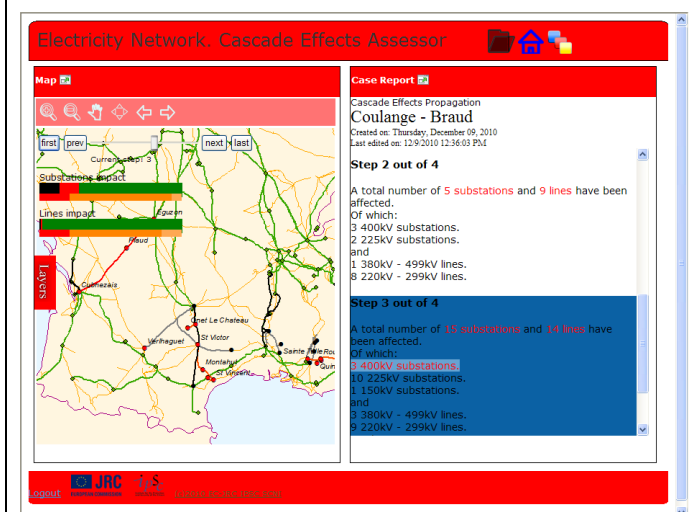
The last point indicates that navigation through the cascade case steps may be performed (in addition to using the *Navigation Control*) by using the *Case Report*.



(a)



(b)



(c)

Figure 22. [CCA] Tool snapshots.

The cartouche corresponding to the current step is in a *selected* state (i.e. has a particular background colour, depending on the application theme). This facilitates finding the current step information when scrolling the report in the case of scenarios with a large number of steps.

Action Synchronization

The information in *Map* and *Case Report* panels is synchronized. The following user actions are available:

- User selects a step in the *Report Panel*. This results in a correspondent map and charts refresh in the *Map* panel.
- User selects a step using *Case Navigator*. This results in selecting the correspondent step cartouche in the *Case Report Panel*.
- User hovers (places the mouse) the current step segment (red) of Substations or Lines charts. This results in highlighting the current step cartouche in the *Case Report*.
- User hovers the *details chart* segments. This results in highlighting the correspondent numerical information in the *Case Report* (Fig. 22(c)).

Q & A

The following are some of the answers the analyst may get by using the *Cascade Case Assessor* tool:

Q1. Which are the system's components affected in a given step?

A1. Look at the *red* components on the map; or
Read the step cartouche in the case report.

Q2. Which are the system's components already affected?

A2. Look at the *black* components on the map; or

Check the step cartouches preceding the selected one in the case report.

Q3. Which is the failure 'spread'?

A3. Look at the 'non-green' spatial distribution on map; or

Q4. Which is the overall impact?

A4. Look at the relationship between the 'non-green' and 'green' system components on map; or

Compare the combined length (black and red) of the affected components segment with the one of the unaffected (green) segment or with the total length of the chart.

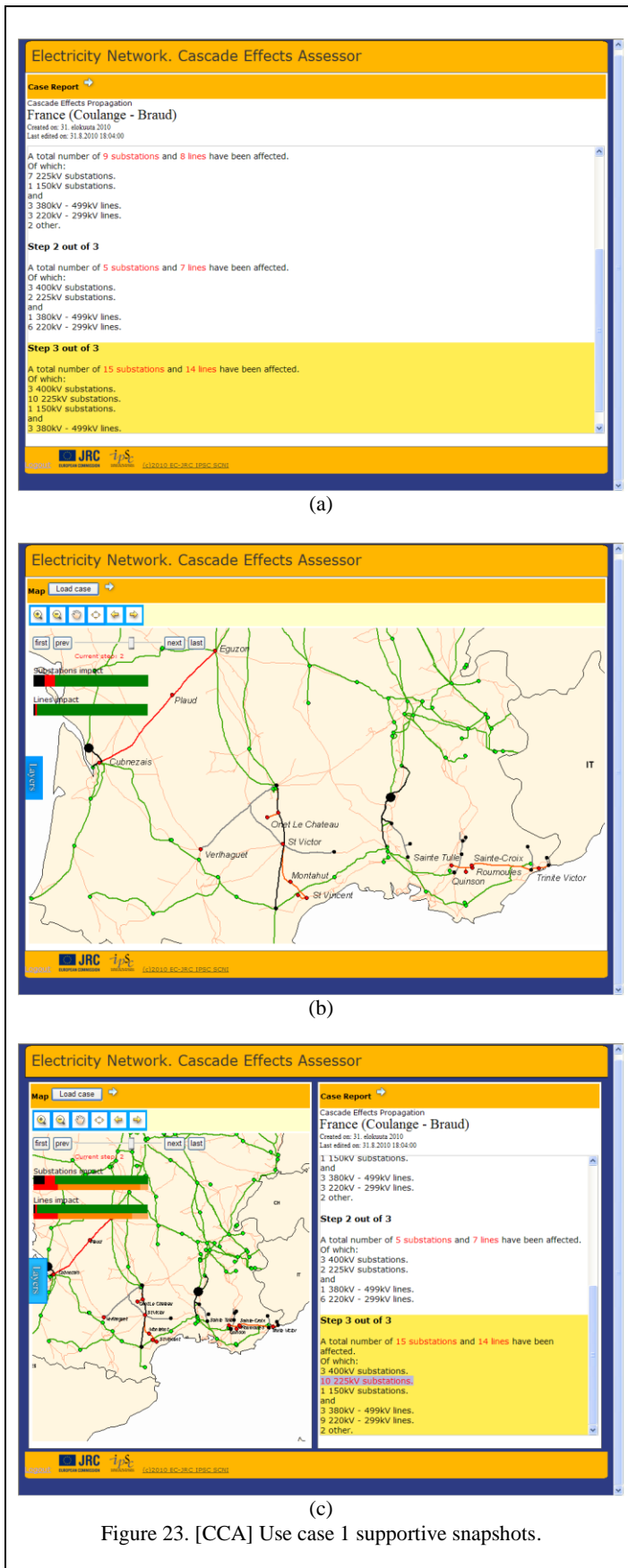


Figure 23. [CCA] Use case 1 supportive snapshots.

Q5. Which is the 'worst step' in terms of number of simultaneously affected components?

A5. Shuffle through the steps. Focus on the case charts and go step by step using the *Case Navigator*. A 'jump' in the size of the red segment indicates a 'bad' case; correlate the case with the numerical information in the *Case Report*; or Check the numerical information (number of affected substations or number of affected lines) in the *Case Report*.

Use Case Examples

The following are two examples of how *Cascade Case Assessor* may come into supporting the assessment of cascading failures in the Power Transmission System.

Use Case 1

The analyst observes from the *Case Report* that the biggest number of affected substations is in Step 3. How does the situational map look like in this case? Which are the affected substations? To get this information the analyst may follow the steps:

- Step 1: Click the Step 3 cartouche in the *Case Report* (Fig. 23(a)).
- Step 2: Minimize *Case Report Panel*.
- Step 3: Maximize the *Map Panel* for better view of the map (Fig. 23(b)).

