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CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

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D7.7 + D7.8 Crisis Scenario and Impact Evaluation and Results of a 3-months test-run of the DSS

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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TABLE OF CONTENTS

1 Introduction

1.1 Objective

The objective of this document is to report about the results obtained by deploying the CIPCast functionalities in two test cases implemented within the CIPRNet project. These cases demonstrate the CIPCast concept and capabilities with respect to the management of a crisis scenario. The two cases aim at showing the DSS general and flexible design, so they cover two areas that are strategic for different reasons: (1) a cross-border area of The Netherlands and Germany and (2) a big city in Italy (Rome). Both test cases' scenarios have been generated by the same natural hazard – a flooding event – resulting from meteorological or climatological simulations in order to compare the efforts required to perform the analysis.

Moreover, CIPCast will be tested in terms of its capability of raising appropriate alerts. This test has been performed by comparing CIPCast alerts with the effective data log of the different faults experienced by Areti[1] on its network during a time span of three months, at the end of 2016. Results of this further test are reported and commented in the second part of the document.

1.2 Structure of this document

The document is organised as follows. Chapter 2 will briefly describe the two test cases, drawing some lessons learned about the different efforts (computational power, availability and accuracy of data, resolution of weather and climatological prediction, scale resolution etc.) required to perform a complete analysis. Chapter 3 will give some information about a three month test-run, including a summary of the major conclusions and observations from these test runs. Lastly, Chapter 4 will summarise some lessons learned for future work.

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[1] Areti SpA is the electrical distribution operator in Regione Lazio (and thus in the area of Roma Capitale). It manages the Medium and Low voltage networks and allows many energy provider companies to supply electricity to millions of customers.

2 Descriptions of the test cases

This chapter describes the two test cases to show CIPCast capabilities in different situations. Aiming at showing that CIPCast is general enough to be used EU-wide, the two test cases have been located in different areas:

1. A large, densely populated metropolitan area (Roma Capitale), with a large concentration of assets and CI, threatened with natural threats mainly related to weather events (precipitations, lightning) and related events (flooding), as being characterized by the presence of a primary and a secondary water basins.
2. A cross-border area between Germany and the Netherland, prone to intense natural events such as flooding; the area of Emmerich am Rhein (North Rhine-Westphalia) hosts a relevant railways node which plays an important role in passenger travel and commercial transport and is therefore treated in the EU as a part of the Trans-European Network in the category “priority projects”. A detailed description of the area is provided in D6.2

To compare a number of Key Performance Indicators (KPIs) of the analysis, both crisis scenarios have been generated as resulting from the same type of natural hazard – a flooding event – induced by meteo-climatic events.

2.1 Crisis scenario 1: Tiber river flooding

Looking for a high populated and economically relevant area, the city of Rome in Italy has been selected as a test case for a number of reasons. Besides fulfilling many of the different requirements (high risks, relevance, possible threats induced by man-made perturbations, large dependency among CI, etc.), this test case has been selected as it would benefit of the large amount of data collected in a number of past and current projects as well as from strong relationships built over the years by ENEA. In fact, we are pleased to acknowledge the Distribution System Operator (DSO) of the Regione Lazio one of the major Italian telco operators, the Italian National Institute of Statistics, and the Chamber of Commerce, among the other relationships, who provided data and knowledge to build a refined model of the area.

The selected scenario (flooding), moreover, is related to the worst-case natural hazards-related scenario that the Civil Protection AND the electrical DSOs are currently investigating as it has a large probability to occur in the five to ten years to come. By the way, due to the CIPCast development and capabilities, ENEA established a long-term collaboration with the Civil Protection of Roma Capitale. They are highly interested in the CIPCast developments.

The Rome flooding scenario is based on the official risk scenario of 200 years’ recurrence time Tiber flooding. The risk scenario (i.e. the area of the city which will be flooded) has been estimated through the analysis of historical data and with the use (in recent times) of a 2D-hydraulic simulation sponsored by the Tiber Basin Authority and performed by the Dept. of Hydraulic Engineering of the University Roma Tre. Data (in GIS format) contains the flooded areas and the corresponding water rods with an x-y resolution of 10 meters (see fig. 1). It is worth noting that this scenario could (statistically) occur in these years (the sequence of large flooding is 1805, 1846, 1870, 1900, 1915, 1937 each with water level higher than 16 meter at the Ripetta Tevere level measurement station). In fact, in the last few years, several weeks of heavy rains have really pushed the Tiber nearly to its limits several times, likely without overflowing. The smaller Aniene River actually overflowed in an inhabited area. Therefore it is worth to double-check the emergency plan in place. With a state of emergency declared, the area around the historic Ponte Milvio pedestrian bridge has been sealed off.

For the test case, the CIPCast system has been input with various synthetic data sets (precipitation rate and cumulated precipitation amount, water level at the major hydrometric points, precipitation prediction for the forthcoming 48 hours) in a way to be able to trigger the alert for a centennial flooding. The expected flooded area in the north part of the city (Ponte Milvio) was uploaded from the CIPCast Database (data have been provided, together with the other information layers related to areas impacted by floods of the primary or the secondary water basins of Regione Lazio by the Regional Water Authority and the Civil Protection). These layers contain, other than the GIS map of the flooded areas, also the heights of water rods in each point of the flooded areas.

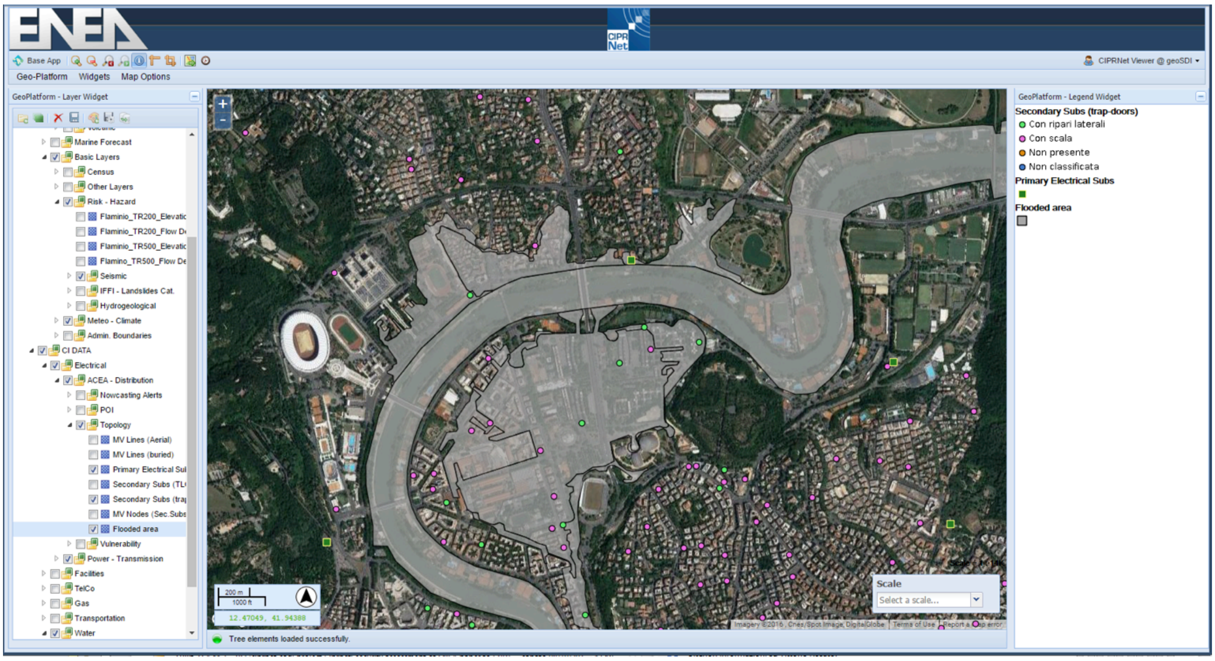


Figure 1: View of the area affected by the centennial flood in the north part of the Roma city (Ponte Milvio area). The grey shaded area (on the north side of the river) represents the flood extension of the bi-centennial flooding. The coloured points on the map represent the artificially distributed position of the electrical substations present in the area. The colour code is related to their position with respect to the ground level.

CIPCast then operates the three different activities to produce:

- Damage scenario;
- Impact scenario;
- Consequence Analysis.

Whereas the activity Damage scenario is a self-consistent action, the definition of the Impact scenario and the analysis of Consequence are somehow related each other, as will be made clear in the following.

