Project no.:

**608540**

Project acronym:

**GARPUR**

Project full title:

**Generally Accepted Reliability Principle with Uncertainty modelling and through probabilistic Risk assessment**

**Collaborative project**

**FP7-ENERGY-2013-1**

Start date of project: 2013-09-01
Duration: 4 years

# D11.1a
# Periodic Report No 1

Due delivery date: 2015-04-29

**Actual delivery date: 2015-04-29**

Organisation name of lead beneficiary for this deliverable:
**SINTEF Energi AS**

| Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013) | | |
|---|---|---|
| **Dissemination Level** | | |
| **PU** | Public | |
| **PP** | Restricted to other programme participants (including the Commission Services) | |
| **RE** | Restricted to a group specified by the consortium (including the Commission Services) | X |
| **CO** | Confidential , only for members of the consortium (including the Commission Services) | |

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|---|---|
| **Deliverable number:** | D11.1a |
| **Deliverable short title:** | Periodic Report No 1 |
| **Deliverable title:** | Periodic Report No 1 |
| **Work package:** | WP11 Coordination and management |
| **Lead Beneficiary:** | SINTEF Energi AS |

| **Revision Control** | | | |
|---|---|---|---|
| **Date** | **Revision** | **Author(s)** | **Comments** |
| | | | |
| | | | |

| **Quality Assurance, status of deliverable** | | |
|---|---|---|
| **Action** | **Performed by** | **Date** |
| Verified (WP deputy leader) | Einar Jordanger (SINTEF) | 2015-04-27 |
| Approved (EB) | EB approval by e-mail | 2015-04-29 |
| Approved (Coordinator) | Oddbjørn Gjerde (SINTEF) | 2015-04-29 |

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The research leading to these results has received funding from the European Union
Seventh Framework Programme under Grant Agreement No 608540.

## 3.1 Publishable summary

### Summary description of project context and objectives

Power system reliability management aims to maintain power system performance at a desired level, while minimizing the socio-economic costs of keeping the power system at that performance level. Historically in Europe, network reliability management has been lying on the so-called "N-1" criterion: in case of fault of one relevant element (e.g. one transmission system element, one significant generation element or one significant distribution network element), the elements remaining in operation must be capable of accommodating the new operational situation without violating the network's operational security limits. Today, the increasing uncertainty of generation due to intermittent energy sources, combined with the opportunities provided e.g. by demand-side management and energy storage, call for imagining new reliability criteria with a better balance between reliability and costs.

Within this context, the GARPUR project designs, develops, assesses and evaluates new reliability criteria to be progressively implemented over the next decades at a pan-European level, while maximizing social welfare. The seven main objectives of GARPUR are:

1. To develop a consistent probabilistic framework for reliability management, covering the definition of reliability, the calculation of reliability criteria, and the formulation of optimization problems expressing the economic costs and the desired target reliability levels at the pan-European level and within each individual control zone.
2. To develop a consistent methodology for the quantitative evaluation of the economic impact on society of different reliability management strategies both at the pan-European level, and within each control zone.
3. To develop a quantification platform able to compare different reliability management strategies in terms of their impact on the social welfare.
4. To ensure the compliance of the developed methodologies with the technical requirements of system development, asset management and power system operation, and to demonstrate the practical exploitability of the new concepts at the pan-European level and in all decision making contexts.
5. To validate the different reliability criteria with the help of pilot tests.
6. To ensure the general acceptance of the proposed methods and tools by all stakeholders affected by the reliability management of the pan-European electric power system.
7. To define an implementation roadmap towards the use of the new reliability management practices.

To ensure progress beyond the state-of-the-art, GARPUR uses 5 different alternatives by which progress can be ensured and evaluated. These are defined as:

1. Model the spatiotemporal variation of the probabilities of exogenous threats and take into account the actual criticalities of service interruptions in the reliability management.
2. Take into account the increased possibilities of corrective control and its probability of failure in the reliability management.
3. Exploit the flexibility provided by demand-side management and energy storage, to achieve the reliability enhancement given the emergence of decentralized renewable generation.
4. Explicitly model the impact of system development and asset management decisions on the reliability management during operation,
5. Explicitly take into account the consideration of low-probability high-impact events, such as the ones originating from extreme weather conditions, possibly through climate change, or those originating from adverse behaviours of external entities.