The map corresponds to the situational map in Step 3. The system's components (substations and lines) affected in the current step are the ones in red. From here, the analyst may want to get an image of 'how much' is the overall system affected in step 3. And, in addition, how many 400kV, 250kV and 150kV are affected?

The answer to the first question is obtained from the *Substations* chart, by looking at the red segment. The number of substations by class is given:

- In a qualitative manner by looking at the *Substations Details Chart*; and
- In a quantitative manner by hovering each of the *Substations Details Chart* and looking for the highlighted information in the *Case Report*. (Fig.23(c)).

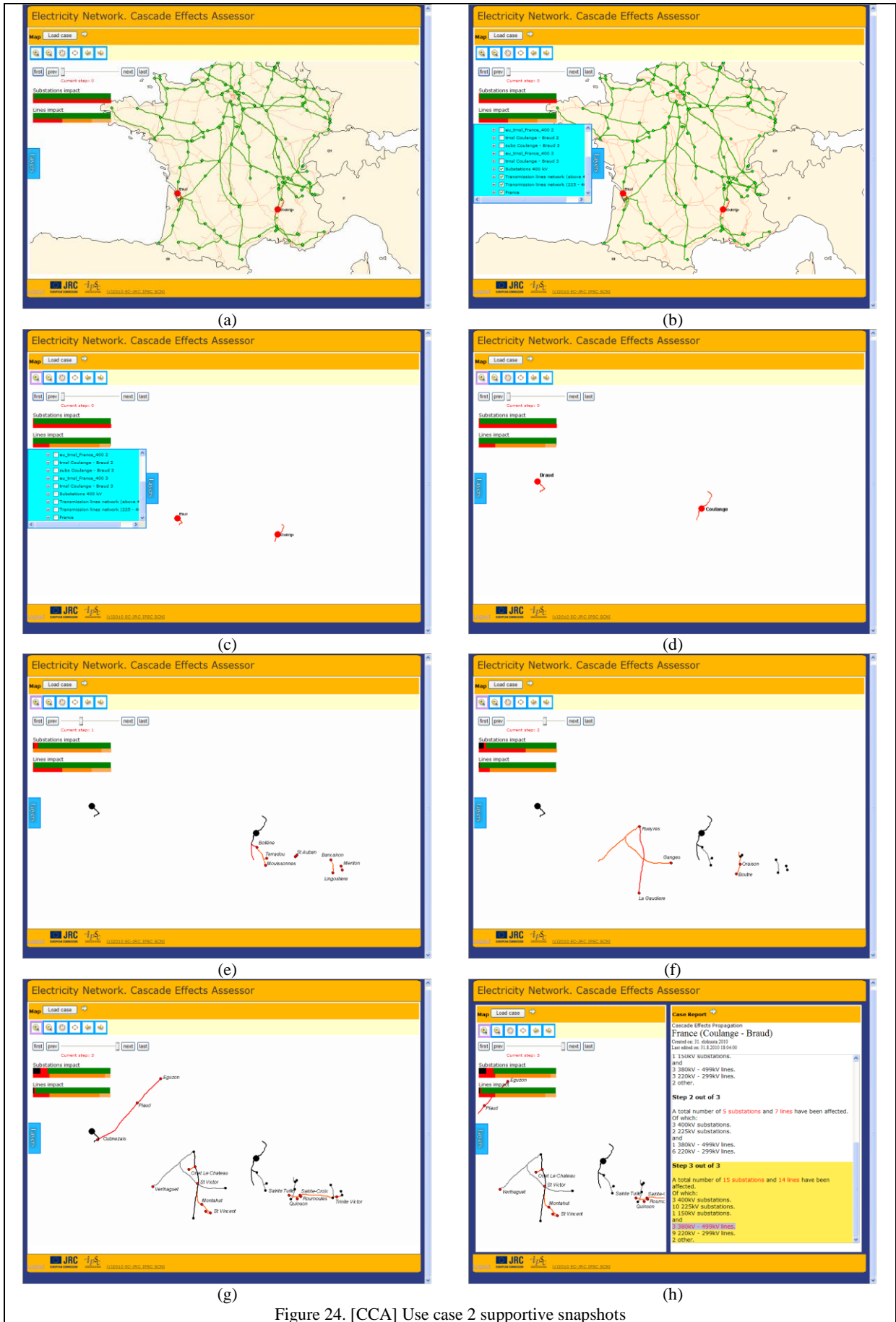


Figure 24. [CCA] Use case 2 supportive snapshots

Use Case 2. Failure spreading pattern

In the following case the analyst is focused on the spreading pattern of the failure (i.e. how the system becomes unavailable).

In this particular case the relevant information on map is only the previously and currently affected components. The failure evolution is obtained by going step-by-step using the *Navigation Control* and observing the growth of the failure on maps.

An example is given in Figure 24 for a simple, four steps case.

The following steps should be followed:

Step 1: Maximize the *Map Panel* (Fig. 24(a)).

Step 2: Display only the relevant (active) layers, by:

(i) click Layers

(ii) turn off the base layers (all the layers that are not ending with numbers);
the map looks like in Fig. 24(c)

Step 3: Go step-by-step using the *Navigation Control* and observe the map.

3.4. Management. Single Case Assessor.

Target: *PowerUsers*

Role: *Management. Single Case Assessor* (MSCA) is the tool for the management of *Single Case Assessor* working cases. The following is a description of the tool and its capabilities. It is assumed that the reader has prior knowledge of the application architecture and functionality.

Using MSCA

The following operations are facilitated through MSCA:


- Add new case, which entails
 - Uploading NEPLAN[®] results files (xls format);
 - Process uploaded NEPLAN[®] files;
- Edit existing case
- Delete case.

Details are given in the sequel.

Add new SCA working case

Adding a new case is a two steps procedure. First, a *source* NEPLAN[®] result file should be uploaded to the *CEIPSec* server. Second, the uploaded NEPLAN[®] file should be processed (the procedure is automatically done by *CEIPSec*, based on minimum user inputs). The new case is then ready for being used in SCA. In short, processing the source file implies building the situational map, the additional data sets and the ArcGIS Map Service, followed by updating the SCA cases database.

To upload a new case, follow the procedure:

Step1: Click the <Upload new NEPLAN file> button (). MSCA will look like Fig.25(a)

Step2: Click <Browse> and select the NEPLAN[®] source file. *CEIPSec* will perform a conformity check¹⁹ of the file to be uploaded.

¹⁹ Only the format of the file will be checked (MS EXCEL xls format).


Step3: Provide a name for the new SCA case. The name should be unique.

Step4: Click <Upload>

Once the new case is defined it is added to the Available Cases list and marked as [not processed] (Fig. 25(b)).

To process the case follow the procedure:

Step1: Select the record corresponding to the new added case in the Available Cases list.

Step2: Click <Process> button ().

Step3: Provide a name for the ESRI Map Service. The name should be unique. The name MUST NOT CONTAIN SPACES!

Step4: Click <OK>

The new case is now ready to be used with SCA (Fig.25(e)).