2.1.1 Damage scenario

Starting from the correlation analysis of the water rods in the different points where Critical Infrastructure (CI) elements were located, CIPCast selected the elements in the Database located in position possibly affected by the water. Some of the electrical substations are located beneath street level; others located on street level or in large buildings. The height value of the water rods expected in a specific point is compared with the position of the electrical substation: if the station is located beneath the road level and the local water rod is different from zero, we assume that the station will be flooded (and set out of order); if, in turn, the station is located into a building, we assume that it will not be affected. The out-of-order station will thus form the "damage scenario". According to the damage scenario, eleven Medium Voltage (MV) substations (SS hereafter) will probably be hit and damaged by the flood.

At this stage, CIPCast is able to produce the following data and results:

(1) the number and the position of MV substations affected (and damaged) by the flood (note that CIPCast enables to set substations in an off-state either simultaneously or by following a pre-selected sequence);
(2) the subsequent blackout of other MV substations along the MV lines where damages occurred;
(3) the subsequent blackout of mobile telecommunication antennas supplied by damaged (or hit as a consequence) MV substations.

2.1.2 Impact scenario and consequence analysis

CIPCast has available in its Data Base the model of the whole MV network of Roma Capitale. Its topology is continuously updated (once each hour) as it is constantly modified by the Operator to adapt the network to the specific power flow it must sustain. The MV network model is described at the description level shown in fig.2, containing all the different types of SS present (automatic, tele-controlled, not tele-controlled), breakers are located along the lines, Primary Stations are also located.

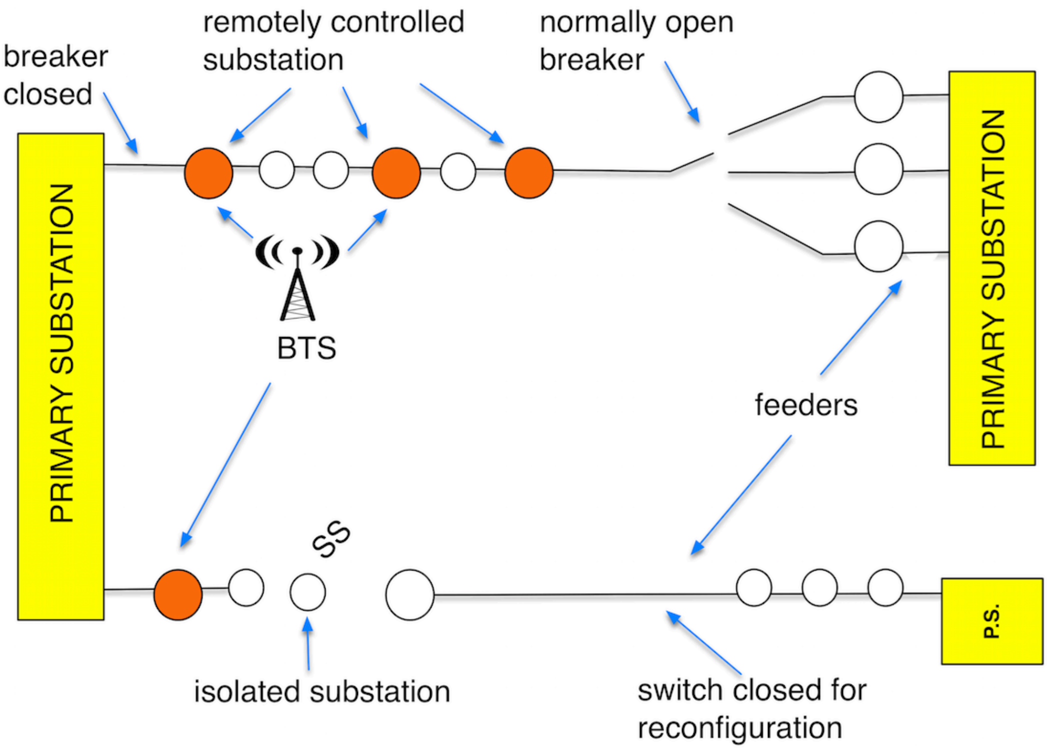


Figure 2: Sketch of the model representing in RecSIM the details of the electro-telco dependent systems. Primary substations are HV-MV transformers (PS rectangles); MV-LV transformers are electrical substations (SS) described with circles. Orange SS are tele-controlled by using services provided by mobile telco antennas BTS

The application dealing with the simulation of outages event is called RecSIM.

Once the damage scenario is issued and received by the appropriate application, RecSIM inputs the damage scenario into the MV model (by putting off-line, at the time in which each SS is predicted to go in an out-of-order state); this model also contains all the dependencies between the electrical network elements and the telecommunication elements (in terms of tele-control dependencies: SS supplying energy to the telecommunication BTS (Base Transceiver Station), BTS providing tele-control capability to the different SS).

The CIPCast operator thus receives the resulting network (with the damaged SS put in out-of-order state) as input. The CIPCast operator can, then, insert as further input of the simulation the work forces and other resources available in the field (number of technical crews, available Power Generators). After having input these further data, the CIPCast operator can start the simulation to reproduce the cascading events that would take place in the network due to the simultaneous outage of the CI elements identified by the Damage scenario.

The RecSIM workflow firstly identifies all SS involved in the outage starting from the sudden faults of the damaged SS. This will result from the action of the automatic switches at the level of Primary Stations (PS) and that of automated SS. The set of hit SS and those faulted by cascading effects will provide the Global Damage Scenario that will trigger the further elaboration of the RecSIM application.

At this stage, RecSIM analyses the different types of faults, estimates through the dependency matrix the telco functionality (if a Base Transceiver Station—BTS—is supplied by a faulted SS, it cannot provide its service to its related SS).

Faults are divided into the following types:

a) Those to be recovered by tele-control operations;
b) Those to be recovered by sending a crew;
c) Those to be recovered by sending a crew and an electrical generator (EG).

Being the recovery time for tele-control operation essentially fixed (~3 min), for each type of faults (b-c), CIPCast can provide the estimated recovery time as follows:

- by using the standard operation times provided by the CI operator;
- by estimating, through a direct analysis on the scenario, the effective displacement times of crews, electrical generators, by estimating them on the bases of traffic forecast data.

For the current test case simulation, data provided by the CI operator have been used. In the simulation the possible perturbation on city traffic induced by heavy rainfalls and/or alert due to the Tiber flood are taking intro account. Therefore, the timings were empirically increased to account for possible traffic slowdowns and jams. In a more advanced version (which is under study) a complete traffic prediction under the flooding conditions will be issued and a more reliable estimate of intervention-recovery times (considering traffic problems) could be released.

Starting from the assessment of all the interventions (and intervention types) to be carried out, the RecSIM application estimates the (sub)-optimal sequence of interventions to be performed in order to reduce as much as possible the KPI of the crisis scenario (i.e. by using the Consequence Analysis result).

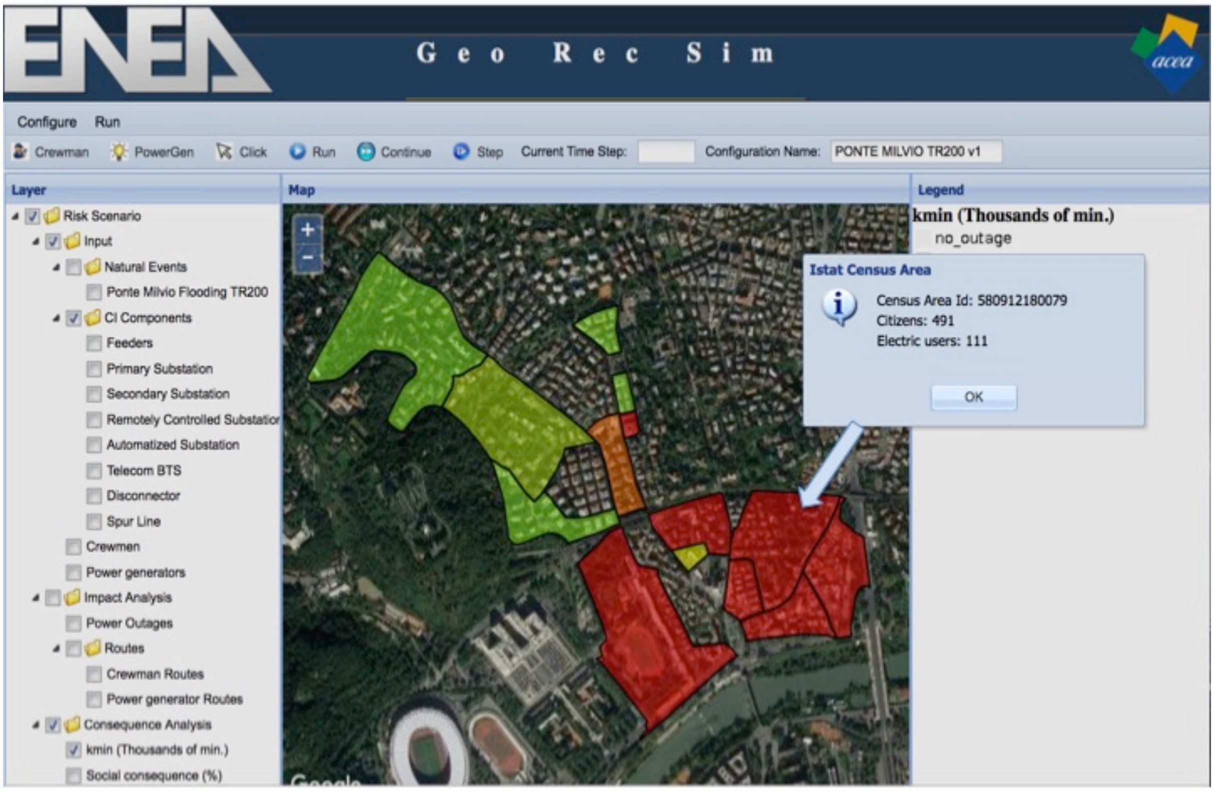
In fact, the “dimension of the crisis” can be estimated, starting from the Global Damage Scenario, by evaluating the outage time of all involved CI elements (and related services) and the corresponding number of citizens (and eventually industrial activities) that will be involved in the outage. The value of these figures can dramatically change as a function of the used recovery strategy, of the amount of forces available on the field (crews, electrical generators etc.) and, particularly, as a function of the current setting of the network topology when the outage starts.