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## Description of the work performed since the beginning of the project and the main results achieved

GARPUR has structured its work into nine technical work packages, one dissemination work package, and one management work package. The following paragraphs summarize the work performed and results obtained during the first 18 months of the 4-year project.

**WP1 "Revisiting reliability management methodologies"** has confronted the literature on power systems reliability with the reliability management approaches currently used by TSOs. The work in WP1 is finished and results indicate that there is a gap between the existing research literature and what is practiced by TSOs. Even if a diversity of probabilistic methods, including socio-economic impact assessment, are proposed in the literature, they are used in practice only to a very limited extent. Further it is revealed that current practices for reliability management mainly follow the N-1 criterion, but with different ad hoc implementations. Finally, the analysis showed that one of the important drivers perceived by TSOs to introduce probabilistic reliability management methods in practice is the need for a better balance between reliability and costs, while a lack of data in terms of probabilities of threats and socio-economic consequences of service interruptions is found to be one of the main barriers.

**WP2 "Development of new reliability criteria for the pan-European electric power system"** develops a consistent probabilistic framework to both assess and optimize power system reliability in the different practical decision making contexts. To reach this objective WP2 works in three logical steps:

1. Functional description of the proposed reliability management framework;
2. Mathematical formulation of the proposed reliability criteria and optimization problems;
3. Design of scalable algorithms for reliability assessment and optimization.

The two main results achieved so far in WP2 are the functional description of a **generic probabilistic reliability management framework** and its **mathematical formulation for real-time control**.
The proposed framework shows how to quantify the effects of the TSO candidate decisions in terms of both technical and socio-economic impacts, so as to enable the choice of an optimal decision. In this framework a reliability criterion is generically formulated in terms of a set of technical and economic constraints and objective functions forming the basis to accept, reject, and rank candidate decisions. The framework has been instantiated in the contexts of real-time control, short-term operation planning, mid-term asset management, and long-term system expansion. The proposed real-time reliability criterion models the spatiotemporal variation of probabilities of (multiple) contingencies, the probability of failure of corrective (post-contingency) controls, and the criticality of service interruptions. Mathematically, it is formulated in terms of a security constrained optimal power flow problem where the set of N-1 constraints is replaced by a chance constraint on the criticality of service interruptions and where the objective function combines costs of preventive control actions with expected costs implied by post-contingency corrective and emergency controls and also includes the expected costs of service interruptions. This criterion allows one to take advantage of all 5 alternatives of progress beyond the state-of-the-art.

**WP3 "Socio-economic assessment of reliability criteria"** develops the methodology to quantitatively evaluate the socio-economic impact of different reliability management strategies that could be implemented in the European electric power system. In WP3 a platform has been created for a common understanding of key concepts across fields (economics, engineering and computer science). In order to develop a methodology for evaluating the socio-economic impact of different reliability criteria, work so far has recalled the underlying principles of social welfare analysis. The socio-economic assessment is prepared by visualizing the financial flows and flows of goods and services between different stakeholders of the electricity market and providing system balances for each stakeholder. Furthermore, the current practices of quantification of socio-economic costs of electricity interruptions are discussed. Work so far hints on the importance of regulation with respect to the alignment of TSOs' objectives with social welfare maximisation. The proposed evaluation methodology is further elaborated for three time

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horizons. The essence of the results of WP3 is summarized under rules to be followed in order to arrive at meaningful social welfare assessment, possibilities and limitations in ex-post assessment, choices to be made when setting up a social welfare assessment and key conclusions for the assessment of reliability criteria.

**WP4 "System development"** refines the generic frameworks developed in WP2 and WP3 in the light of the practical needs of system development in the context of long-term decision-making in a multi-area/multi-TSO system. To start this work, a functional analysis of the system development process, as it is currently carried out by European TSOs, has been carried out. System development deals with taking decisions that change transmission capacities either within a TSO's own system or towards other TSOs systems. Inputs to the work of WP4 have been gathered from workshops in the GARPUR project and a questionnaire to 10 representative TSOs that are either part of GARPUR consortium or a member of GARPUR reference group. The investigation gives a clear overview of the common logical organization of the system development process used by different TSOs: it describes how they first obtain data sets that are used by the system development planner, how then the future system needs are identified in an initial assessment process, and how finally a detailed assessment of possible expansion projects is carried out to construct or revise a precise system development plan. It is also found that current practice of system development at TSOs is dominated by the deterministic N-1 criterion, while the need for probabilistic methods has been recognized for some time. Some TSOs have modified their planning methods to take into account a crude approximation of probabilistic reliability indicators. The potential for improving the system development process by using well-founded probabilistic reliability management methods is established, and some insights in how to migrate from deterministic methods towards probabilistic ones are highlighted.