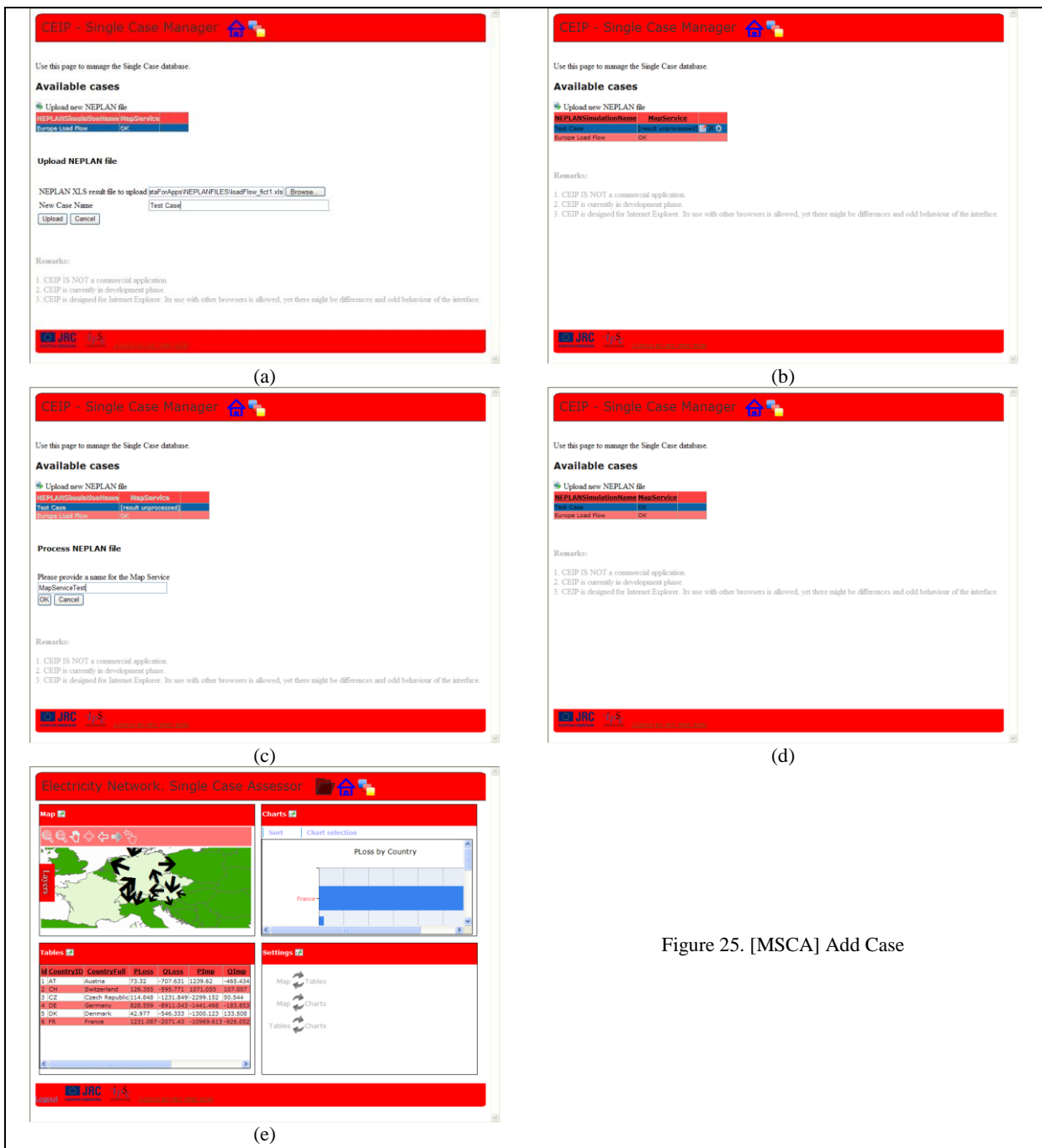



Figure 25. [MSCA] Add Case

Edit case

Editing a case allows modifying the case *Simulation name* and / or *Map service*. Note that changing the map service **does not** create a new map service on the GIS server. This option should be used for updating the SCA map service in the case of modification of the map service name / location **on the GIS server**.

To enter the *Edit* mode:

- Step1: Select the SCA case in the Available Cases list.
- Step2: Click <Edit> ()


MSCA interface in *Edit* mode is given in Fig. 26(a).

Delete case

Used for removing a SCA case. The following options are available:

- *Delete map service* – removes the SCA case map service from the GIS server.
- *Delete map project* – removes the SCA map project (*mx*d and shape files) from *CEIPServer*.
- *Delete NEPLAN source* – removes the SCA case NEPLAN[®] source file.
- *Delete case files* – removes the SCA case additional data sets.

To delete a SCA case:

- Step1: Select the SCA case in the Available Cases list.
- Step2: Click <Remove case> ()

MSCA interface in *Delete* mode is given in Fig.26(b).

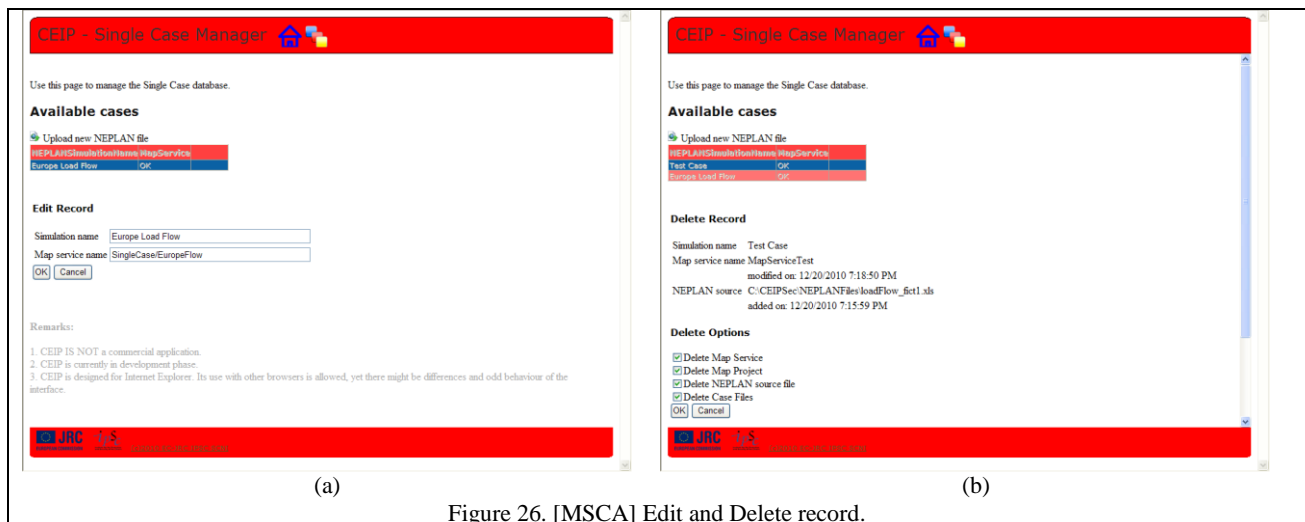


Figure 26. [MSCA] Edit and Delete record.