All these data are input to the model; according to these, RecSIM explores the space of possible strategies that can be adopted (at fixed input parameters) and provides a solution (a restoration sequence), which reduces the current KPI, such as:

(a) *kmin*[2], "kilo-minutes", a service continuity indicator, consisting in the value of the product between outage duration (of single SS) times the number of citizen involved (i.e. served by that SS). This quantity is usually expressed in 10^3 minutes.

(b) *Costmin*, the "economic losses" associated to the loss of services in the industrial domain. Consequence Analysis developed in the CIPRNet project has allowed to introducing a relation between the relevance of the different services (electricity, telecommunication, gas and water supplies) for the economic achievements of a given firm (taking into account its specific business domain). Also in this case the value of *Costmin* is estimated in terms of revenues lost as a function of the outage duration.

In the test case, optimisation is performed taking into account only the *kmin* indicator which is the parameter currently accounted for by the CI operator, as it is the indicator which must be periodically reported to the Authority for Energy and whose threshold is indicated in the contract between the CI operator and the Municipality.



Configuration Name: PONTE MILVIO TR200 v1

Istat Census Area

Census Area Id: 580912180079
Citizens: 491
Electric users: 111

Figure 3: Resulting *kmin* in areas shut by the flooding. Colour code refers to the *kmin* experienced resulting in the given area due to the outage of one (or more) SS there contained. Data contained in the inset have been arbitrarily modified and do not correspond to real figures; the inset has been presented only for showing the type of information obtained by the consequence analysis.

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[2] Kmin is a specific KPI used by the Italian Energy Authority to qualify the consequences of an outage: it is calculated for each single CI element as its outage duration multiplied times the number of customers affected by the outage. As the value strongly depends on the specific CI element outage duration, it should be estimated for each CI element (having thus a spatial extent) and subsequently summed up with all the other values coming from other areas served by other CI elements that can have experienced a different outage duration.

Simulation of the test case has encompassed the test of two different topological setting of the electrical network (T1 and T2), and for various numbers of technical crews available in the field. Also some modification of the characteristic times for faults recovery has been used to widen the operator's options. Figure 3 and Figure 4 report some snapshots for the simulation, presenting some of the features that RecSIM allows to estimate and to show.

Please note that ARETI did not provide us the clearance for providing a Public Level of Dissemination of the figures resulting from the simulation.

In Table 1, we resume the input data for all simulations. All these data have been kept fixed for all simulations. All simulations have been carried out with two different topologies T1 and T2 (differing each other from the different position of some switches along the perturbed MV lines).

Table 1: Input data for all simulations. These data have been kept fixed in all simulations.

Data	Value
Number of SS directly damaged	7
Total number of SS involved in the outage	10
Total number of SS analysed by RecSIM	13,540
Number of Electrical Generators available	unlimited

Several CIPCast simulations have been carried out by using several parameters (number of technical crews and restoration times) to provide the CI operator with a forecast of the crisis as accurate as possible, allowing the Operator and the Civil Protection to better perceive the extension and the severity of the expected impacts and consequences of the crisis.

Table 2 (a-d): Resulting data from the simulations upon parameters variation. Real figures have been omitted. Tables have been added to show the type of estimates that the RecSIM tool allows to determine.

Data	Value
Topology set	T1
Number of technical crews on the field	3
Recovery times for type (a-c) faults	(a)=3 min; (b)=45 min; (c) 180 min
Total Kmin for the outage duration	xxxxxxxxx
Number of used Electrical Generators	10
Total number of affected citizens	zzzzzzz
Maximum duration of a local fault	yyyyyyy
Number of citizens affected by local max duration fault	hhhhhhhhh

Table 2a: Resulting values of the development of the crisis with T1 network configuration, three technical crews available and for the specific choice of restoration timings. Sensitive data have been removed

Data	Value
Topology set	T1
Number of technical crews on the field	4
Recovery times for type (a-c) faults	(a)=3 min; (b)=45 min; (c) 180 min
Total Kmin for the outage duration	xxxxxxxxx
Number of used Electrical Generators	10
Total number of affected citizens	zzzzzzz
Maximum duration of a local fault	yyyyyy
Number of citizens affected by local max duration fault	hhhhhhhhh

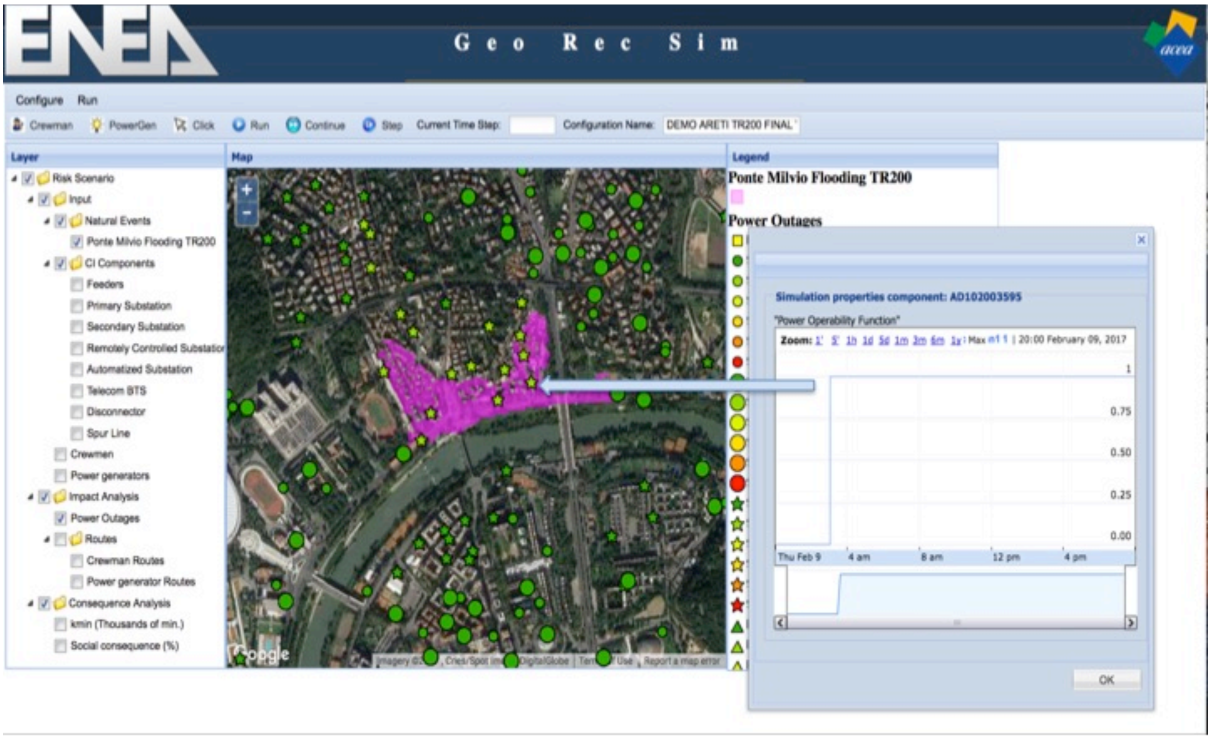
Table 2b: Resulting values of the development of the crisis with T1 network configuration, four technical crews available and for the specific choice of restoration timings. Sensitive data have been removed