**WP5 "Asset management"** refines the generic frameworks developed in WP2 and WP3 in the light of the practical needs of asset management, and specifically asset maintenance policies in the mid-term decision making context. To start this work, the state-of-the-art and the practical needs for reliability centred maintenance has been investigated and documented. The first main recommendation for the subsequent work consists in proposing models to calculate realistic failure rates for the different components. These models should not only consider the age and maintenance history of the component (although these are likely to be the most important factors), but also other factors such the sustained stress endured, or the hostility of the surrounding environment. Assessing the system wide reliability benefits of maintenance activities is another main topic of investigation. Therefore, the proposed methods should account for the seasonal variations impacting these failure probabilities (winter snowfalls, bird migration,...) instead of being limited to yearly average values. Finally, such models should also be able to integrate field-observed input on the state of the component, when available. Another main topic of interest regarding WP5 lies in proposing a well founded outage scheduling framework that enables to determine where and when maintenance activities should be carried out, by accounting for the future grid reliability while the scheduled outages are being carried out. Furthermore, the topic of budgeting the maintenance and replacements efforts over longer-term horizons is another decision-making problem that needs further research for its proper formulation and resolution.

**WP6 "Power system operation"** refines the generic frameworks developed in WP2 and WP3 in the light of the practical needs of short-term operation planning and real-time operation in a multi-area/multi-TSO system. The results of WP6 provide insights into how to migrate towards probabilistic reliability management within system operation and recommendations for future work in GARPUR. One important conclusion is that even though outage scheduling and contingency management are largely based upon the N-1 criterion at present, the N-1 criterion is sometimes abandoned based on operator experience and operators perceive that they need to perform internal risk assessments in order to make exceptions to the N-1 criterion to properly capture the actual risk they take. There are therefore various urgent needs

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to improve risk assessment in the short-term and real-time operation. There are however also a number of barriers that exist to implementing such improvements. One such barrier is the lack of information on how exogenous factors affect line failure probabilities. System operators have general knowledge about the long-term reliability of specific components, but there is presently no method in use for calculating a dynamic short-term reliability of components based upon weather variables (i.e. increase in risk due to an increase in wind speed). Resolving the gap between the present intuitive approach to manage this risk and the ideal quantitative approach GARPUR intends to implement is an objective that needs to be reached within the project. Another important practical aspect to consider within the GARPUR project is to make sure that the proposed methods are compatible with the currently available data, databases, and software solutions already used in the control rooms of European TSOs.

**WP7 "Development of a quantification platform for reliability criteria"** develops a testing environment via a computational quantification platform, to assess the impact of different reliability criteria before putting them into service in real-life. The quantification platform will simulate the use of the methodologies brought forward by WP2 and WP3 and further refined in WP4-6, as well as the current methods in use (based on the N-1 criterion). The quantification platform will thereby enable the evaluation of different new reliability management strategies by comparing them with the current variations of the N-1 criterion. The platform will be developed progressively, with a first prototype version deployed inside the GARPUR project for pilot testing and a final version delivered at the end of the project. The main results of WP7, at this stage of the project, are the specification of the overall requirements of the prototype version of the platform encountering the needs of the pilot tests, and a preliminary design of the software and hardware architectures of this platform.

**WP8 "Pilot scale validation"** tests the new proposed reliability criteria for selected TSOs, or group of TSOs, using the quantification platform, both in a given control zone and throughout the pan-European system. So far the ambitions for the pilot tests have been agreed upon as documented through Milestone no 1 of the GARPUR project, but no actual tests have been started yet.

**WP9: Recommendations and roadmap** for migration collects the lessons in all the previous work packages, WP1 to WP8, to analyse challenges for applying the proposed methods in practice, and to define a roadmap of R&D and policy decisions that are suited to make the evolution towards the practical use of new probabilistic reliability management methods possible at the pan-European level. So far only some first preparations for this work have been started.