3.5. Management. Cascade Case Assessor.

Target: *PowerUsers*

Role: *Management. Cascade Case Assessor* (MCCA) is the tool for the management of *Cascade Case Assessor* working cases. The following is a description of the tool and its capabilities. Same as in the previous section case, prior knowledge of the application architecture and functionality is required.

Using MCCA

The following operations are facilitated through MCCA:

- Add new case
- Edit existing case
- Delete case.

Each will be detailed in the sequel.

Add new CCA working case

MCCA provides the interface for facilitating the construction of the Cascade Effects Case setting file (Fig. [X](a)). The following information should be provided:

- The CCA ArcGIS Map Service Name;
- The CCA case name;
- Layer group name – the information is obsolete and is kept for compatibility with previous versions of *CEIPSec*.
- Base Substations Layer – the name of the map layer holding the *system substations*. The substations information in the *Cascade Case Report* is compiled from this layer. The Substations Layer may be of any kind (i.e. not necessarily an *active layer*). However, the Substation Layer must contain the substations information required by the application (i.e. CATEGORY);
- Base Lines Layer – the name of the map layer holding the *system transmission lines*. The same remarks are valid for the lines layer.
- Active Layers – the list of layers holding the step-by-step simulation results. The name of the layers should be given as the root (common part) of the active layers;
- Line info active layer – the active layer used for statistics on the transmission lines;
- Info field name – the name of the data field of the active layers holding the step information;
- Number of cascading effect steps.

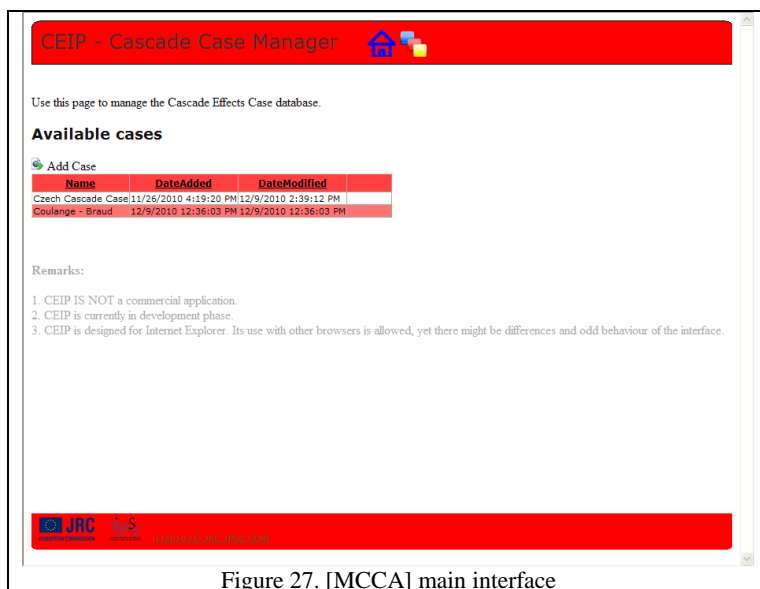


Figure 27. [MCCA] main interface

Several features have been developed to ease the construction of a new CCA case. Thus, the Map Service combo is automatically populated with the map services found on the *CEIPSec* ArcGIS Server (Fig.29(b)). For setting-up the different layers one may use the *Layers* window. The *Layers* window (Fig. 28) lists all the layers of a given map service and also provides a way of automatically fill-in the layer names in the desired destination.

To display the *Layers* window click the <Layers> button ().

Setting the base layers can be done either by directly typing-in the name of the layers or by using the *Layers* window.

To add an active layer one should follow the procedure:

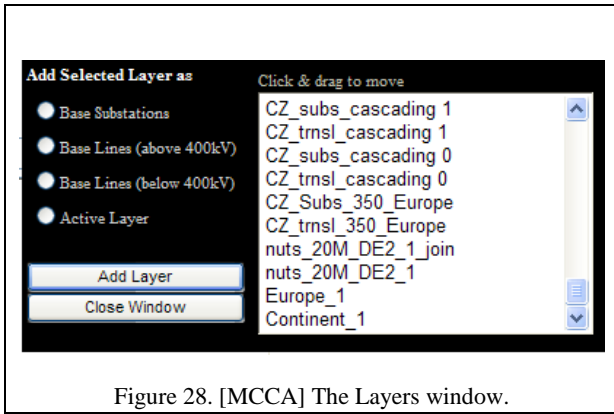


Figure 28. [MCCA] The Layers window.

Step1: Fill-in the Active layers Textbox with the root name of the active layer either by typing-in or using the *Layers* window.

NOTE: if using the *Layers* window one should make sure that the ending step number in the name of the active layer is removed.

Step2: Click <Add>. The layer is added in the Active Layers list.

The set an active layer as *Line info active layer*:

Step1: Select the layer in the Active Layers List.

Step2: Click <Set as Lineinfo>.