Data	Value
Topology set	T1
Number of technical crews on the field	4
Recovery times for type (a-c) faults	(a)=3 min; (b)=60 min; (c) 200 min
Total Kmin for the outage duration	xxxxxxxxx
Number of used Electrical Generators	10
Total number of affected citizens	zzzzzzz
Maximum duration of a local fault	Wwww minutes
Number of citizens affected by local max duration fault	hhhhhhhhh

Table 2c: Resulting values of the development of the crisis with T1 network configuration, four technical crews available and for larger values for the duration of restoration technical activities. Sensitive data have been removed

Data	Value
Topology set	T2
Number of technical crews on the field	4
Recovery times for type (a-c) faults	(a)=3 min; (b)=60 min; (c) 200 min
Total Kmin for the outage duration	xxxxxxxxx
Number of used Electrical Generators	9
Total number of affected citizens	zzzzzzz
Maximum duration of a local fault	yyyyyyy
Number of citizens affected by local max duration fault	hhhhhhhhh

Table 2d: Resulting values of the development of the crisis with T2 network configuration, four technical crews available and for larger values for the duration of restoration technical activities. Sensitive data have been removed



Configuration Name: DEMO ARETI TR200 FINAL

Simulation properties component: AD102003595

"Power Operability Function"

20:00 February 09, 2017

Figure 4: Pink: the flooded area; in green the SS in the area and the fault profile of the outage of one of the SS shut by the flooding (directly or through cascading effects)

The test has been purposely designed to assess the capability of CIPCast to allow the CI operator to use as many degrees of freedom to attempt to solve the crisis with a lowest possible level of final *kmin*, resulting from the outages. The relevant degrees of freedom are:

- The possibility of testing different network reconfiguration in order to increase the network resilience for that specific predicted event. This possibility has been allowed through the availability of a second network topology (T2) assumed to be fitter with respect to T1 to be used to sustain the event. In fact the *kmin* resulting from T2 (see Table 2d) is slightly lower than that experienced in the corresponding test on T1 network (see Table 2c).
- The use of a larger (or smaller) number of technical crews.
- The need of a certain number of electrical generators to solve the crisis. For large crisis, the value of the needed number of electrical generators is a quite relevant output of the problem as usually operators have a small buffer of electrical generators available. This could be overwhelmed in large crisis scenario; in that cases, the CI operator could promptly make the appropriate queries to increase immediately the number of generators to be sent to the field.

2.2 Crisis Scenario 2: Cross border flooding with a major breach

This scenario has been described in detail in the deliverable **D6.2**. In this scenario, different components of the electrical distribution network in the area and of the telecommunication network are considered to fail because of a flooding event. The simulation of the scenario required the integration of the two major technological outcomes of the project that are CIPRTrainer and CIPCast. In particular, the integration activity involved the integration of RecSIM within the CIPRTrainer platform. To this aim, the web application WebRecSIM (running on the CIPCast public server at ENEA) has been implemented to provide RESTful API allowing remote access to RecSIM (this integration activity is described in **D7.5+D7.6** deliverable).

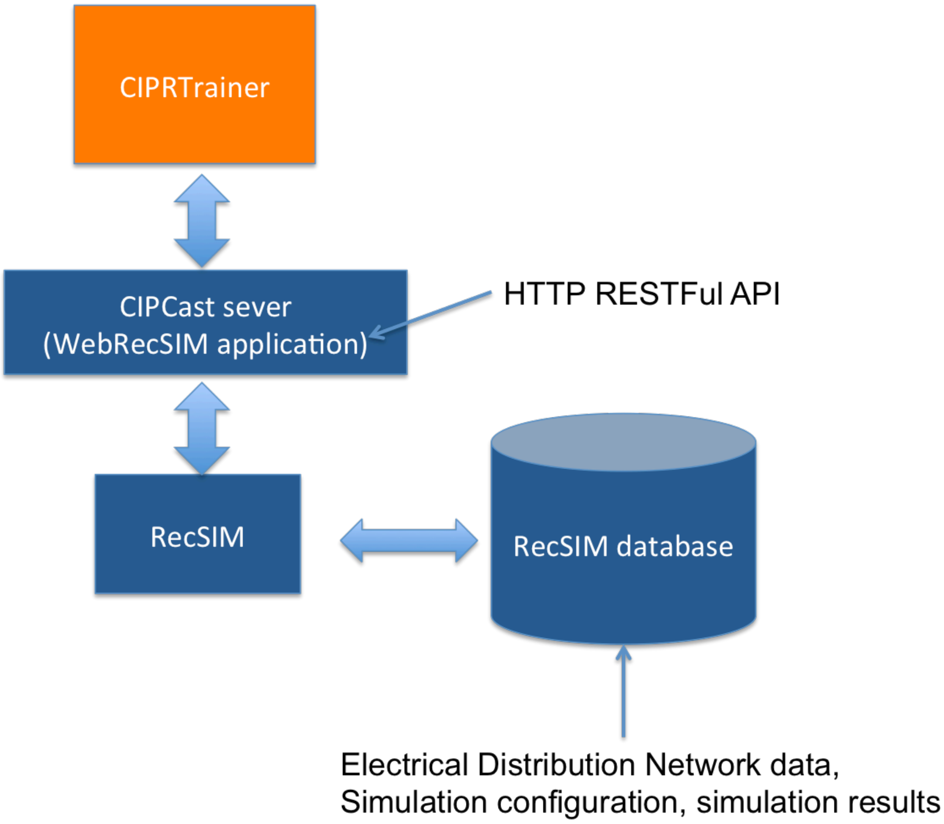


Figure 5: CIPRTrainer - RecSIM integration

The first integration activity has been the modelling of the electrical distribution network of the Emmerich area in the RecSIM database (Figure 5 and Figure 6). This task has required the analysis of the electrical distribution network stored in a GIS file used to display the electrical network information layer on the CIPRtrainer GIS interface. The RecSIM input database has different tables to store the electrical grid topology and to store the simulation configuration data. Indeed, different information are needed in order to allow the simulation of the reconfiguration procedures on an electrical distribution grid of a specific area:

- The topology of the distribution electrical network.
    - For each primary cabin the on-going electrical lines;
    - For each electrical line the sequence of secondary substations on to the line (the order is of a primary importance);
    - The position of the final switch of each line;
    - For each which is/are the possible lines that can be used (closing the final switches) during a contingency to reenergize the last secondary substations in the line after the failure. In other words, the RecSIM model needs to know for each line which are the contingency lines;
    - Information related to the type of the electrical secondary stations. Each substation can be remotely controlled or not.
- Dependencies data
    - The electrical grid SCADA system and telecommunication network dependencies. In particular, each remotely controlled substation needs to be associated with the telco components providing the telco service. On the other hand, for each component of the telco domain providing a service to the SCADA system the database needs to store the electrical substation providing energy to this component.

- Simulation configuration data. These data are not contained in the GIS file. These data will be provided by the end users using the CIPRTrainer application.

The task has required the implementation of ad-hoc procedures to transform GIS data into RecSIM input model database.

WebRecSIM implements a number of HTTP RESTful endpoints / service to allow the communication between RecSIM and CIPRTrainer. The end points are equipped with an HTTP operation (GET, POST, PUT or DELETE) as needed.