**WP10: Dissemination** accompanies the research activities and the pilot tests by approaching the TSO community within EU27 and beyond, through the Reference Group of TSOs which are involved in output quality checks and dedicated dissemination tasks towards their own control zone stakeholders, as well as other impacted stakeholders through interactive workshops. During the first reporting period ENTSO-E members have expressed strong interest for GARPUR. In addition to the seven TSOs in the consortium four TSOs and two TSO organisations have joined the GARPUR reference group. Contact has also successfully established with regulators and energy ministries representatives.


A project website has been created containing public information about GARPUR, its progress and results. The website is being updated continuously and linked to existing relevant information sources. http://www.garpur-project.eu/

GARPUR has been presented at Innogrid2020+ (2014 and 2015) and several papers are in the pipeline for IEEE PowerTech Eindhoven 2015.

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**WP11 "Coordination and management"** secures an efficient communication and decision-making process for the consortium. So far the internal communication and information management tool, the GARPUR eRoom, which was used during the application and negotiation phases, has been adapted to the execution phase. Further, most of the individuals working within GARPUR have demonstrated that they have learned to utilize the tool for enhanced communication and information sharing. The GARPUR project is up and running and deliverables have been submitted to the EC according to the plan.
All internal procedures and routines are in place; and are being further developed when need arise.

The expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far),

It is believed that GARPUR will show that new criteria for reliability management of the pan-European transmission system can and should depart from the N-1 criterion, by using a probabilistic approach that ensures pan-European system reliability while optimizing social welfare. The diagram below summarizes the expected outcomes.

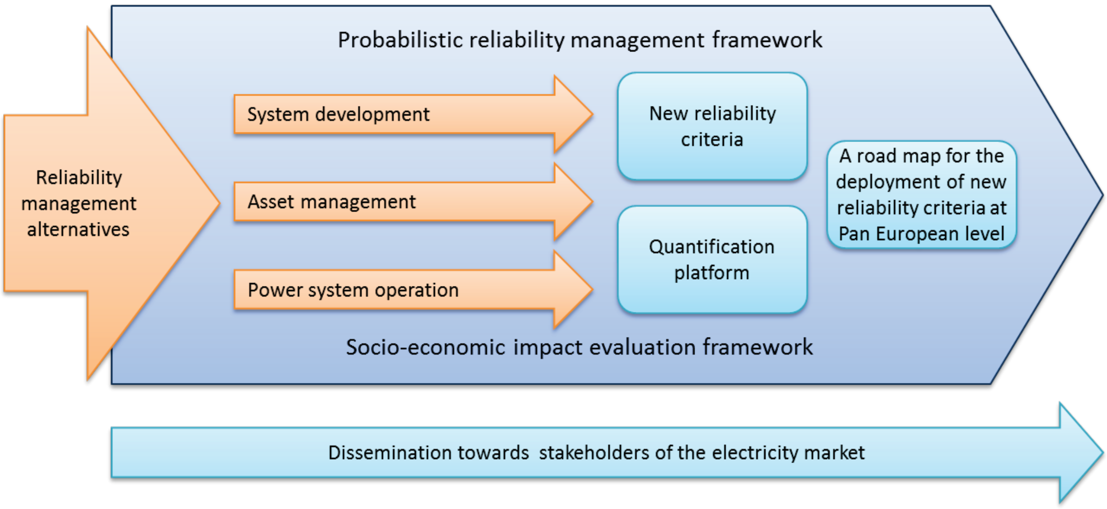


**Figure 1: GARPUR outcomes.**

GARPUR develops a comprehensive and coherent probabilistic methodology using five reliability management alternatives to ensure scientific and technological progress, for the different TSO activities (system development, asset management, operations). For each studied reliability management alternative, the Quantification Platform will link the socio-economic consequences of their implementation. This is mathematically modelled as an optimization problem, based on two consistent frameworks: one for probabilistic reliability management and another for socio-economic impact evaluations. The deployment roadmap for the new reliability criteria will show relevance at the pan-European level for applications by TSOs within the three time horizons.

There will probably be extra investments involved to deploy the probabilistic reliability management framework. Yet the extra benefits of providing adequate levels of reliability may override the required costs as it will be possible to show by the use of the quantification platform. Indeed:

- information technology capable of extensive data processing and network simulations tools make a probabilistic approach to reliability management increasingly realistic.
- in the future TSOs must cope with potentially critical situations due to the massive arrival of stochastic generation, the development of a pan-European electricity market leading to massive cross border exchanges, and the opportunities to leverage new sources of flexibility in the context of operation as well as in the context of long-term planning.

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