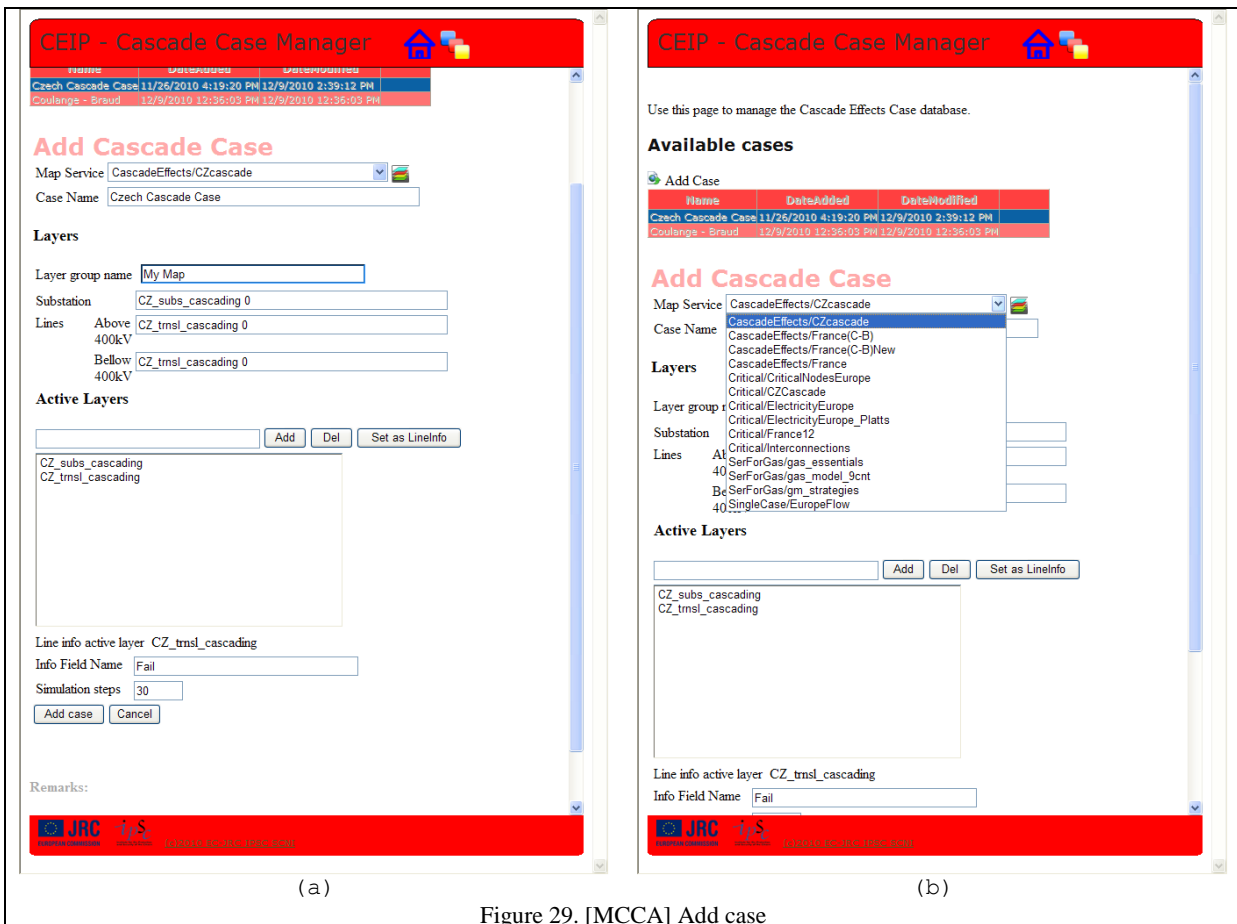



Figure 29. [MCCA] Add case

Edit CCA Case

Editing a CCA case allows modifying *all* the information on the particular case *but* the GIS map service.

To enter the *Edit* mode:

Step1: Select the CCA case in the Available Cases list.

Step2: Click <Edit> ()

Delete CCA Case

To delete a CCA case:

Step1: Select the CCA case in the Available Cases list.

Step2: Click <Remove case> (X)

Deleting a CCA case results only in removing the Cascade Case definition file from the *CEIPSec* server and the case record in the cases database. The map service remains on the server.

4. Concluding Remarks and Future Developments

This document may be used as guidance for working with *CEIPSec*. It is mostly oriented towards users, details on internal architecture and implementation details of *CEIPSec* being intentionally left outside its scope. More technical information would be provided in a subsequent document.

CEIPSec is a research-grade, proof of concept product. The application has not been subject to systematic debugging / testing procedures. Therefore, there are some 'known issues' ('strange' behaviour) coming either from browser(s) characteristics or from the difference between development and production systems. A list of some of the known issues is given in the sequel.

Odd appearance of the panels

Location: all the modules.

Occurrence: not systematic. This occurs with higher frequency when the application is first accessed.

Potential source: browser-related.

Workaround: re-dimensioning the browser window (maximize then restore) solves the panel layout problem.

Resource initialization failure

Location: *Cascade Effects Assessor*.

Occurrence: when first loading a *Cascade Effects Case*.

Potential source: differences between the ArcGIS versions (9.3 vs. 10) between development and production servers.

Workaround: the failure is reported in the *CEIPSec* error page. When this occurs, the user should:

- Go Back to the CCA by using the *Back button in the error page* (and NOT the browser's Back button);
- Open the same Cascade Case again.

As a final, general rule, whenever the application goes in an error state (i.e. *CEIPSec Error Page* is displayed) ALWAYS use the Back button in the error page.

CEIPSec is a proof of concept. Possible improvements / future developments address several facets of the assessment framework, as listed below:

- A. Augmenting the simulation models set (i.e. addressing other infrastructures that can be molded onto the *CEIPSec*'s assessment framework). This mainly entails (i) the development of translation modules, with the role of generating *CEIPSec* specific data from the results of the sector-specific simulators and (ii) plugging-in the new modules into the existing *CEIPSec* application.

Possible candidates are:

- a. The European Gas System – the most at hand, since impact studies on the gas system have also been subject of this Administrative Arrangement, being addressed by ESU Petten;

- b. The transportation system (road / rail);
 - c. The ICT system – a more problematic business due to the lack or scarcity of *data* and ICT security and impact assessment *methodology* and *tools*.
- B. On the Application
- a. A thoroughly testing / debugging in order to provide a more stable, mature application.
 - b. Better security in terms of information transmission over the network, mainly entailing the encryption of data between client and server (in the current version the data is passed in ‘clear-format’ which makes *CEIPSec* vulnerable for e.g. ‘man-in-the-middle’ attacks).
 - c. Implementation of *comparative assessment* capabilities. As in the current format *CEIPSec* only delivers one scenario for assessment. The capability of having several scenarios opened simultaneously and also compared with each other should definitely be taken into account.
 - d. Enhancing the framework with ‘scenarios building’ capabilities. In the current form, *CEIPSec* only acts as results visualization platform. Scenario building would provide to the stakeholders an integrated and intuitive way of generating simulation-request.
- C. On the assessment framework - Automating the simulation phase in a ‘fire-and-forget’ manner.

As mentioned in the introductory section of this document, simulating complex networks might be (and in most cases is) an intricate, time consuming process. Developing an application that would encompass the assessment workflow (i.e. define, run, assess scenarios) in a sequential manner is not a good approach since long simulation times is synonym with long dead-time for the user / analyst. This is even more valid for web-based applications since pretending the user to stare at a frozen browser window for even 2 minutes would be preposterous.

The contemplated solution is to treat the request, simulation and assessment phases separately. In this approach, the user would generate / build the new scenario(s) and send it / them to a simulation queue. While simulation occurs the user is free to use the application for e.g. assessing previously run scenarios, or even leave the application completely. Once simulation is performed the user is informed and can access the results.

Naturally the success of such approach also depends on external factors, mainly on the third party sector-specific simulator software. The feasibility of this approach will be further investigated.

ANNEXES

Annex 1. CEIPSec Architecture

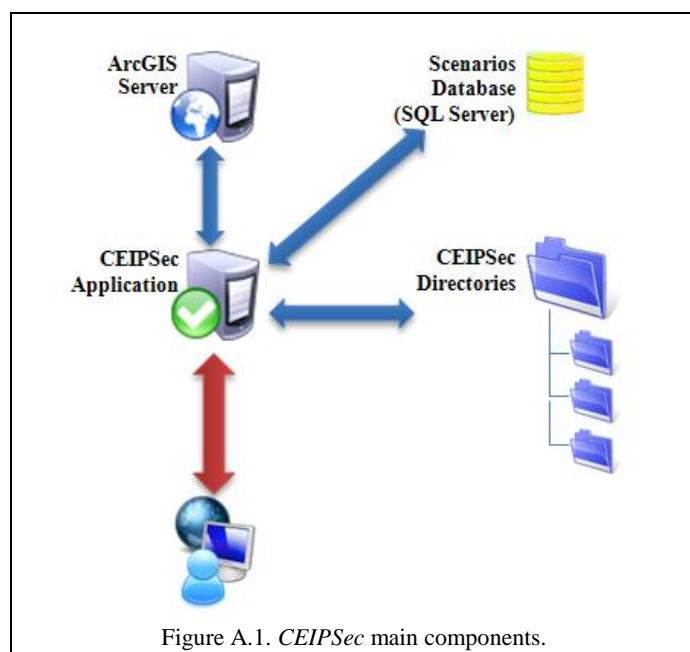


Figure A.1. CEIPSec main components.