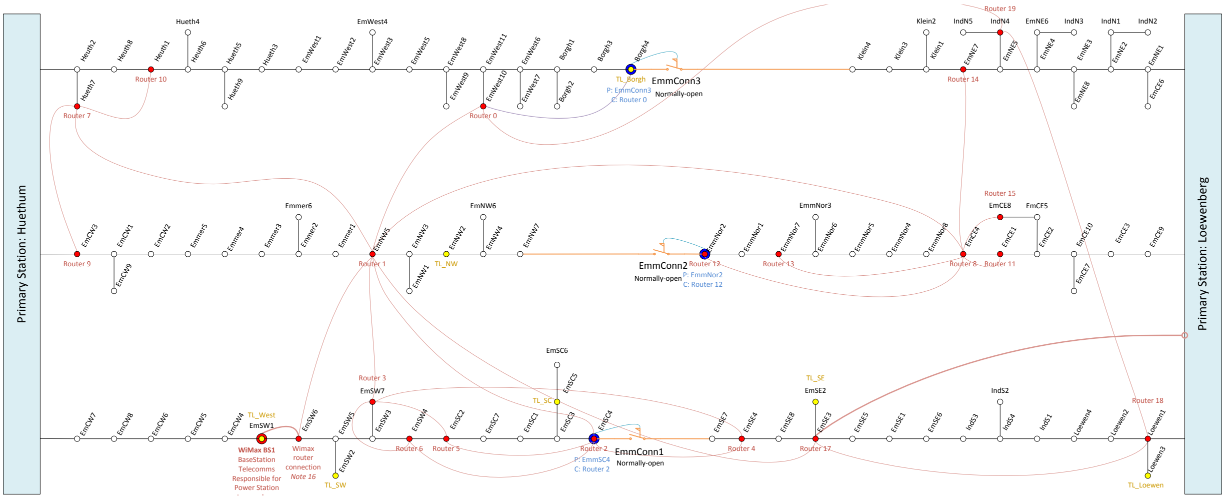


Figure 6: The artificial Emmerich electrical distribution network

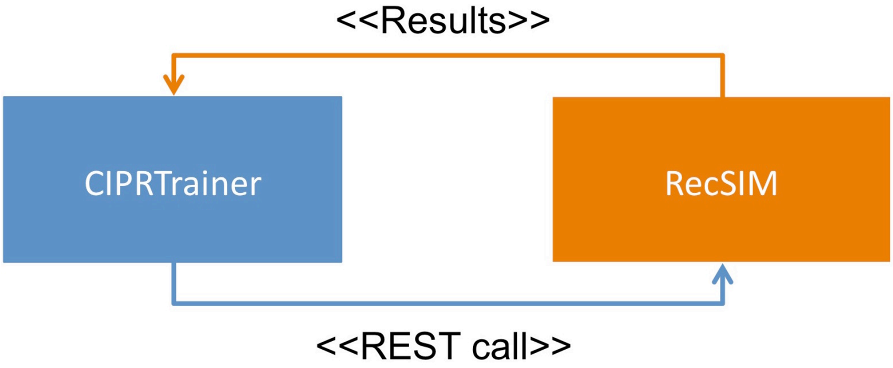


Figure 7: RESTful functional interfaces between RecSIM and CIPRTrainer

The RESTful web services interfaces (Figure 7) run on the CIPCast server at ENEA and the implemented RESTful end points allow:

- to run RecSIM simulation using specific simulation configuration. The result of the simulation is represented by a list (in a JSON forma) containing the outage time of each electrical substations;
- to display the simulation configuration parameters. The service returns A JSON dictionary of the configuration parameters used in the last used configuration;

  to change the configuration parameters. Using this service it is possible to change the tlc_time (the time needed to perform a remote tele-controlled operation) and the isolation_time (the time needed to an emergency crew to perform a manual operation) setting of the simulation configuration simconf. It is important to note that changing the

two parameters tlc_time, and isolation_time makes it possible to model and simulate congested telecommunication network and/or congested traffic mobility infrastructures.
- to display the failures associated to the last configuration used or to a specific configuration
- to configure the electrical substations in failure. This service can be used to set in failure the secondary substations contained in the comma separated failures list parameter.
- to display or to configure the number of crewman available for a simulation

There are two possible ways of integration of CIPTrainer and WebRecSIM:

- Using the CIPRTrainer application the end users can visualize the time development of a crisis due to an extreme natural event (e.g. a flooding event). The application allows the simulation of decision makers/emergency operators decisions during the natural event time development. For example, the application end users can assess the consequences of different course of actions due to different resources allocation strategies. In general, the natural event will impact the critical infrastructures and in particular the electrical distribution grid of the affected area. Then, WebRecSIM can be invoked to assess the impact of a damage scenario where some electrical components are in failures, on the electrical distribution grid. The impact assessment depends, in general, on the functioning status of the electrical SCADA systems and the related telecommunication infrastructure and on the number of emergency teams available to perform manual electrical distribution grid restoration actions. The output of WebRecSIM is represented by the outage time of each electrical component. In general, it is very important to know and to control the functioning status of the electrical distribution grid during a crisis in order to isolate specific network segments for safety reasons and, at the same time, to guarantee the provision of electricity to specific loads (hospitals, governmental buildings, emergency management and operation centres);
- The CIPCast platform can be used to visualize the impact of an electrical damage scenario using electrical operator specific indicators (e.g. number of users affected by a blackout times the number of minutes of outage) and the consequence on the society in general (using the CIPCast consequence analysis module)

3 Results of the 3-month test-run of the DSS

This chapter will briefly describe the output of a three month test-run of the DSS used in "operational" mode, reporting the "log file" of the DSS as well as a summary of the major conclusions and observations. The test run has been carried out from August 31st to November 30th 2016. The test comprised connecting CIPCast with Areti SpA (formerly ACEA Distribuzione SpA), the electrical distribution system operator (DSO) for the Regione Lazio (and the Roma city).

3.1 Test-run environment and information workflow

The test-run had the main objectives of:

(1) validating and testing the settlement of a point-to-point Virtual Private Network (VPN) between the ENEA and the Areti information systems shown in Figure 8; the VPN – using the IPsec protocol – allows a secure, robust and reliable interaction link between the CIPCast system (and its database) and the Electrical Network Management System.

(2) demonstrating the CIPCast capabilities, particularly the one related to the probability of failure of one or more electrical secondary stations following severe weather conditions.

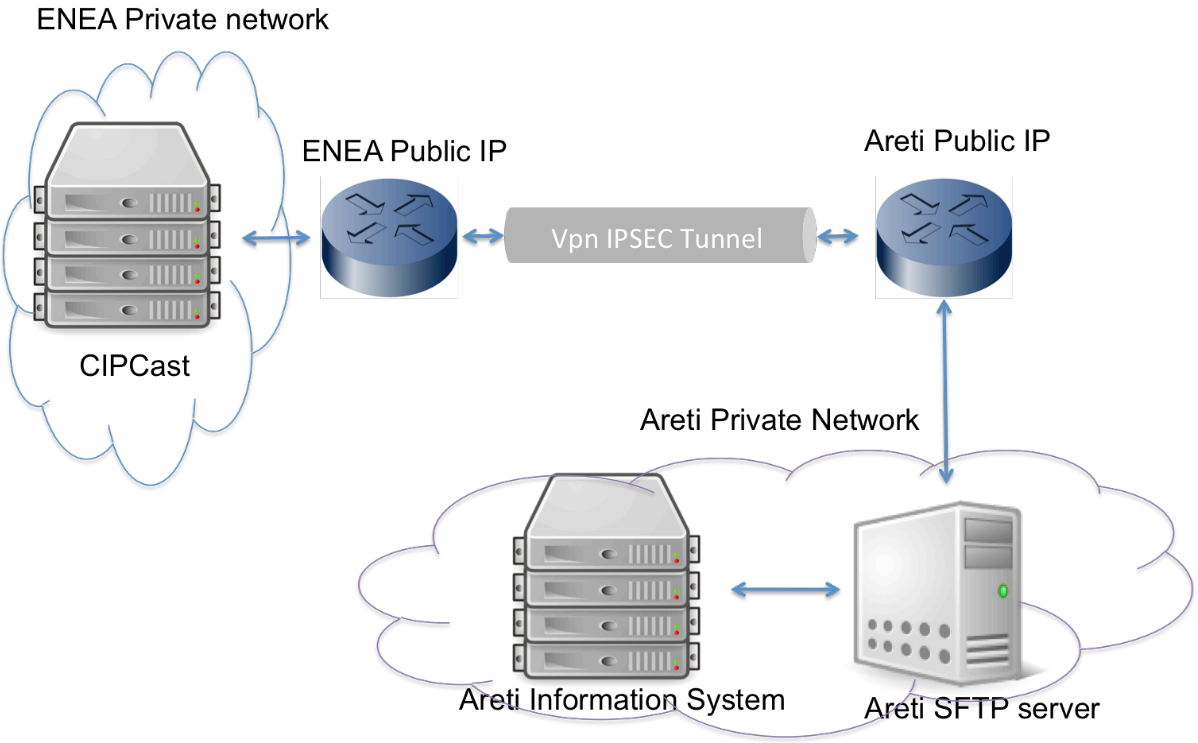


Figure 8: VPN IPsec implementation.

Going into more details, the VPN IPSec connection allows to receive from Areti SpA real-time data related to the electrical distribution network and to send various types of data (e.g. historical meteorological data, damage scenario impact analysis) to the Areti information system (Figure 8). In particular, the Areti data during the test run were related to the network topology i.e. the position of open breakers along the MV lines. Through the VPN IPSec tunnel CIPCast can access and upload (using the SFTP protocol) the file containing the following data:

- The Areti electrical network normal configuration (once a day). The electrical normal configuration is the ideal network configuration;

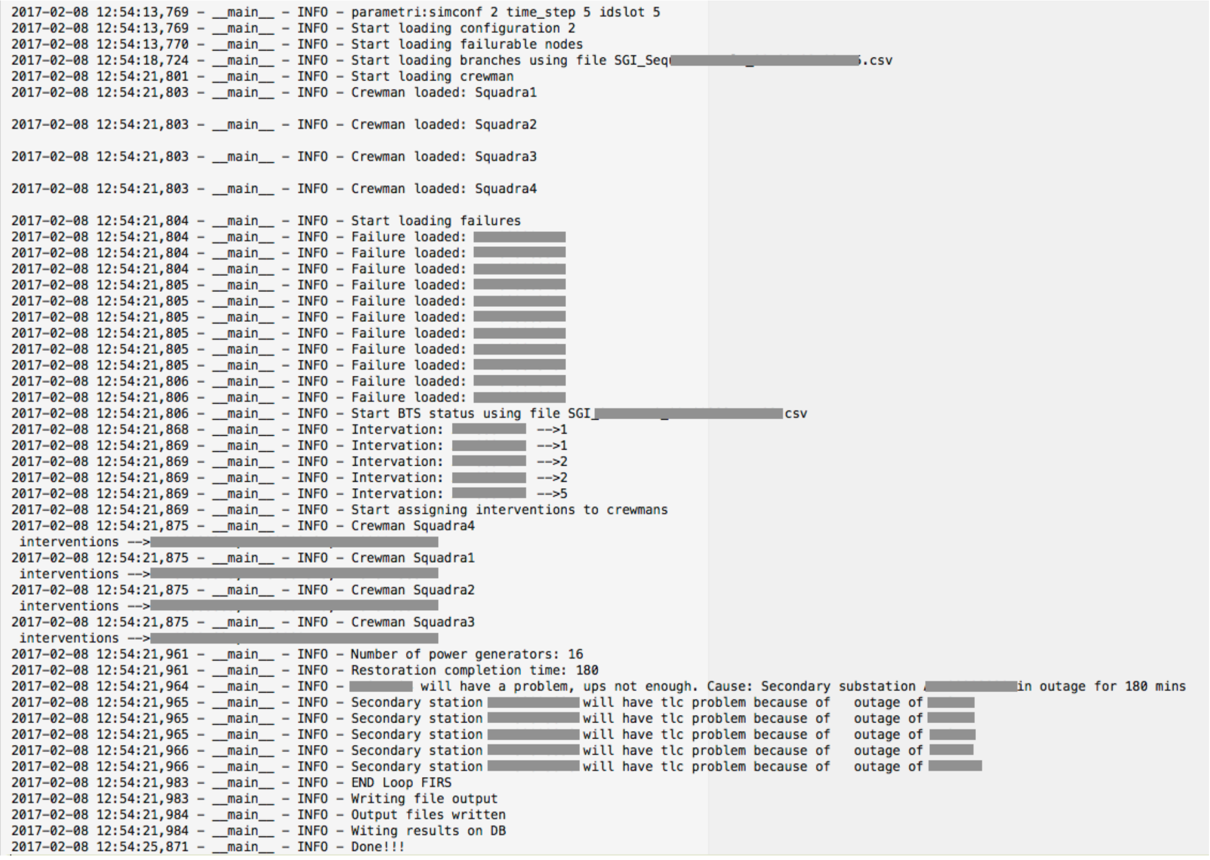
- The electrical network real configuration (each hour). In general, due to maintenance interventions and to failures the electrical network is not configured in a normal way;
- The vulnerability indexes of each component of the electrical network (each hour). Using this indexes, the platform computes which components will be affected by a natural event (e.g. heavy rainfall);
- Following an extreme natural event, CIPCast computes a damage scenario. If the damage scenario involves one or more electrical components (mainly secondary stations), CIPCast, using the RecSIM algorithm, computes the impacts of the damage scenario on the electrical network. Then, CIPCast uploads the output of the RecSIM impact assessment computation to the Areti server.

3.2 Test-run Log Analysis

The fault log file of a three months' period in Areti Electrical Network has been compared with the alerts provided by CIPCast during the same period.

It is worth noting that the number of alerts in the CIPCast Alert log file is obviously quite dependent on real (weather) conditions. The adopted strategy is that of sending reports to the Operators in a way to avoid an overwhelming information flux.

A typical report generated by CIPCast in the internal log file is reported in Figure 9.



```
2017-02-08 12:54:13,769 - __main__ - INFO - parametri:simconf 2 time_step 5 idslot 5
2017-02-08 12:54:13,769 - __main__ - INFO - Start loading configuration 2
2017-02-08 12:54:13,770 - __main__ - INFO - Start loading failurable nodes
2017-02-08 12:54:18,724 - __main__ - INFO - Start loading branches using file SGI_Seq[redacted].csv
2017-02-08 12:54:21,801 - __main__ - INFO - Start loading crewman
2017-02-08 12:54:21,803 - __main__ - INFO - Crewman loaded: Squadra1

2017-02-08 12:54:21,803 - __main__ - INFO - Crewman loaded: Squadra2

2017-02-08 12:54:21,803 - __main__ - INFO - Crewman loaded: Squadra3

2017-02-08 12:54:21,803 - __main__ - INFO - Crewman loaded: Squadra4

2017-02-08 12:54:21,804 - __main__ - INFO - Start loading failures
2017-02-08 12:54:21,804 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,804 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,804 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,805 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,805 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,805 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,805 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,805 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,805 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,806 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,806 - __main__ - INFO - Failure loaded: [redacted]
2017-02-08 12:54:21,806 - __main__ - INFO - Start BTS status using file SGI_[redacted]csv
2017-02-08 12:54:21,868 - __main__ - INFO - Intervation: [redacted]  -->1
2017-02-08 12:54:21,869 - __main__ - INFO - Intervation: [redacted]  -->1
2017-02-08 12:54:21,869 - __main__ - INFO - Intervation: [redacted]  -->2
2017-02-08 12:54:21,869 - __main__ - INFO - Intervation: [redacted]  -->2
2017-02-08 12:54:21,869 - __main__ - INFO - Intervation: [redacted]  -->5
2017-02-08 12:54:21,869 - __main__ - INFO - Start assigning interventions to crewmans
2017-02-08 12:54:21,875 - __main__ - INFO - Crewman Squadra4
 interventions -->[redacted]
2017-02-08 12:54:21,875 - __main__ - INFO - Crewman Squadra1
 interventions -->[redacted]
2017-02-08 12:54:21,875 - __main__ - INFO - Crewman Squadra2
 interventions -->[redacted]
2017-02-08 12:54:21,875 - __main__ - INFO - Crewman Squadra3
 interventions -->[redacted]
2017-02-08 12:54:21,961 - __main__ - INFO - Number of power generators: 16
2017-02-08 12:54:21,961 - __main__ - INFO - Restoration completion time: 180
2017-02-08 12:54:21,964 - __main__ - INFO - [redacted] will have a problem, ups not enough. Cause: Secondary substation [redacted]in outage for 180 mins
2017-02-08 12:54:21,965 - __main__ - INFO - Secondary station [redacted]will have tlc problem because of   outage of [redacted]
2017-02-08 12:54:21,965 - __main__ - INFO - Secondary station [redacted]will have tlc problem because of   outage of [redacted]
2017-02-08 12:54:21,965 - __main__ - INFO - Secondary station [redacted]will have tlc problem because of   outage of [redacted]
2017-02-08 12:54:21,966 - __main__ - INFO - Secondary station [redacted]will have tlc problem because of   outage of [redacted]
2017-02-08 12:54:21,966 - __main__ - INFO - Secondary station [redacted]will have tlc problem because of   outage of [redacted]
2017-02-08 12:54:21,983 - __main__ - INFO - END Loop FIRS
2017-02-08 12:54:21,983 - __main__ - INFO - Writing file output
2017-02-08 12:54:21,984 - __main__ - INFO - Output files written
2017-02-08 12:54:21,984 - __main__ - INFO - Witing results on DB
2017-02-08 12:54:25,871 - __main__ - INFO - Done!!!
```

Figure 9: A typical section of the CIPCast log file presenting the alert on specific locations. The log file contains the sequence of intervention that should be followed by the different crews. Some details have been hidden for security reasons

From the results of the log file, an appropriate Alert File is then sent to the operator, in a way to expose the alerts in a more usable form, with clear indication of the SS under potential threats and with the minimum possible information to avoid overwhelming information.