The main components of CEIPSec are given in Figure A.1.

CEIPSec Application is the ASP.NET project of the application. It is published through Microsoft Internet Information Server (IIS).

The ArcGIS provides the mapping capabilities for *CEIPSec*. In other words, *CEIPSec* consumes the geographical information from the ArcGIS server.

Scenarios Database is the database containing the definition information for the SCA and CCA working cases (case name, correspondent map service name, date created, etc.)

CEIPSec Directories are the folders on server used by the application for different tasks. It is recommended for the *CEIPSec Directories* to be all located under a common parent folder. There are no

restrictions in terms of naming the folders. In order to be used by *CEIPSec* the *CEIPSec Directories* must be defined in the 'web.config' file of the *CEIPSec Application*. Figure A.2 depicts a possible *CEIPSec Directories* structure:

- `CascadeEffectsSet` – holds the CCA working cases non-geographical data;
- `SingleCasesSet` – holds the SCA working cases geographical and non-geographical data;
- `NEPLANFiles` – is the repository for the uploaded NEPLAN[®] files;
- `TEMPLATES` – holds the full MXD project used as template for the SCA maps.

```
C:\
- CEIPSec DATA
  + CascadeEffectsSet
  + SingleCasesSet
  + NEPLANFiles
  + TEMPLATES
```

Figure A.2. CEIPSec Directories. Example

For the given *CEIPSec Directories* the 'web.config' should contain under the <appSettings>:

```
<add key="CascadeCaseXMLDescriptionPath" value="C:\CEIPSec DATA\CascadeEffectsSet\"/>
<add key="mxdCommonPath" value=" C:\CEIPSec DATA\SingleCasesSet\"/>
<add key="templatesPath" value=" C:\CEIPSec DATA\TEMPLATES\"/>
<add key="NEPLANrepository" value=" C:\CEIPSec DATA\NEPLANFILES\"/>
```

The next annexes describe what happens 'under the hood' when Single Case Assessor and Cascade Case Assessor working cases are generated.

Annex 2. Single Case Assessor Working Case.

A Single Case Assessor [SCA] working case is defined by:

- An ArcGIS map service referencing an ArcGIS project file (mxd) containing a set of ESRI shapefiles. The map service is consumed in the Map Panel of the [SCA] application.
- A dataset file containing the impact data at country level. This data is consumed by the charts and numerical panels of the [SCA] application.

Construction of a new case.

A [SCA] case is created in two steps: (i) upload the NEPLAN[®] excel file to the CEIPSec server; (ii) and process the uploaded file.

In the sequel the CEIPSec folders name are considered the ones given in Annex 1.

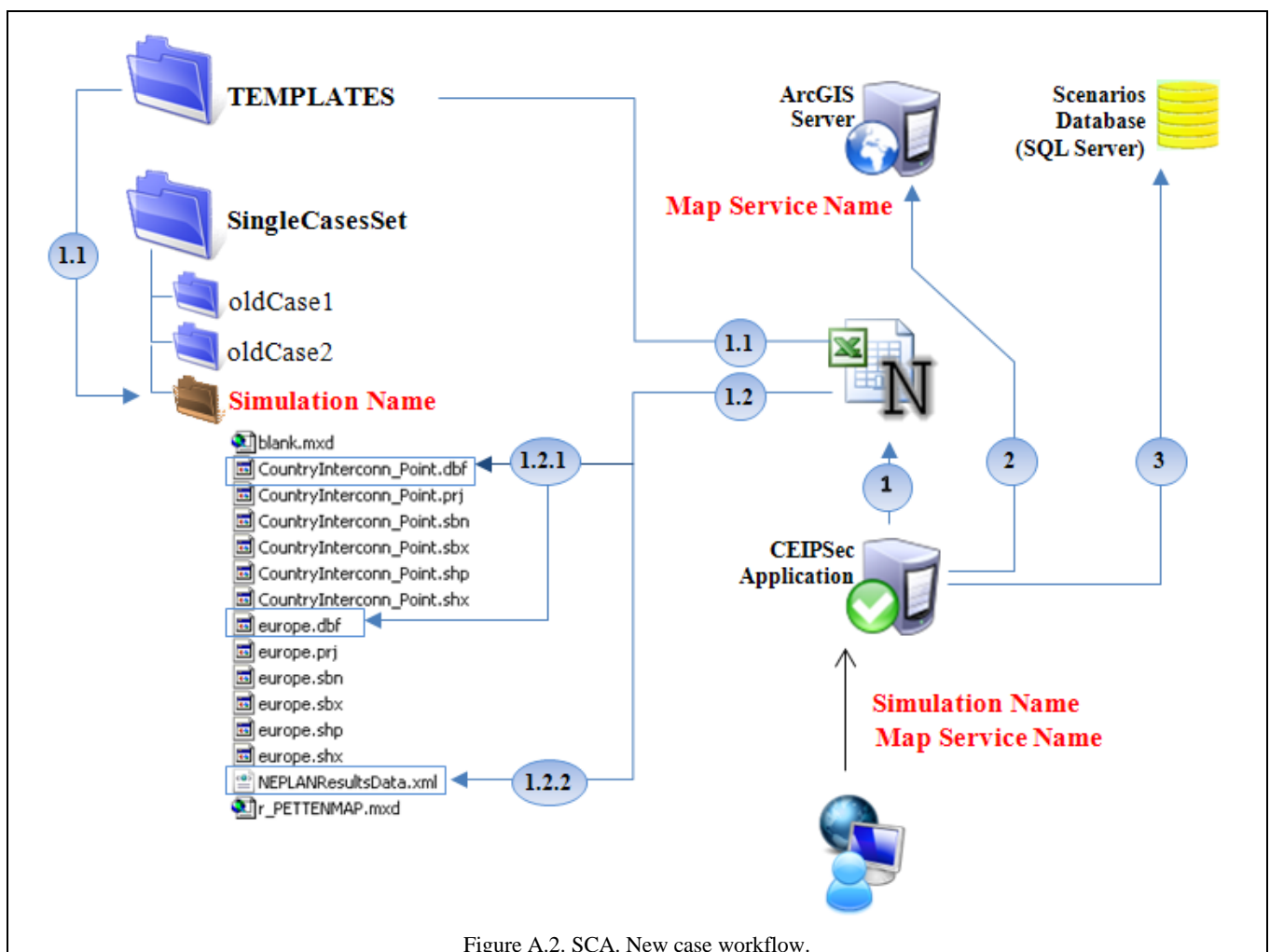


Figure A.2. SCA. New case workflow.