At the end of the three months period the comparison of the CIPCast alert log file and the Areti fault log file showed a few striking features:

- CIPCast tends to overestimate the alerts;
- In normal conditions, it did not provide any heartbeat thus producing a false perception of an “out-of-order” system.

The second feature has been immediately corrected: a heartbeat feature has been added to the list of the required developments to be implemented in the next development step.

With this in mind, the log in the appendix shows alarms on August 31st, October 2nd, and November 15th and 25th, 2016 because those are the days when it rained enough, as is shown in Figure 10.

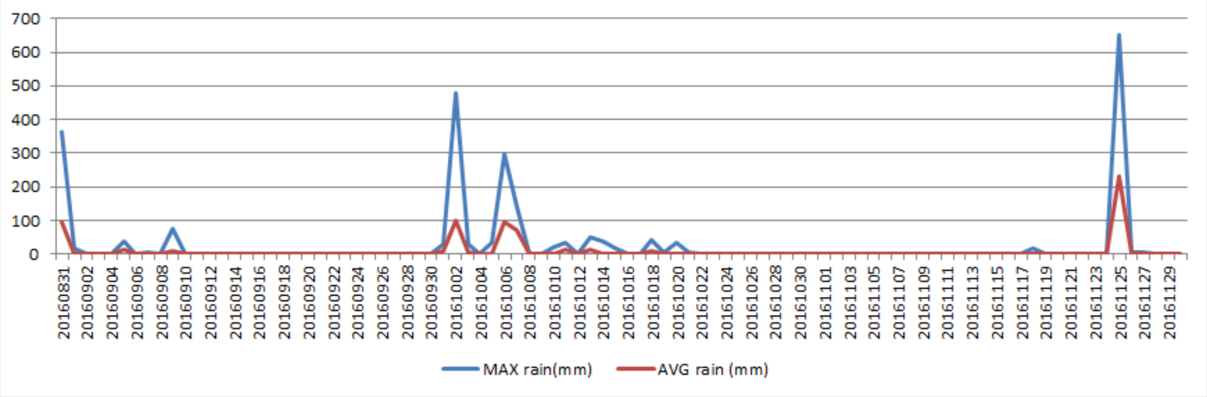
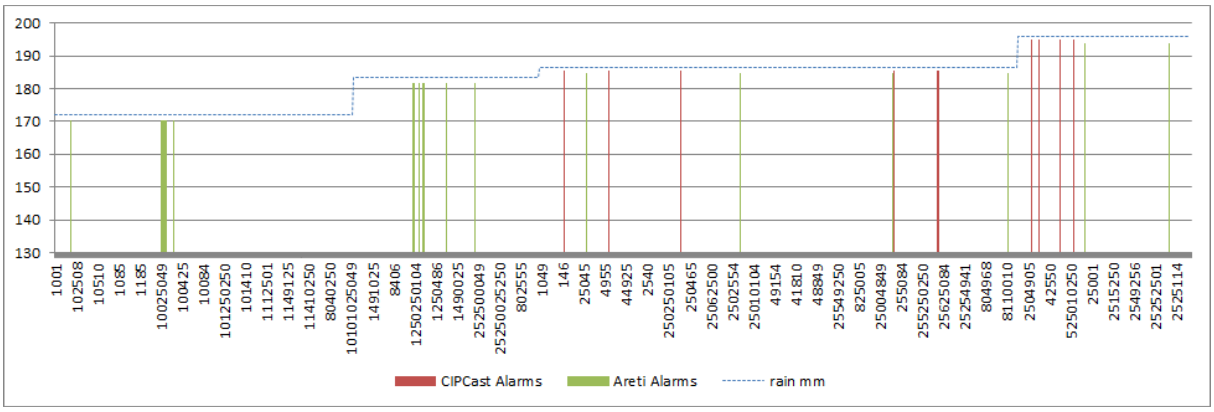


Figure 10: Precipitation in mm in the period August 31st – November 30th as reported by Regione Lazio dedicated department.

In order to evaluate the accuracy of the raised alarms, they have been compared with the real alarms logged in the Areti database that are not attached to this document for security reasons. We have also used official data on the registered rain amounts by the Regione Lazio.

The most frequent potential threats to induce alerts in the CIPCast Damage Scenario are rainfalls (and lightning). For this reason, we have specifically compared the prediction made by CIPCast with the official ex-post documentation (on rainfall abundance and lightning) provided by public sources.

The graphs reported in Figure 11 refer to October 2nd.



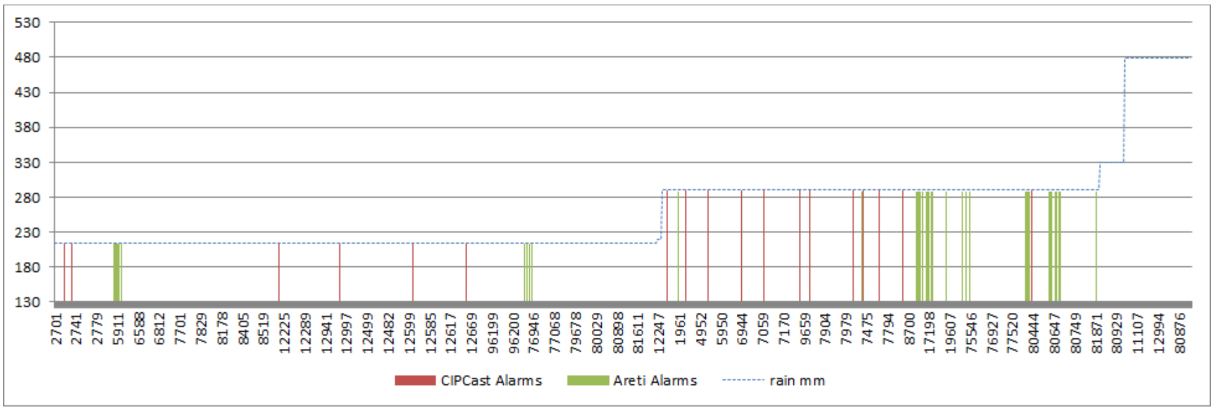


Figure 11: The figures report three different kinds of information. In abscissa the (anonymised) name of the Areti substations and, in the ordinates, the rain value taken by different rain gauges spread over the city territory. The rain datum is the day integral of rain (in mm). Colour bars represent CIPCast alerts (brown bars) and Areti reported faults (green bars). Close substations are thus located in nearby locations, as they are compared to a given rain abundance (i.e. close to the same rain gauge).

They display registered rain mm and raised alarms over the total of 14,477 substations comprised in the MV electrical network. Displayed cabins IDs have been changed with respect to real names.

In Figure 11, the rain abundance (integral over 24 hours) recorded on different rain gauges is displayed (light blue dotted line). The brown vertical bars represent the raised CIPCast alerts, while the green bars represent the effectively faulted Areti substations. When two bars are close, it means that the substation positions are closer as they "belong" to the same rain gauge. Even if the correlation is not valid everywhere, closer substations belong to the same MV line. Flat rain abundance is the result of a unique rain gauge. Thus, many alerts (effective or CIPCast raised) under the same rain gauge mean that a true perturbation has been registered in that specific area (i.e. MV line). Although not in a "punctual" way, CIPCast alerts seem to be able to approximately locating the areas of the city where perturbation occurs. One should consider, however, that whereas the true faults occurred after (or during) the event, the CIPCast alerts are usually issued **prior** to the event, by correlating nowcasting data to substations vulnerability. Although nowcasting is in general a quite reliable and (almost) accurate system to predict rain abundance, it results however in an estimated datum which can also be quite different (at least under the quantitative point of view) with respect to that which effectively occurs. This might, in part, explain the differences found between estimated alerts and effective faults.

To give a general overview about the outcome of the validation phase, we should consider the following points:

- The system contains many false positive and false negatives. This is associated to different causes:
    - Each cabin's sensitivity to rain has been estimated from a high number of historical alarm files and (independent) historical data about rain abundance. In the historical faults log file, there was not indicated the reason of the fault (but just the fact that the substation has gone in off state at a specific time of the day). This means that our statistical analysis has encompassed faults not necessarily produced by the rain abundance but by other causes (common cause failures). This has probably introduced some over-sensitivity value to rain in same substation.
    - Faults log used as historical data are several years old (2010-2014); some of the substations which have been prone, in that period, to frequent faults have been fixed or managed in a way to reduce their proneness to faults (new technologies, safer installa-

  - tion conditions etc.). This has thus produced a reduction of vulnerability that our database could not be aware of.
  - Cabin vulnerability changes over time, due to maintenance and equipment update we were not informed about.