The NEPLAN[®] excel files are saved into the CEIPSec's [NEPLANFiles] folder. Let it be reminded that in the Process Case phase (Section *Management. Single Case Assessor*) the user is required to provide a Simulation Name and a Map Service Name. Once this information is provided the following occurs (Fig. A.2.).

1. Create the [SCA] case data sources based on the NEPLAN[®] file.

[SCA] data sources for a given case are *the situational map* and *the additional data* (source for charts and numerical panel). The data sources are generated by parsing the NEPLAN[®] file.

- 1.1. A copy of the [TEMPLATES] content is made into a new folder [Simulation Name], created under the [SingleCasesSet] folder.
- 1.2. The datasources are updated / generated as follows:
 - 1.2.1. The map data (dbf files) is updated with:
 - The Country-transfers layer (CountryInterconn_Point.dbf)
P_Tie and Q_Tie – inferred from the NEPLAN[®] file;
P_TABs and Q_TABs – the absolute values of the P_Tie and Q_Tie.
 - The Country-impact level (Europe.dbf)
P_Loss, Q_Loss, P_Imp, Q_Imp, P_Gen, Q_Gen, P_Load and Q_Load values read from the NEPLAN[®] file.
 - 1.2.2. The additional dataset (NEPLANResultsData.xml) is generated. The additional dataset is the source of information for the charts and the numerical panel in the SCA Application. The additional dataset holds the failure impact indicators at country level. For each affected country the following data is recorder:
 - [ID] – primary key;
 - [CountryID] – the country name (short format);
 - [CountryFull] – the full country name;
 - [P_Loss], [Q_Loss], [P_Imp], [Q_Imp], [P_Gen], [Q_Gen], [P_Load] and [Q_Load]
2. A Map Service with the Map Service Name provided by the user is created on the ArcGIS Server. The new service Data Source is the 'r_PETTENMAP.mxd' file in the [Simulation Name] folder.
3. The Scenarios Database 'tblResults' table is updated as to indicate that the new [SCA] case is ready to be used.

Editing a case

When a working case name is modified using Edit option in the [MSCA] application the following occurs:

1. The name of the SCA working case folder is modified to reflect the new case name;
2. The *mxd* path is modified in the case-correspondent ArcGIS Service, to point towards the new *mxd* location.

Deleting a case

When deleting a [SCA] case the case definition record is removed from the *Scenarios Database*. In addition, depending on the user selection, deleting a [SCA] working case entails:

- *Delete map service* – removes the SCA case map service from the GIS server.
- *Delete map project* – deletes the *mxd* and *shp* files from [SimulationName] folder.
- *Delete NEPLAN source* – removes the SCA case correspondent NEPLAN[®] source file from [NEPLANFiles] folder.
- *Delete case files* – [SimulationName] folder from [SingleCasesSet].

Annex 3. Cascade Case Assessor Working Case

A Cascade Case Assessor [CCA] working case is composed of:

- An ArcGIS map service referencing an ArcGIS project file (mxd or msd) built after a predefined scheme (described in the sequel).
- A Cascade Effects Scenario Definition File holding the definition of the current case and the information about case report generation data sources, as described below.

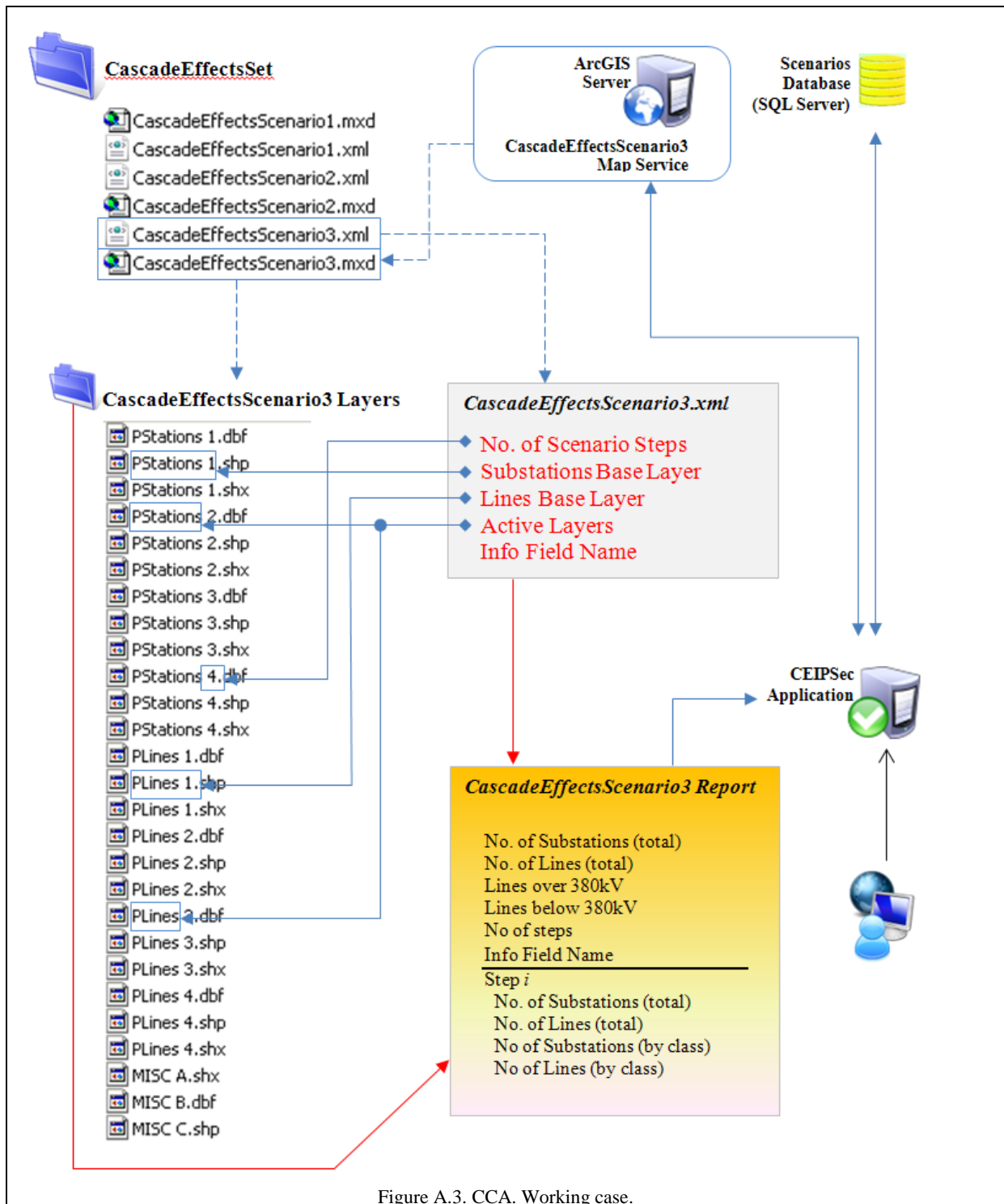


Figure A.3. CCA. Working case.