To cope with this problem, it has been agreed with Areti to establish, together with the network topology, a communication data flow containing also vulnerability indexes that will replace the current sensitivity thresholds.

- Almost all false negatives are due to the fact that not all Areti faults (even in a rainy day) were due to the effect of adverse weather conditions. Areti fault log does not specify the fault origin that could also has been due to common causes. To make a complete analysis, a complete log datum of the faults would be needed (fault origin, restoration times, type of intervention required).
- Some of the false positives as well as some of the false negatives are due to some wrong now-casting data. Algorithm checking is still on going and it is aimed at checking if CIPCast received unreliable forecasts. This will be performed by assimilating real data from rain gauges to predicted events, to estimating the quantitative differences between expected and effective rain abundances. Nonetheless, providing (quite often) reliable weather forecast with a spatial granularity of 800 meters is a big step ahead in the state of the art, and it is greatly appreciated by the DSO who currently relies on a reliable weather forecast for the city as a unique datum (from the spatial and the temporal viewpoints).

In conclusion, we say that we have, in all cases, systematically raised more alerts than the number of events that occurred. The main sources of error are the vulnerability parameters of each substation. We do believe that an improvement in this respect (i.e. by using the same vulnerability parameters estimated by the DSO) will improve our capability of making more correct predictions. The current vulnerability set of parameters allows to make correct "local predictions", i.e. alerting on specific tract of the network (i.e. a specific MV line). A correct punctual (i.e. related to a specific Substation) alert will be achieved when all vulnerability parameters will be appropriately set, in collaboration with the DSO.

3.3 Lessons learned

At the end, we can resume in the following list, the requirements, deduced by the data analysis, that will drive further developments of the CIPCast tool (and the applications contained in the whole CIPCast workflow). The list will be compiled by taking the different workflow phases as sections:

Damage Scenario

- A major role is played by the CI elements vulnerability data. In many cases and for the most frequently experienced threats (i.e. rain) DSOs have usually their own vulnerability data which might be of help in providing basic data. For less frequent threats, a more direct estimate made on the bases of technical data sheet and their information sources should be attained. CIPCast has obtained to have these data from Areti; data has been introduced into the hourly data flow from Areti to CIPCast.
- The reliability and the quantitative accuracy of the system of prediction of natural events (particularly weather forecast and nowcasting) should be also assimilated versus real data. Although nowcasting has a more direct relation with observations, it also results from a modelling activity that might lead its quantitative predictions to be quite inaccurate (particularly with that relates with the expected rain abundance). Thus, when a specific nowcast source is selected, a quite long assimilation period should be performed in a way to estimate the statistical accuracy of the predictions that are made. CIPCast has been using,

during the time, two different sources of nowcasting data in order also to have a double check on predictions. Moreover, a new technology to estimate the rain abundance in real time based on analysis of the attenuation of the signal coming from communication satellites is under an on-going check; this will constitute a further mean to calibrate nowcasting data.

Impact analysis

- The major outcome of this testing phase in the Impact analysis has been the recognition of the need of having a continuously updated topology of the network during the operation. In fact, the RecSIM tool must simulate its fault cascade prediction on the basis of the effective configuration of the network. In order to allow this continuous information flow, it has been realized the point-to-point VPN (described in the previous section) from the operation network system of Areti and CIPCast. In order to avoid configurations overwhelming, it has been agreed with Areti, a communication frequency of the network topology each hour of a day, which is a typical period of validity of specific networks configurations (which are seldom modified for shorter operational periods).
- The RecSIM tool is currently able to propagate the faults toward the telecommunication network. A further method to establish the goodness of the prediction made at the level of Impact Analysis could be the analysis of the telecom operator fault log file (in a way to infer the correctness of the fault propagation dynamics predicted by RecSIM. In this case that was not possible: however, for a future case, the availability of this data would be relevant as it could be used to assess the qualitative behaviour of the Impact Analysis module.

Consequence analysis

- The current version of CIPCast estimates the expected Impact by optimising its solution on the basis of a single KPI for Consequences: the *kmin* parameter, which associates the severity of a crisis with its duration and with the number of involved electrical customers. This has been mainly due by the fact that the social or economic KPI (related to the SAW –Service Access Wealth–indices) are much more difficult to estimate. The analysis of the economic activities in specific areas is a quite long and complex job that has been performed on single city zones. A lesson learned during the test case is to devote a specific task of a future project activity to the definition of socio-economic assessment of the areas of a city as a preliminary requisite for the consequence analysis to be performed. The CIPCast (and the RecSIM) application are already ready to cope with a further KPI parameter (other than *kmin*) which could be used to drive the optimisation of sequence of restoration interventions.

GUI and reporting

- Reporting, at the end of the consequence analysis, has been also a major concern. Several aspects have been pinpointed:
    - Turning off the alarms (i.e. a too low frequency data communication to CI operator) could originate the doubt that the system is not working. A heartbeat strategy is thus useful to provide a check that the system is on-going.
    - Reporting data have been made available in both formats: that of fig.7 and a less extended data set, with just weather information (or other main predicted natural event) and Damage, Impact and Consequence analysis results.
- GUI has been appropriately cared. The strategy of providing selected set of data to different end-users has been approved by CI operators. Operators have mainly requested the access to their own data and to the external data. Public Authorities (such as local Civil Protection) have prompted the idea of "services" availability visualisation.

4 Conclusions

The test cases and the simulation of real (as in Roma Capitale scenario) and synthetic (as for the Emmerich) cases, have allowed establishing the current reliability and accurateness of the whole CIPCast workflow and the efficacy of the proposed solution for the results communication to Operators and other stakeholders.

Although the quantitative agreement between CIPCast prediction and the real alerts experienced by the CI operators is still only approximate (and related to extended locations rather to specific points of the network), several lessons have been learned which will drive the further work on the tool. In the next years, this work to improve the tool and to increase its Technological readiness Level (TRL) value will be carried out by solving some of its current limitations and by applying it in a larger number of operational environments.

During the time of the CIPRNet project, a Field Agreement between ENEA and the Roma Capitale Civil Protection Dept. has been signed. This will provide a further occasion to establish another CIPCast web service deployed for a Emergency Management/Crisis Management operators; this will also enhance the capabilities of CIPCast as, for this end user, the ability of stressing a global observation standpoint (rather than having the specific perspective of a specific CI operator) will be more important. This will be beneficial for the general assessment of the damage scenario, to allow a fast and more reliable assimilation with real (and official) data and will hopefully allow the ENEA team “to enter” into the Civil Protection mechanisms.

A further general lesson that has been learnt concerns with the use of CIPCast as a *city dashboard*. Many different Italian cities, having been informed of the CIPCast functionalities, have asked the opportunity of testing the tool in the their city areas. Some attempt will be done in the near future, by starting from medium size cities (population < 300.000 inhabitants). This will require the integration, in the CIPCast database as input data coming from the field, data coming from city sensors that have been purposely neglected in the CIPRNet project (like e.g. pollution sensors, traffic sensors, etc.). This has been, in fact, strongly required by municipalities in the course of several meetings, for a twofold aim: the re-use of equipment resulting from previous investments and the need of using CIPCast as a “complete” city dashboard collecting all type of data (not only those coming from technological infrastructures). These experiences will further improve the capabilities of CIPCast of dealing with a very large number of sensors of different types, enabling a better and better recognition of the external situation, a more accurate prediction of events and to cope with the new IoT (internet of things) paradigm which is going to be widely used in Smart City initiatives.

5 References

[DoW]	Annex I – Description of Work (Annex to the Grant Agreement of CIPRNet).
D6.2	Application Scenarios
D7.5-7.6	Integration of meteo-climatological simulators, flood forecasts, earthquakes data and analysis tool and Interface to the technical demonstrator for federated CIP MS

6 Acronyms

BTS	Base Transceiver Station
CI	Critical Infrastructure
CIP	Critical Infrastructure Protection
DSO	Distribution System Operator
DSS	Decision Support System
EG	Electrical Generator
GUI	Graphical User Interface
HV	High Voltage (transmission network)
KPI	Key Performance Indicators
LV	Low voltage (distribution network)
MV	Medium Voltage (distribution network)
PS	Primary substation
SAW	Service Access Wealth
SCADA	Supervisory Control And Data Acquisition
SS	(electrical) Substation (primary and secondary)
TRL	Technology Readiness Level