For each Cascade Case the information about the constituent parts are held into the [tblCascadeCases] table of the *CEIPSec*'s Scenarios Database. Each cascade effects case record holds:

- [Name] – the name of the scenario;
- [DataSourcePath] – the map project name (without the *mx*d / *ms*d) extension;
- [MapServiceName] – the name of the ArcGIS Map Service pointing at the [DataSourcePath] project;
- [DateAdded] – the date the new case has been created;
- [DateModified] – the date when the case has been last modified;
- [LayerGroupName] – obsolete information kept for compatibility with previous versions of *CEIPSec*.

The Cascade Effects Scenario Definition File ([CESD]) is automatically created when a new Cascade Effects Case is added to *CEIPSec* by using [MCCA] Application. [CESD] holds information that characterizes the working case in terms of:

- Number of steps of the Cascade Effects scenario;
- Name of the Substations Base Layer
- Name of the Lines Base Layer
- List of the case Active Layers (the ones turned on/off when navigating between steps)
- Name of the data field holding the cascade effect step.

When a working case is opened in [CCA] a Case Report is generated on-the-fly from the data provided by the Case Map Service. The case report is compiled from information in different data sources (see Fig.A.4.); the data sources are indicated in the [CESD] file. The link between the *case report* and the [CESD] items is given in table below.

Requirements for Cascade Effects Cases

Creating a *Cascade Effects Case* implies:

- i. Build the case map data sources (layers) representing
 - a. the system under consideration (power stations, power lines, etc.)
 - b. the set of layers rendering the system snapshot in each of the cascade effect step (the Active Layers)

The format for the map data sources is ESRI Shape File.

- ii. Create an ArcGIS project (*mx*d or *ms*d) having as data sources the shape files in step (i);
- iii. Publish / create to the ArcGIS Map Server a new Map Service referencing the ArcGIS project created in step (ii)
- iv. Create the *CEIPSec* [CCA] case by using the [MCCA] module and referencing the Map Service created at step (iii).

There are several requirements that should be met in steps (i)-(iv), that are presented in the sequel.

Requirements for building the Case Map

The layers created in step (i) are the ones foreseen to play different roles in the *CEIPSec CCA case*. In order to provide full compatibility with *CEIPSec* CCA module the following requirements should / must be met:

The Foreseen Substations Base Layer

Req.1. should contain as features all the substations composing the system.

Req.2. must have a data field (numerical) playing the role of the *Info Field* <InfoField>.

For each feature the value of the <InfoField> is the cascade effect step in which the substation corresponding to the feature is reached by the failure. For setting a feature as the starting point of the failure one should set <InfoField> value to 100.

Report Information	Data Source	Method
Case-related		
Number of Substations (total)	Substations Base Layer	Count number of records
Number of Lines (total)	Lines Base Layer	Count number of records
Number of Lines (per category)	The First Line Layer	Query and count by: CATEGORY = '380kV - 499kV' CATEGORY = '220kV - 299kV'
Step-related		
Number of Substations (per step)	Base Substations Layer	Count the results of filtering by [InfoFieldName]
Number of Substations (per step, per category)	Base Substations Layer	Filter Number of Substations (per step) by: Subs400 [VOLTAGE] = 400 OR [VOLTAGE] = 380 Subs225 [VOLTAGE] = 220 OR [VOLTAGE] = 225 Subs150 [VOLTAGE] = 110 OR [VOLTAGE] = 150 SubsOther as number of all the other records.
Number of Lines (per step)	The Step 0 correspondent of the Line Info Layer	Count the results of filtering by [InfoFieldName]
Number of Lines (per step, per category)	The Step 0 correspondent of the Line Info Layer	Filter Number of Lines (per step) by: LinesOver380 [CATEGORY] = '380kV - 499kV' OR [CATEGORY] = NULL LinesBelow380 [CATEGORY] = '220kV - 299kV'

Req.3. **must** have a data field named [VOLTAGE].

Missing [VOLTAGE] field leads to error when opening the CCA case.

The values for [VOLTAGE] **should** be {110, 150, 220, 225, 380, 400}. Any other value entails the correspondent substations being considered as *other* when creating the Case Report.

The Foreseen Lines-Base-Layer

Req.4. **should** contain as features all the transmission lines composing the system.

The Step 0 Correspondent of the Line Info Layer

Req.5. **must** have a data field (numerical) playing the role of the *Info Field* <InfoField>.

For each feature the value of the <InfoField> is the cascade effect step in which the line corresponding to the feature is reached by the failure. For setting a feature as the starting point of the failure one should set <InfoField> value to 100.

Req.6. **must** have a data field named [CATEGORY].

Missing [CATEGORY] field leads to error when opening the CCA case.

The values for [CATEGORY] **should** be { '220kV - 299kV', '380kV - 499kV' }. Any other value entails the correspondent substations not being counted when creating the Case Report.

General Requirements

Req.7. the <InfoField> name **must** be the same in both the *Substations Base Layer* and *Step 0 Correspondent of the Line Info Layer*.

Requirements for building the ArcGIS Project

Req. 8. The project (mxd or msd file) **must** be saved in CEIPSec's <CascadeCaseXMLDescriptionPath> folder.

Req. 9. The Active Layers **must** be named in a {NAME ROOT} + {blank} + {step} manner

Examples:

```
{NAME ROOT} = 'Cascade Effect Scenario X'  
Step 0 Layer Name: 'Cascade Effect Scenario 0'  
Step 1 Layer Name: 'Cascade Effect Scenario 1'  
Step 2 Layer Name: 'Cascade Effect Scenario 2'  
Step 3 Layer Name: 'Cascade Effect Scenario 3'
```

Requirements for Publishing the ArcGIS Map Service

When creating the new Map Service the path to the Map Document **must** be given as *absolute path* (e.g. "e:\CascadeEffectsSet\myProject.mxd").

If using ArcGIS Server Manager publish the service by using Add New Service option, under the Services tab. DO NOT use the Browse button for providing the Map Document path. COPY the *mxd* file absolute path (taken from e.g. Windows Explorer) and PASTE it to the Manager.

European Commission

EUR 24764 EN– Joint Research Centre – Institute for the Protection and Security of the Citizen

Title: Critical Energy Infrastructure Protection. Assessment Results Communication

Authors: Bogdan Vamanu, Marcelo Masera

Luxembourg: Publications Office of the European Union

2011 – 40 pp. – 29.7 x 21 cm

EUR – Scientific and Technical Research series – ISSN 1018-5593

ISBN 978-92-79-19756-7

doi:10.2788/71469

Abstract

Computer simulation of real systems is most of the time a complex task, both in terms of the analytical models describing the process and the usage of the tools that implement the models themselves. The results of such tools are also mainly professional oriented. However, depending on the addressee and the goal of the assessment, communicating the results in an „out-of-the-business" manner is sometimes required. This document introduces CEIPSec, a web based GIS centric application developed by IPSC SCNI for results communication and visual assessment of the impact of failures on the European electrical power transport system. CEIPSec was developed within the context of the Administrative Arrangement Critical Energy Infrastructure Protection between DG ENERGY and the JRC.

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